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JUSTIFICATION OF PARAMETERS OF TECHNICAL AND TECHNOLOGICAL SERVICE COOPERATIVES

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Abstract. The current state of agro-industrial production and pecularities of functioning of technical and technological service cooperatives are considered. It is offered during the study of technical and technological service cooperatives to consider them as appropriate technological systems. The analysis of deterministic and statistical methods of justification of the parameters of technical support of techno-technological service cooperatives that provides definition of functional indicators of their efficiency is performed. The scientific and methodical approaches to justification of parameters of techno-technological servicing cooperatives are offered. The components of functional indicators of efficiency of techno-technological service cooperatives are substantiated. The peculiarities of the system-event basis of the study of volumes of late-performed mechanized works by techno-technological servicing cooperatives are revealed. The peculiarities of determination of the length of downtime of equipment during the agrometeorologically acceptable time due to the lack of mechanized works are substantiated. The method of substantiation of the need for technical support for techno-technological servicing cooperatives is offered. It is based on statistical simulation of the functioning of technological systems. The causal links between events and mechanized works performed by techno-technological servicing cooperatives are substantiated. The opposite nature of the change in the dependence of the untimely execution of mechanized works and downtime of equipment during working hours is established because of the absence of these works on the parameters of technical support of technical and technological service cooperatives.The dependence of functional indicators of the efficiency of technical and technological service cooperatives on the parameters of the corresponding technological systems is substantiated. The obtained dependence is the basis for determining the rational (optimal) parameters of the technical support of technical and technological servicing cooperatives by value or energy criterion.

Keywords: service cooperatives, parameters, modeling, efficiency, indicators, technological system.

INTRODUCTION

The effectiveness of activities in agricultural production is largely due to its technical support. Unfortunately, in Ukraine technical potential of agriculture is characterized negatively - in the majority of agricultural commodity producers (ACP) there is insufficient equipment for carrying out works in optimal agricultural terms. In addition, existing machinery is characterized by a long term of use, which often leads to their failure to perform agricultural work. It negatively affects the production of agricultural products - the potential harvest is lost, the cost of its production increases. The solution of this problem, as evidenced by the experience of developed countries of the world, is possible through the development of technical and technological service cooperatives.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

A sufficient legal basis has been created in Ukraine to form service cooperatives (Ukrainian Law 2003). However, until recently, effective development of cooperation in agricultural production is not observed. The reasons for this situation lie both in the absence of proper state support and in the lack of scientific substantiation of the relevant socioeconomic process. In particular, the corresponding state target program has not yet been created. Existing scientific developments are mainly concerned with the functioning of cooperatives (Tryhuba 2015a; Tryhuba 2015b; Tryhuba *et al.* 2019). Questions about their formation are not substantiated enough. In particular, there are no scientific recommendations for substantiating the parameters of technical and technological service cooperatives.

The experience of the developed countries of the world shows that the organization of agricultural production on a cooperative basis is one of the most progressive forms of its functioning. It allows not only to ensure the production of competitive agricultural products, but also, to a certain extent, to solve the social issue - to ensure employment of the rural population.

Today in Ukraine there are more than 50 thousand ACP, which own land resources and are potential production cooperatives. In particular, there are 1023 agricultural service cooperatives and 992 agricultural production cooperatives. Their technical potential is ineffective (degraded and requires a significant amount of work per year). Its updating is possible in two ways: a direct replacement in the ACP of the old (worn out) technology for a new one; the formation of machinery in service cooperatives. For each of them, appropriate projects should be implemented that are characterized by a certain efficiency. Determining (predicting) numerical performance indicators of these projects is an important stage in their management (Tryhuba *et al.* 2019).

We will identify the main components of the relevant scientific and methodological foundations. The first component of these bases is the development of a method for forecasting indicators of the effectiveness of the technical capacity of the ACP. From an engineering point of view, this task is formulated in this way - to determine the power and number of techniques that should be available for this or that ACP. It is well-known that power (P_r) and the number (N_r) of mobile power engineering are the main parameters (Z_r) of the machine-tractor park ACP (Adamchuk *et al.* 2014). For their justification, two main methods are used - deterministic and statistical (probabilistic) (Adamchuk *et al.* 2014). The deterministic method is more simple and affordable for engineering calculations, but it does not take into account the probable nature of the processes of the use of technology, and therefore does not guarantee the reliability of the results (Adamchuk *et al.* 2014). In other words, the use of this method can lead to false results.

Is the disclosure of scientific and methodological approaches to the substantiation of the parameters of technical and technological service cooperatives.

RESULTS AND DISCUSSION

When using the deterministic method, the justification of the parameters (Z_r) of the technique is first given by the power (P_r) of a single technical means. Subsequently, based on the annual plan of mechanized work of this or that ACP, technological operations are presented for the cultivation of all crops in the given ACP. After that, agricultural machines are selected which can be aggregated with the appropriate power tool. This makes it possible to determine the daily productivity (q_φ) of each machine (machine-tractor) unit for performing each (φ-th) technological operation of the annual plan of mechanized works. The required number ($N_{r\varphi}$) of the r-th brand of power tools to perform φ-technological operations is determined from a known dependence:

$$N_{r\varphi} = \frac{Q_\varphi}{q_\varphi \cdot t_\varphi^o}, \quad (1)$$

where Q_φ – square, which should be processed while performing the φ operation, ha; t_φ^o – optimal agrotechnical term of the φ operation, taking into account the effect of bad weather, days.

After determining Nrφ a calendar schedule of energy needs should be built, taking into account the possible overlapping t_φ^o of their use in individual operations. According to this schedule, we estimate possible periods of intense in using energy (periods with the highest values $\sum_\varphi N_{r\varphi}$. For each such period, the possibility of reducing the number of energy resources by adjusting (shifting) agrotechnical terms is considered. Ultimately, on the basis of the analysis of the appearance of the calendar schedule, the corrected demand for power vehicles with a given engine power of P_p, make decisions about the value $\sum_\varphi k \cdot N_{r\varphi}$ (where k – agricultural crop grown in ACP).

Thus, the method under consideration does not take into account the risk of lowering the yield due to the lack of timely performance of agricultural work, as well as possible unproductive simple energy during working hours due to lack of work. At the same time, the method under consideration makes it possible to quickly orient in the technical need of the ACP without proper evaluation of the effectiveness of a project of their technical support. Conceptually, we consider the new, developed by us, method of substantiating the parameters of the technical support of the ACP based on the use of the probabilistic approach. In this regard, we note that technological processes in crop production occur in a changing natural environment. In particular, it is inherent in the stochastic influence of agrometeorological conditions, which determine the feasibility and the possibility of performing those or other mechanized works. In this case, appropriate events are considered with probabilistic time of their onset.The method of substantiation of the need for ACP in the technical support developed by us is based on the statistical simulation of the functioning of technological systems (FTS), which consist of a plurality of fields to be processed (plowing, fertilizing, sowing, care of crops, harvesting), technical means by which mechanized operations are performed on the processing of fields, as well as performers (operators) that provide this processing. The statistical simulation of the functioning (technological processes) of the FTS is based on the system-event approach, which allows taking into account all major events and work in projects of agricultural production (Tryhuba *et al.* 2013). Let's concentrate on the methodical peculiarities of the system-event approach (Adamchuk *et al.* 2014).

Events apply to all major components of FTS: 1) Fields (*P*); 2) agricultural crops (*k*); agrometeorological conditions (*A*); 4) performers (*C*); 5) technical means (T_n) (Sydorchuk *et al.* 2012). The presence of fields (*P*), each of which is cultivated or harvested by one or another agricultural crop (*k*) forms the base set of corresponding events of the first species - $\{P_C\}$. The operations to be performed on these fields form the derivative of the set of events – $\{\varphi_k\}$. Agrometeorological conditions determine the set of basic events of the second kind – $\{A_{\varphi k}\}$. These events relate to each individual crop (*k*) cultivated in the corresponding fields (φ) of a particular APC. Therefore, the peculiarities of their research are the study of the influence of agrometeorological conditions on the state of fields with sown on them crops. Thus, events with performers are also derivatives. They determine for each working day the possible time for the beginning and end of mechanized agricultural work, determines the release of performers to work and the termination of it because of the limitation of the variable time of their work. In addition, the time for commencement and completion of work in one or another day is also determined by agrometeorological conditions that form the basic events of the second species. These conditions affect the physical condition of the surface of the fields of cultivated crops, as well as the air environment, which predetermines the possibility of mechanized agricultural work. Thus, on the basis of comparison of the time of occurrence in each particular era subject-agrometeorological and social (the presence of performers, ready to perform work) events is determined by the time of the beginning and completion of these works. Summarizing the results of the analysis of the events of the functioning of the FTS, we note that for each field and the agricultural crop cultivated on it determine the events of the beginning of seasonal work, weather and humidity intervals in these seasons, the beginning and end of breaks of good intervals of time within individual days, as well as completion mechanized works of one kind or another during the season (Adamchuk *et al.* 2014). In addition, for each type of seasonal work on the basis of simulation determine the amount of mechanized work performed outside agrotechnical optimum time. This volume for φ-o type of work determines the loss of potential yield of k agricultural crop. As a result of the simulation of the functioning of the FTS, they also identify simple T_{nrs} r machines, due to the lack of φ-o type of work. At the same time, we note that the simple T_{nrf} are determined for the agronomically optimal period of execution of the φ works. Indicators and $T_{nr\varphi}$ relate to the functional performance indicators of FTS (Adamchuk *et al.* 2014). They are conditioned by relevant events (Tryhuba *et al.* 2013):

$$\left(Q^{н}_{\varphi k}, Tn_{r\varphi}\right) = f(\{\Pi_{k\varphi}\}, \\ t^{o}_{\varphi k}\{A_{\varphi k}\}, \{C\}, \bar{w}_{\varphi k}), \qquad (2)$$

where $\{\Pi_{k\varphi}\}$ – the set of fields with k culture, on which φ-a mechanized operation is performed; $t^{o}_{\varphi k}$ – the duration of the agrotechnical optimum period for the implementation of the φ-mechanized operation for k agricultural crop; $\{C\}$ – set of events of possible and impossible execution of mechanized processes (operations) due to a social factor; $\bar{w}_{\varphi k}$ – the average tempo of execution of the φ-mechanized operation for k culture.

An average pace was $\bar{w}_{\varphi k}$ performance of φ-ї operation of growing k culture depends on parameters (power) P_r and amount N_r of used machines, and also manufacturing features B_n fields:

$$\bar{w}_{\varphi k} = f^{//}\left(P_r, N_r, B_n\right). \qquad (3)$$

Let's notice, that manufacturing features B_n of fields and parameters P_r machines determine speed $V_{r\varphi k}$ of their movement on fields, and also frequency of occurrence (β_{po}) and duration of performance (t_{po}) of their reversal:

$$V_{r\varphi k} = f^{///}(B_n, P_r); \\ (\beta_{po}, t_{po}) = f^{IV}(B_n, P_r). \qquad (4)$$

Moreover, features B_n of fields and parameters P_r of machines determine technological stops, that have negative impact on time pace $\bar{w}_{\varphi k}$ of performance of mechanized operations. Probabilistic character of components of average pace $\bar{w}_{\varphi k}$ of performance particular operations determine the necessity of its estimation. Taking into account an impact of all the events $\{A_{\varphi k}\}$ of agrometeorological conditions on performance of agrarian works, their functional indicators $\left(Q^{н}_{\varphi k}, Tn_{r\varphi}\right)$ are probabilistic. Estimation of the statistical characteristics of the corresponding distributions is possible only on the basis of statistical simulation modelling of systems for growing crops (Tryhuba *et al.* 2018a; Tryhuba *et al.* 2018b; Hulida *et al.* 2019; Gonchar 2014; Vasylieva 2016).

Considering such systems as FTS, the rationale for their efficiency is reduced to the definition of rational parameters, which are divided into characteristics (S_n) of production plans of mechanized works, parameters (Z_t) of technical support of service cooperatives, as well as parameters (Z_n) providing by executors (Tryhuba 2017). The engineering and technical task of substantiating the parameters of techno-technological service cooperatives is reduced to the definition of a rational relationship between their indicators and parameters (Tryhuba 2015a). Conceptually, we designate the characteristic trends of changes in functional indicators $\left(Q^{н}_{\varphi k}, Tn_{r\varphi}\right)$ from parameters FTS. If there are fixed plans (S_n=*const*) and amount of the performers (Z_n=*const*), then increase of parameters Z_m leads to decrease of an average value $\bar{Q}^{н}_{\varphi k}$ and increase of an average value $\bar{T}n_{r\varphi}$ (Figure).

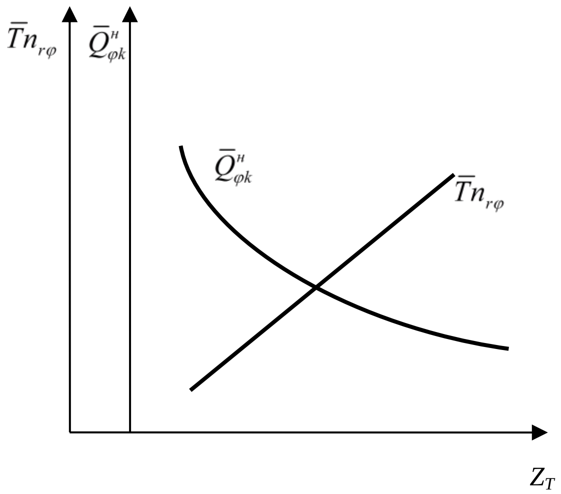

Figure 1. Trends in changing the average volume ($\bar{Q}^{н}_{\varphi k}$) of untimely executed mechanized works and average downtime $\bar{T}n_{r\varphi}$ of equipment from the parameters of technical support FTS

The opposing tendencies of changes in the mean values of functional indicators are the main reason for determining the optimal (rational) value of FTS parameters. To do this, the average values of functional indicators $\bar{Q}^{н}_{\varphi k}$ i $\bar{T}n_{r\varphi}$ should be presented in energy or money value. Volume $\bar{Q}^{н}_{\varphi k}$ of untimely mechanized works leads, as already noted, to crop losses, which are easy to assess either in energy or in monetary units (Tryhuba 2017; Bushuev 2009). Downtime $\bar{T}n_{r\varphi}$ of machinery due to the lack of work in the working agronomically allowed time, cause the increase in the cost price of the crop - increases the cost of depreciation from the "freezing" of capital funds (investments). These costs can also be expressed in terms of energy equivalent. Thus, having predicted with the help of statistical simulation the average values of functional indicators for different parameters of technical support of FTS, as well as evaluating these indicators in monetary or energy equivalents, it is possible to find the optimal values of these parameters, which provide the minimum values of total losses and costs when performing that or other mechanized work. The considered methods of substantiation of the technical support parameters of the agricultural production of the FTS are important components of the justification of the effective parameters of technical and technological servicing cooperatives. In particular, they are the basis of decisions not only of managerial tasks to justify the corresponding parameters of cooperatives, but also the current management of the formation of their efficiency at the expense of a rational distribution of technology for the implementation of mechanized works in individual fields. In this case, the management task is formulated as follows: in each separate working day it is necessary to distribute the technique according to the planned mechanized work in such a way as to minimize the loss of yield from the untimely execution. Solving this problem requires the development of appropriate methods that we do not consider in this article.

CONCLUSIONS

1. The justification of the effective parameters of techno-technological service cooperatives is based on the results of solving the managerial task of reconciling the characteristics of production plans with the parameters of technical support, as well as the number of performers of mechanized works performed by cooperatives (FTS).
2. Existing methods for solving these problems are based on two basic models of functioning of cooperatives - deterministic and statistical.
3. Deterministic model allows tentatively determine the parameters of technical support. The statistical model allows to take into account the distribution of all the effects of agrometeorological conditions on the implementation of mechanized agricultural processes and to justify the rational parameters of the technical support of cooperatives on the basis of minimizing the total average losses and capital costs for the implementation of mechanized agricultural processes.
4. The developed scientific and methodical bases for the development of statistical simulation models for the implementation of mechanized agricultural processes allow taking into account all the main factors of the efficiency of the functioning of technical and technological service cooperatives and ensuring the reliability of forecasting their indicators.

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ERGONOMIC EVALUATION OF THE WORK COMFORT OF EMPLOYEES OPERATING THE POTATO STORAGE ROOM

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Abstract. The aim of the research was an ergonomic evaluation of the working environment in the potato storage room. The scope of work included the measurement of the basic parameters of the physical environment in individual rooms of the potato storage room. On the basis of measurements, the degree of thermal comfort of employees with PMV and PPD indicators was determined. There were no significant irregularities in the studied work environment, this observation applies to all measured values. It should be noted that people working in the storage room performed maintenance operations, where the energy expenditure rarely exceeded 1 meter. Based on the value of the PPD indicator, it can be stated that thermal discomfort will be felt by only 5% of the crew, which in the light of the applicable guidelines is a permissible value.

Keywords: microclimate, physical environment, noise, ergonomics

INTRODUCTION

The working environment in the potato storage room is determined by the technological process, which forces the microclimate to maintain a certain regime, which may be contrary to their optimal range required by man.

The temperature of the external environment, both heat and cold, has a significant impact on human work due to the impact it has on physiological processes, psychomotor performance and cognitive processes (Sudoł - Szopińska *et al.* 2006). The constant warmth of the human body is maintained thanks to the thermoregulatory mechanisms, which, however, cannot always meet the thermal loads that the body is exposed to in the work environment (Tabor *et al.* 2003). Heat exchange between man and the environment is determined by physical factors such as: air temperature, air movement speed, average radiation temperature and water vapor pressure, as well as clothing and energy expenditure of man (Sudoł-Szopińska *et al*. 2006).

Koradecka (1999) defines thermal comfort, as the most favorable conditions, the microclimate of the room in which a person feels good, and the thermal management of his system is at its most economical. This condition results from the balance between the amount of heat produced in the body as a result of metabolic changes and heat losses from the body to the surrounding environment. As a result of biological differences, it is not possible to provide thermal comfort to all persons staying in a given room (Sudoł-Szopińska and in. 2007). Providing employees with a sense of thermal comfort by adjusting appropriate parameters of the work environment positively influences, among others, to improve concentration, reduce the number of mistakes made, reduce the number of accidents and occupational diseases, thereby reducing professional absences, as well as improving work efficiency (Kroner *et al.* 1994). Studies analyzing relationships, between quality of work and various physical variables of the environment, confirm that it correlates better with comfort than with any other single variable (Allan *et al.* 1979).

The basic and commonly used indicators of assessment of the moderate environment are: PMV (Predictive Mean Vote) - predicted average thermal comfort rating and PPD (Predicted Percentage of Dissatisfied) - predicted percentage of dissatisfied (Fanger *et al.* 1974). PMV is an indicator used to determine the so-called predicted average thermal environment rating in a given room. For a given PMV value, it is also possible to determine the PPD index, i.e. the expected percentage of dissatisfied persons, thus assessing the definitely negatively studied thermal environment (Sudoł-Szopińska *et al.* 2007). According to PN - 85 / N - 080013, the PPD should assume for a moderate climate a value of less than 10%, then the PMV indicator is 90% and falls within the range from - 0.5 to +0.5. Such values of indicators inform about the fact that 90% of people in given conditions feel thermal comfort, and 10% feel discomfort. It was shown that the exposure to temperature higher than 21˚C causes a decrease in psychophysical fitness by 6% in relation to the neutral temperature, while at a temperature exceeding 26 ˚C one can observe a decrease in the level of attention, perception and reflex, especially during short, ie below 120-minute exposure time (Traczyk *et al.* 2004)

According to the norm PN - 85 / N - 08013, the optimal value of air temperature for the summer period and the work of medium heavy type should be in the range from 20°C to 23°C (Śliwowski 2000). The feeling of draft depends on the degree of turbulence, also on the degree of air temperature and the surface of the body exposed to it. A significant influence on thermal comfort is also the insulation of work clothing and protective clothing used at workplaces, especially the so-called a barrier that fundamentally limits the heat exchange between man and the environment (Kozłowski *et al.* 1995).

Noise is one of the most common harmful and burdensome factors in the work environment. Long-term exposure to it and its high levels (above 80-85 dB) may pose a significant threat to the organ of hearing and the health of employees (Augustyńska *et al.* 2012). According to Wilkus [2007], noise is one of the most important health risks for an employee of the agri-food industry both in the preparation process and during the production itself. Noise at lower levels (55-75 dB) can be a nuisance, obstructing work and causing stress and various health problems (Augustyńska *et al.* 2012). Puzyna (1981) also states that noise has a significant impact on the quality and accuracy of the work performed, and it is even more noticeable to them that this work requires more focus or accuracy.

The aim of the conducted research was an ergonomic assessment of the work environment in a potato storage room. The scope of work included measurement of basic physical environment parameters such as lighting intensity, sound level, air movement speed, heat radiation, air temperature, relative humidity in individual rooms of the potato storage room. In addition, the influence of selected values on the thermal comfort of employees was described by PMV and PPD indicators. The research was carried out during the summer during maintenance works of storage devices and work to prepare the storage room for accepting potatoes.

RESULTS AND DISCUSSION

Methodology. The research was carried out in a potato storage room belonging to the Top Farms "Głubczyce" Spółka z o.o. producing about 30 thousand each year. tons of potatoes. The subject of the research was the evaluation of the microclimate in the potato storage room, taking into account the rooms included in the complex and having significant importance from the technological point of view. The storage room in which the tests were carried out consisted of seven storage chambers and one cooling chamber with a total capacity of 16 thousand tons of potatoes and rooms: for washing potatoes, social and office. The corridor used for technological purposes was the place connecting all storage rooms. Measurements of basic microclimate parameters were made in fifteen places of each of the storage chambers tested (Figure 1) and in twenty-four places located in the handling corridor and in fifteen places of the room used for rinsing potatoes.

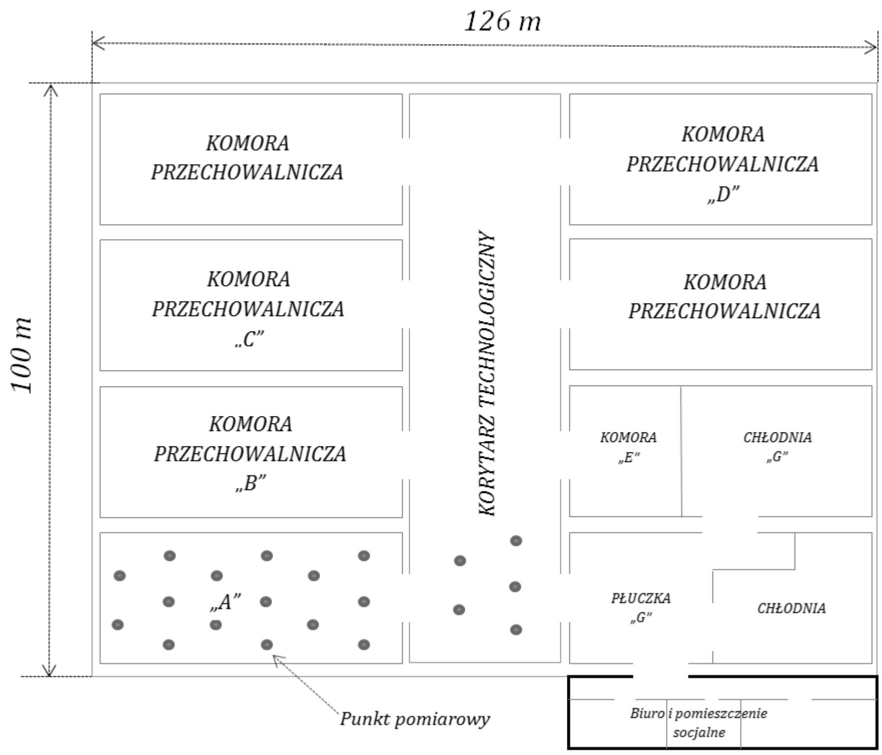

Figure 1. An example of distribution of measurement points in the tested object
Source: own study

To exclude false results, the measuring points were removed from the side walls by at least 1.5 m, while the height of the measurement points was the same for all measurements and was 1 m. The measurements of basic physical parameters of the air were made by the MM-01 microclimate complying with the PN-ISO 7726 standard. Air temperature, thermal radiation temperature, air relative humidity, air movement speed was measured and after declaring the thermal insulation value of clothing (clo) and individual energy expenditure of an employee (met), the PPD and PMV indicators were determined.

To measure the sound level a class 2 sound level meter (PN-79 / T-06460) type I-01 was used, whose operation is based on the measurement of sound pressure. Determination of measurement points and principles of noise measurements were made in accordance with the applicable Polish Standard PN - EN ISO 9612. In order for the measurement results to be close to the actual human auditory sensations, a correction system was applied, the corrected weighted level, so-called decibel A. The results presented in dB (A) indicate the use of a correction curve in the course of a measurement that is inverse to the course of 40 phonemes. Measurements were made at the dynamic behavior setting "S" (slow), while the calibration of the meter with the microphone was performed using the MKD PF 101 - 62709 calibrator.

The intensity of light was measured by an L-50 luxmeter with accuracy class A according to CIE (Commision Internationale de l'Eclairage). The measurement of daylight intensity was made based on the PN - EN 12464 - 1 standard.

Results. It was observed that the average air temperature in the analyzed work environment was 18 ° C and had very little differentiation (less than 1 ° C). The largest variation in the air temperature value was recorded in the storage chamber "A", which expressed by the coefficient of variation was 4.7% at an average temperature of 18 ° C.

Taking into account the total synergy of many factors related to the work environment, clothing and the type of activity performed, the PMV indicator was determined. In the case of the analyzed rooms

(Fig. 2) no irregularities were found. The average value of the PMV indicator was -0.09, which indicates that the working people felt a slight coolness in the storage room. The greatest sense of coolness was recorded in room "E" where the value of the PMV indicator was -0.31 with a relatively high coefficient of variation of up to 62%. Only in the case of room "G" the value of the PMV indicator was a positive value (0.075), which corresponded to the feeling of slight heat by the people working there.

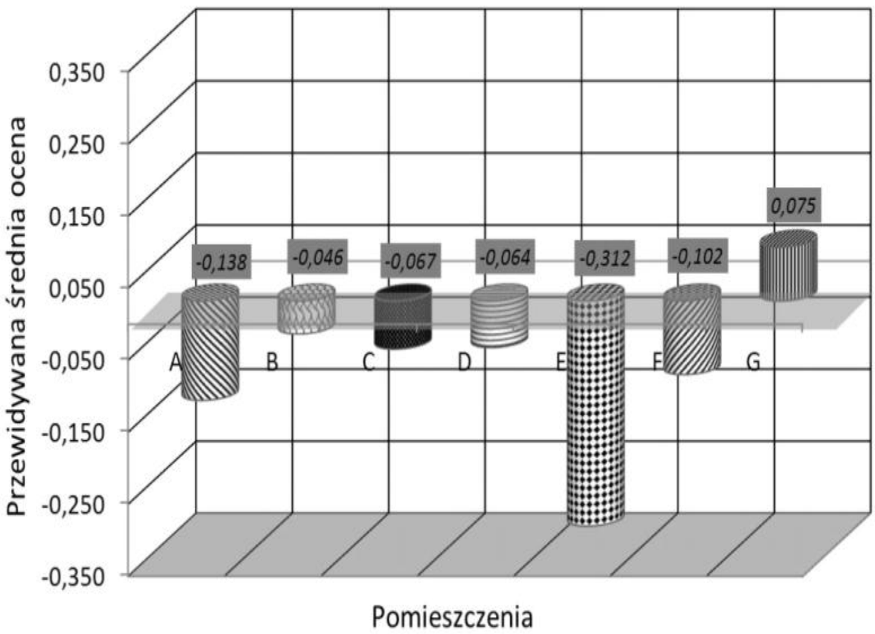

Figure 2. Average value of the PMV index (expected average rating) in the rooms under examination
Source: own study

The highest variation in the value of the PMV indicator (coefficient of variation over 200%) was characterized by room "D". It should be noted, however, that the high coefficient of variation was characterized by low mosaicism of the spatial structure (Figure 3).

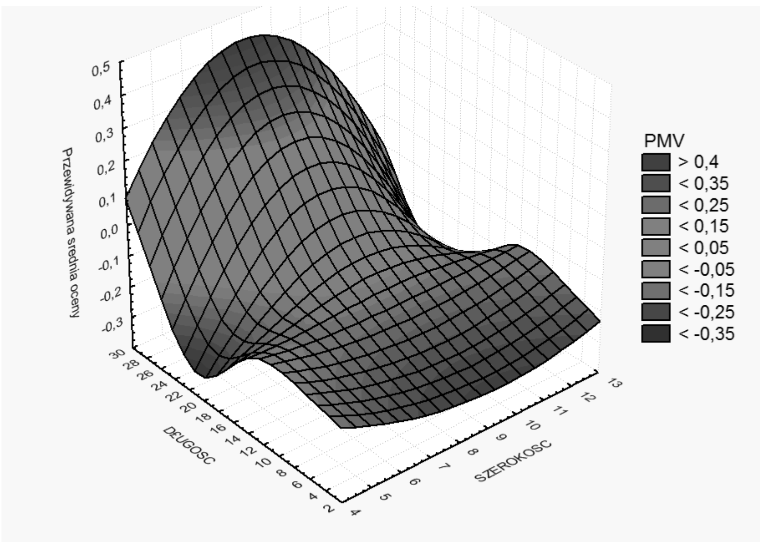

Figure 3. Spatial distribution of the predicted average rating in the room "D"
Source: own study

The highest PMV indicator (0.4) was found near the entrance to the room, and the smallest values of the analyzed index of -0.35 were recorded in the interior of the room. The average value of the PMV indicator in the subject room was -0.064, which meant good working conditions with a slight sense of coolness.

Figure 4 presents the average value of the PPD index recorded in individual rooms. The average value of the PPD index, including all the rooms studied, was 5.8%. The highest PPD ratio of 8.48% was found in the "E" room, which was 3.36 units higher than the smallest value recorded in the "C" room.

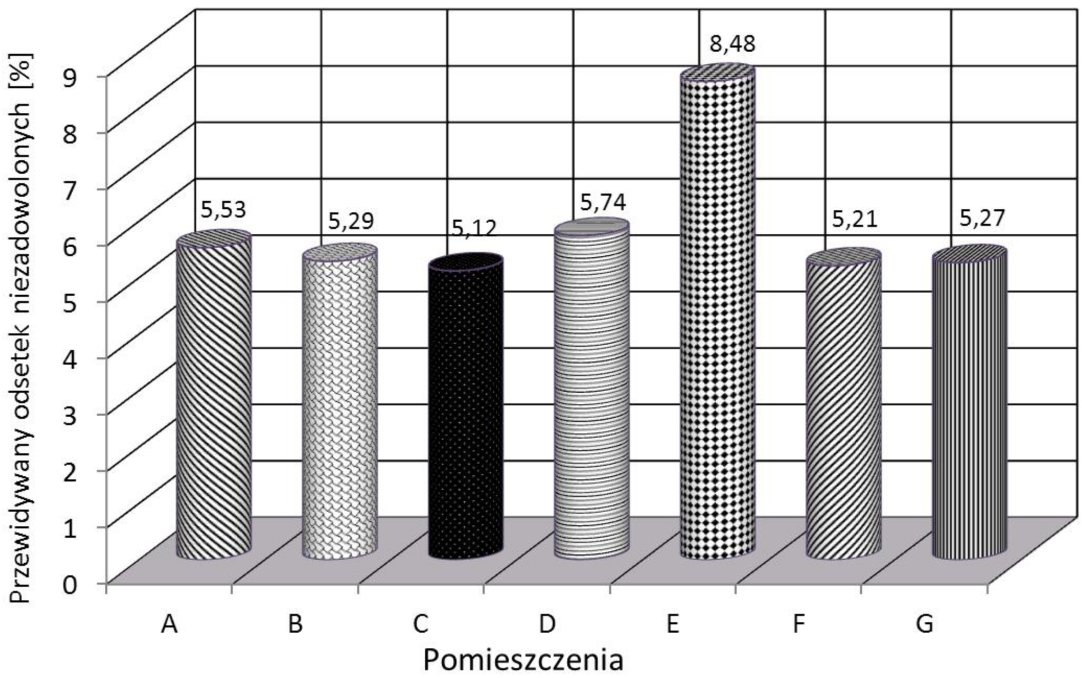

Figure 4. The average value of the PPD index (expected percentage of dissatisfied) in the examined rooms
Source: own study

There was relatively small variation in the analyzed size within individual rooms not exceeding 10%, except for room 'E', where the coefficient of variation was 16.8%.

In the case of spatial analysis of the expected percentage of people dissatisfied with the working conditions in a potato rinsing room, it was found that in the central part of the room conditions prevail, from which more than 10% of employees were dissatisfied. At the same time, it should be noted that the smallest thermal discomfort was felt in the vicinity of the side walls of the room where the PPD index fluctuated in the area of zero with the arithmetic mean of the room being 5.27%. Despite the comparable average PPD index of 5.21%, the spatial structure of the volatility of the indicator in the corridor was of a different nature.

There were high PPD values in the area of the rear entrance, decreasing towards the front entrance, where the number of people experiencing thermal discomfort did not exceed 5%.

The highest value of the air movement speed (fig. 6) was found in the room "F", where it was 0.16 m · s-1 at a relatively high, as much as 72% coefficient of variation. The average value of the air velocity in the tested rooms was 0.07 m · s-1. The relative difference between the extreme recorded values of air velocity was as much as 90% (room "B" and "F"), but in absolute terms it was only 0.14 m · s-1.

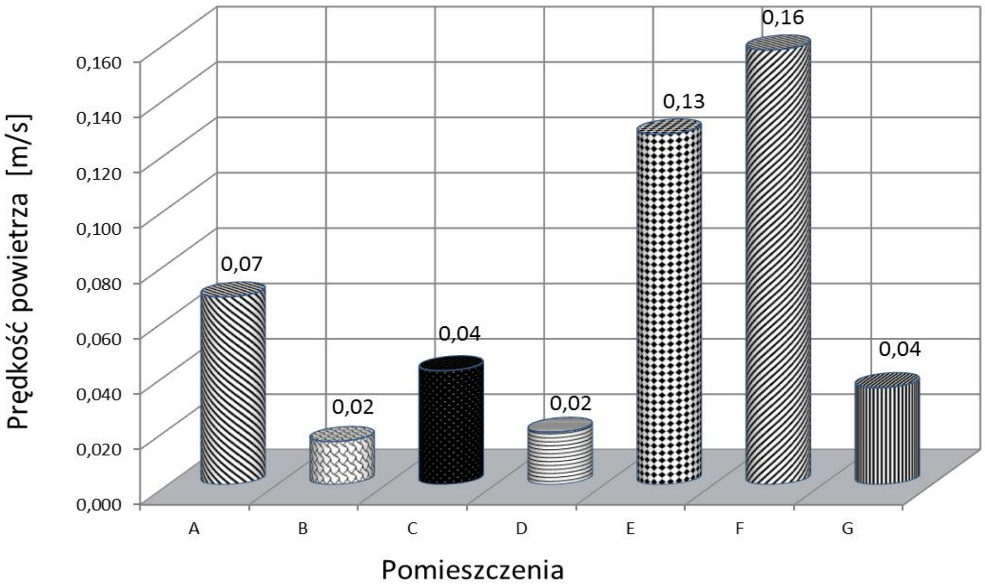

Figure 5. Air velocities in the tested rooms
Source: own study

The largest variation in the air velocity values was recorded in room "A", where the average value of the air velocity is 0.07 m · s-1 coefficient of variation reached the value of 129%.

The highest humidity of 74.4% was recorded in the room "G" while the lowest in the room "F", which was by 13.5 units smaller. The average value of relative humidity including all tested rooms was 65.8%. Analyzing the differentiation of relative humidity in individual rooms it was found that the highest coefficient of variation was characterized by room "F" (11.2%), while the lowest coefficient of variation of 3.9% room "C".

The average value of light intensity in the rooms under examination was 150.6 lux. The largest value of 738.9 lux was recorded in the "F" room (technological corridor). Apart from the technological corridor where the most manipulations are performed, there is a potato rinsing room ("G"), where the light intensity was 154.5 lx with the coefficient of variation 27%. The spatial structure of the light intensity was adequate to the technological sequence for rinsing potatoes, i.e. the highest values of light intensity were located along the room.

From the point of view of comfort and safety at work, the level of sound intensity is important. Figure 6 presents the average values of sound intensity recorded in the rooms under examination. The highest sound level of 76.8 dB (A) was found in the room "G" (cold room and a room for rinsing potatoes), and the smallest 53.6 dB (A) in the storage chamber (room "E"). It should be noted that the sound intensity measurement in the "G" room took place during operation of devices used for rinsing potatoes. The average sound level of all analyzed rooms was 62.6 dB (A). It should be noted that in rooms marked with the symbols "A", "B", "C", "D" being storage chambers, from which potatoes were removed, the level of sound intensity was on the level of 60 dB (A), which is admissible in the light of current standards. The greatest variation was found in room "A", where the coefficient of variation was 19%. The average value of the sound intensity in room "A" was 53 dB (A). Analyzing the spatial distribution of sound intensity, it was observed that the lowest values below 37 dB (A) were recorded in the central part of the room, while the highest values of over 67 dB (A) were found near the entrance door. It should be noted that the difference in sound intensity within the analyzed room was about 30 dB (A).

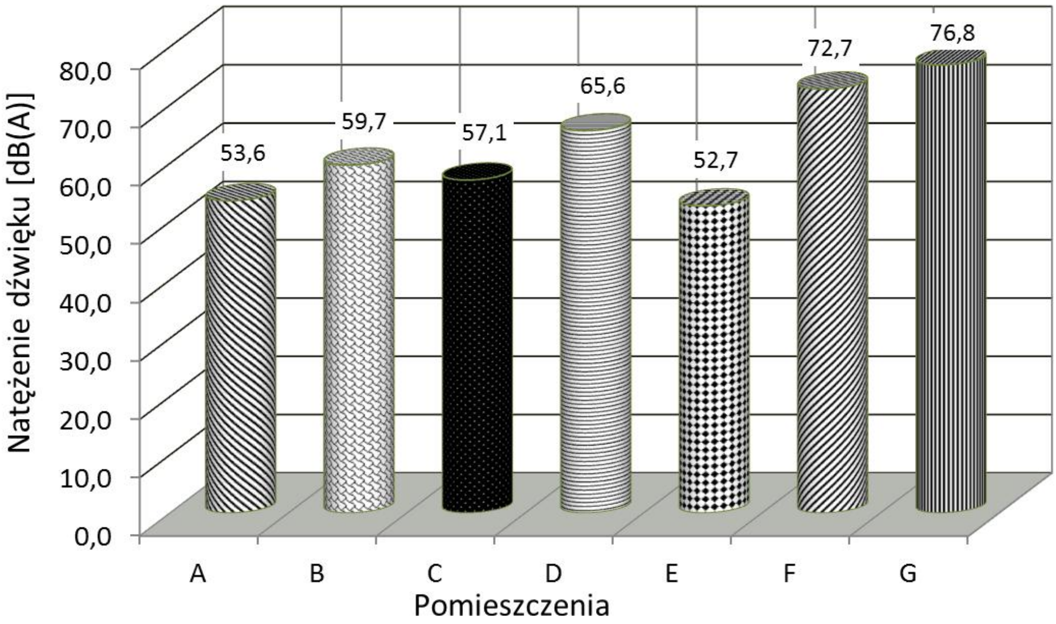

Figure 6. Differentiation of sound intensity in the rooms under examination
Source: own study

Analyzing the spatial structure of the sound intensity in the "G" room used for rinsing potatoes, it was noted that the highest sound intensity values occurred along the central part of the room. In this part of the room, the current standards were exceeded (over 85 dB (A)).

CONCLUSION

1. It was found that there was no abnormality in terms of thermal comfort expressed by the PMV index, the value of which fluctuated between -0.32 (working people in the storage room they felt a slight coolness) up to 0.075 (corresponds to the feeling of slight heat felt by those working there).
2. The average value of the PPD index was 5.8%. The highest PPD ratio of 8.48% was found in room "E", which was 3.36 units larger than the lowest recorded value of this indicator.
3. The observed relative difference between the recorded extreme values of air velocity was as much as 90% (room "B" and "F"), but in absolute terms it was only 0.14 m · s-1.
4. The average value of light intensity in the rooms under examination was 150.6 lux. The highest value (738.9 lux) was recorded in the room "F" (technological corridor), while the lowest intensity (2.0-2.4 lux) in the storage chambers "B" and "C".
5. The highest sound level of 76.8 dB (A) was found in the room "G" (cold room and a room for rinsing potatoes) and the smallest 53.6 dB (A) in the storage chamber (room "E"), which translated into a 30% relative difference.

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INFLUENCE OF SPATIAL DATA INTERPOLATION METHOD ON VISUALIZATION AND IMAGE GENERALIZATION OF THE DIVERSITY OF SELECTED PARAMETERS IMPORTANT IN THE AGRICULTURAL PRODUCTION PROCESS

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Abstract. The work determined the effect of using different interpolation methods of spatial data on the generalization of spatial image map of selected operating parameters concerning a machine unit, i.e. skid and fuel consumption. The scope of work included the measurement of selected operating parameters during field study conducted within field of the area equal 30 ha, complete with an indication of geographical coordinates at the time of subsoiling stubble. Deterministic and stochastic interpolation maps of the spatial distribution of measured values submitted for analysis the impact of the selection of interpolating algorithm on spatial visualization of their volatility. Obtained results were compared with maps constructed by alternative method for interpolation, consisting in determining the statistical average value of the data size for the trial of the immediate neighborhood. It was noted that the best results will give the method of ordinary kriging interpolation. However, some other methods, especially IDW method allows for quite correct mapping of spatial measured values.

Keywords: visualization, spatial interpolation, GPS, GIS

INTRODUCTION

Modern precision agriculture is inextricably linked with the use of computerized technologies, which include, among others, the so-called Global Information System (GIS). Its task is to collect, store, process, analyze and share spatial data (e.g. location, shape or size) and descriptive data (Kwietniewski, 2008; Selvam *et al.* 2019). GIS is often used for creating digital maps. Digital maps are a representation of reality. Due to its complexity, they only present simplification. Differences between digital maps and real maps can be spatial as well as attribute ones because they result from measurement errors. In the case of GIS systems, measurements are carried out only at selected locations and with very limited accuracy. It causes many problems, which in turn contributes to the occurrence of serious errors (Hengl, 2007, Benett *et al.* 2013).

Interpolation is for the numerical method. Positioning the value of the function anywhere on the spot in which the *z (x, y)* value is determined. They are so-called interpolation nodes (Hoang 2016). With these points there is a chance to determine the interpolation function: *z=f(x,y)*. This formula expresses the approximation of a function with an unknown notation that was originally describing the phenomenon. The function goes through the same points with a predetermined *z (x, y)* value. However, it is not certain whether it runs in the same way as the output function.

The most common methods in the interpolation process are:

a) Nearest Neighbor Method

the nearest measurement point. As a result, the division into polygons with a uniform value of a given parameter (the so-called Thyssen polygon) is created. The change of values at the boundaries of the polygons occurs in a stepwise manner. It is an interpolation method called deterministic, faithful, local, non-continuous (Pudełko, 2007).

b) Inverse Distance Weighted

The value assigned to a point in space results from the interpolation of the values from the measurement points. They come from the previously designated neighborhood. The weighted average of the observation is then significant. The obtained weights are inversely proportional to the distant individual measuring points. It can be a linear dependence or raised to a power (usually second or third degree). This method can be considered as deterministic, local and faithful.

The purpose of this work was to determine the influence of the spatial data interpolation method (Inverse Distance Weighted and Nearest Neighbor) on the degree of diversity in spatial map image generalization, using selected operating parameters such as: skid and fuel consumption by the tractor.

MATERIALS I METHODS

The study used research done in 2016 in the area of agricultural land of Top Farms Głubczyce. The farm covers an area measuring 12,000 hectares. It is located in the south of Poland, in several municipalities. The area of the experiment had a rectangular shape with an area of 30 ha, and the soil belonged to plastic clay.

The research was of a staged nature. The activities were carried out in several successive phases. The overview diagram shows all activities related to their implementation (Fig.1). The aggregate crossed out a rectangular, cross-country course, which made possible to create clear maps of the spatial differentiation of the parameters studied. With the use of such a method of running the aggregate, the direction of earlier crops of the field had no effect on the results of the analyzes. Subsequent passages were divided by a distance of no more than 30 m. This allowed to collect enough information, at the same time obtaining a faithful image of the measured quantities. The research used copying depth control of the subsoiler, amount to 0.3 m. The aggregate speed during measurements was 1 $m \cdot s^{-1}$, while the sampling rate of the instruments: 1 Hz.

The main tests included measurement of operating parameters unit. They were made in autumn on the stubble after harvesting winter wheat. During the measurements, a cultivating aggregate was used, consisting of a Massey Ferguson 235 agricultural tractor and a U460 / 2 subsoiler (Fig.2). The agriculture tool has been modernized in such a way that it is possible to adjust the copying depth of work. The aggregate is equipped with measuring equipment. Due to it, data on the real speed of the aggregate, its skid and fuel consumption by the tractor were obtained.

Composed of a cultivating unit and sensors, the measuring system is integrated with a portable computer thanks to unified connectors. A central, mobile measuring unit was created in this way. The Panasonic CF 29 computer was placed in a special stand inside cabine (Fig.3). It cooperated with the DaqBook / 2000A measuring card.

Specially prepared software (Kiełbasa *et al.* 2005) allowed to correlate all measured quantities. Additionally, in order to obtain geolocation data, an antenna receiving a GPS signal - NovAtel Smart was mounted on the roof of the tractor. This system enabled the necessary positioning of the aggregate. A free GPS Monitor application was used for all configurations used in determining coordinates.

2.1. *Method for measuring the skid of tractor drive wheels.* During the tests, the difference between the real speed value of the tractor's drive wheel skid was measured, measured by the CORREVIT L-400 sensor and the theoretical speed calculated from the rotation of the drive wheels. The main components of the measuring device are ferrite magnets and reed switch sensors (Kiełbasa 2011).

The inner part of the tractor's drive wheels is equipped with steel rims with a radius of 0.4 m, to which, in turn, at the intervals of 0.105 m, twenty-four magnets are fixed (Fig. 4). At a distance of approx. 0.005 m, inductive sensors were placed immovably and frontally against magnets. The sensors generated magnetic impulses recorded by the software and the measurement card as a result of rotation of the wheel.

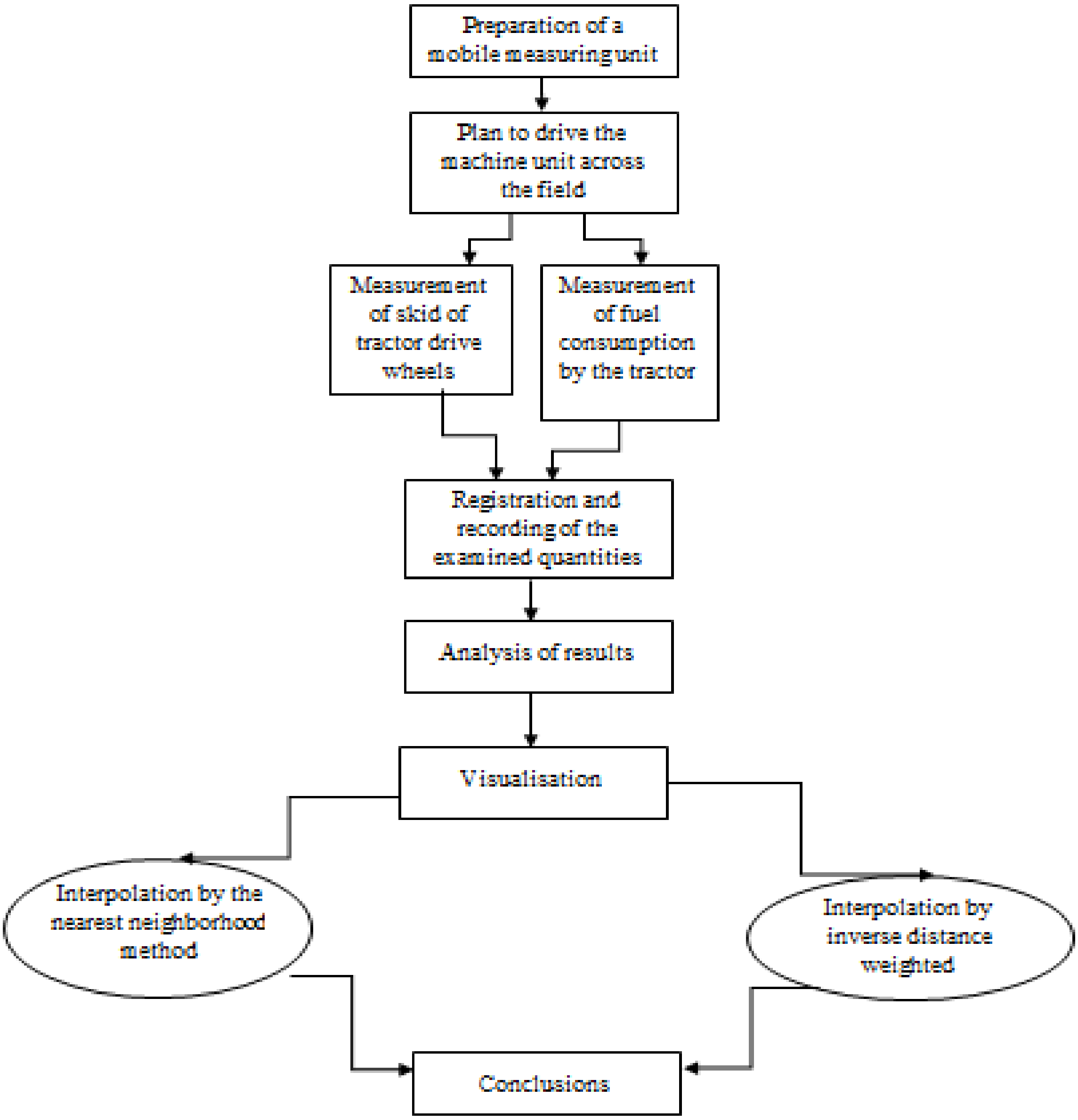

Figure 1. Schematic diagram of the conducted research

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a) b)

Figure 2. Cultivation aggregate used in the tests - a) MF 235 tractor and b) subsoiler U 460/2

a) b)

Figure 3. Measuring stand in the MF 235 tractor equipped with a) Panasonic CF 29 computer board and b) DaqBook 2000A measuring card

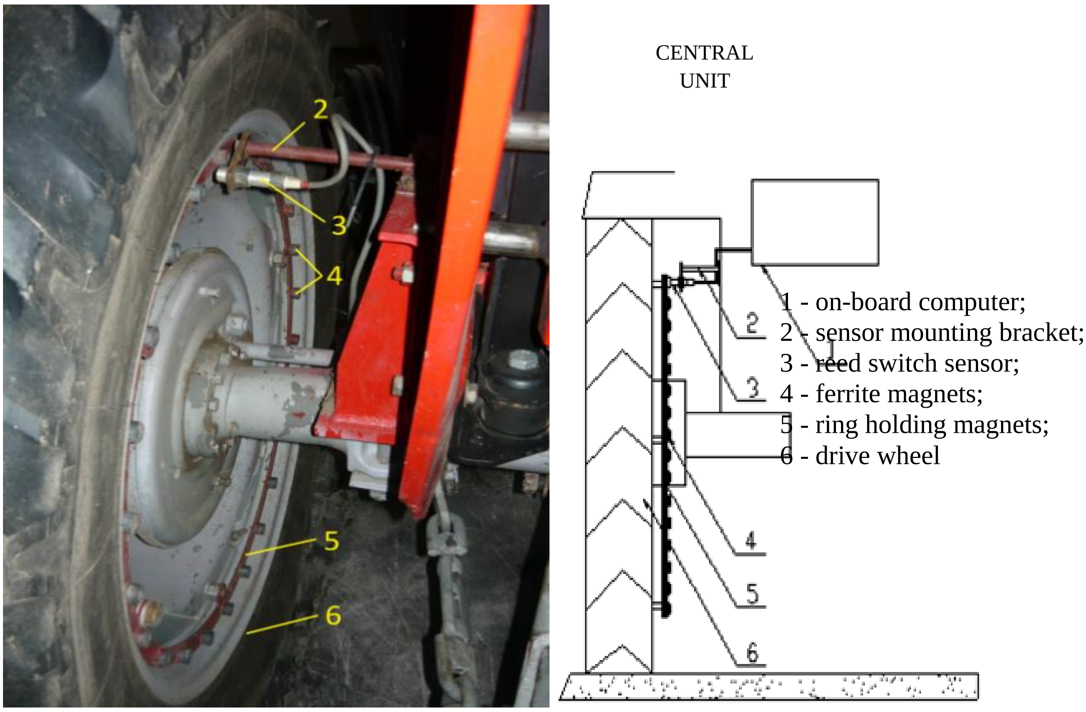

Figure 4. View and schematic of fixing the reed switch sensor at the drive wheel of the MF 235 tractor

To calculate the actual number of rotations of drive wheels, the tractor used the formula:

$$n_{rz} = \frac{l_i}{l_m}\ [rev \cdot s^{-1}] \qquad (1)$$

where:

n_{rz} - rotational speed of the tractor's drive wheel $[rev \cdot s^{-1}]$;

l_i - number of pulses per unit of time [s^{-1}];

l_m - number of magnets on the circumference of the wheel.

To measure the skid of the drive wheels, their dynamic radius had to be determined. On the 50-meter section of the concrete ground, the rotation of the tractor's driving wheels was counted using the video-computer method, travel this distance during towing; as well as using tractor own drive (Budyn *et al.* 2003). The tractor, regardless of the type of drive, moved at a constant speed of 1 $m \cdot s^{-1}$.In this way, data was obtained for calculating the dynamic radius of the tractor's drive wheels.

These quantities were used to calculate the radius using the dependence:

$$r_d = \frac{2s}{2\pi(n_1+n_2)}\ [m] \qquad (2)$$

where:

r_d - dynamic radius of the drive wheel [m];

s - the length of the measuring section [m];

n_1 - number of turns of the tractor wheel when driving with own drive;

n_2 - number of turns of the tractor wheel during towing;

Finally, the value of the tractor's driving wheels skidding was obtained using the dependence:

$$\delta = \left(\frac{v_t - v_{rz}}{v_t}\right) \cdot 100\ [\%] \qquad (3)$$

where:

δ - skidding of the tractor's drive wheels [%];

v_{rz} - real speed of the aggregate determined by an optical sensor [$m \cdot s^{-1}$].

2.2. *Method of measuring fuel consumption.* To determine the fuel consumption of the MF 235 tractor, measurements were made using the VZO-4 fuel meter. This meter consists of a piston placed eccentrically in a cylinder with a larger diameter, with two holes (Fig. 5). The rotating piston pumps the specified amount of fuel (diesel oil) per unit of time. The inlet aperture is supplied with diesel oil filling the space between the partition and the inside of the piston, introducing it into motion. Then flowing further through the outlet opening. This is one cycle. During each cycle, the same amount of fuel is pumped through the meter, because the meter module is a vessel with a specific capacity. The magnetic clutch rotates the piston, and the individual revolutions are recorded and counted, which allows the measurement of flowing fuel.

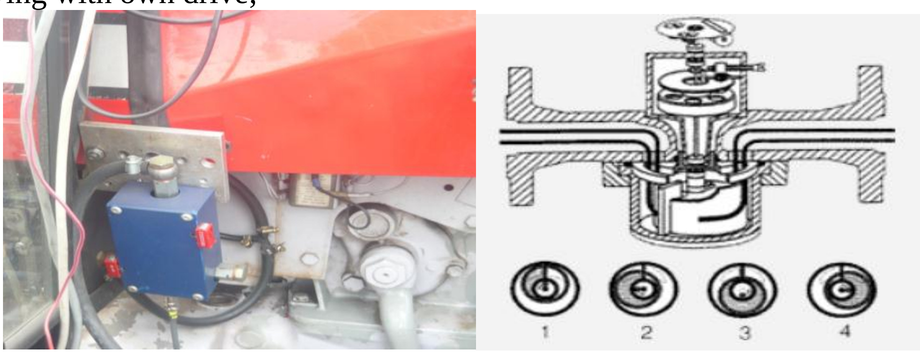

Figure 5. Cross-section and demonstrative principle of operation of the VZO-4 fuel meter

The fuel meter has been placed in the fuel system of the MF 235 tractor in front of the injection pump. Excessive amount of fuel from the injectors was directed not to the tank, but to the injection pump. Due to this, a repeated measurement of the same amount of fuel was not possible. The VZO-4 sensor generated a signal that went through the measuring card to the implemented on-board computer software of the tractor.

3. Results. Visualizations showing the diversity of selected aggregate parameters were made in the SAGA GIS program. The resulting maps have been subjected to two methods of interpolation:

NN (Nearest Neighbour)

IDW (Inverse Distance Weighted)

3.1 *Fuel consumption.* The most popular, deterministic method of interpolation is the Inverse Distance Weighted method. Figure 6 presents spatial visualization of fuel consumption by an agricultural tractor, resulting from the real measurement. The data obtained was interpolated using the IDW method, using a power factor of two, with a model resolution of 10 m. Analyzing this case, it could been notice a "strip system" of the parameter under examination.

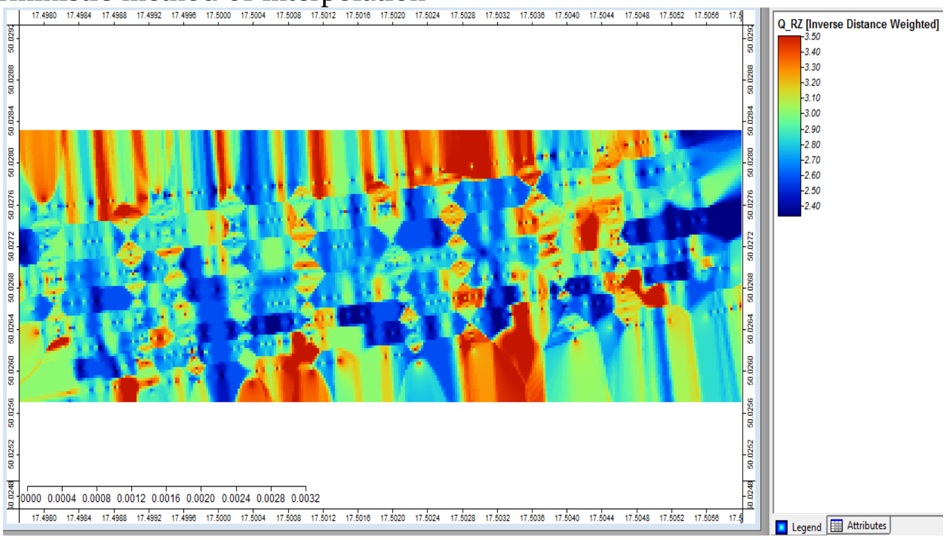

Figure 6. Window for visualization of interpolated data of real fuel consumption using the IDW method

It can be observed that the lowest fuel consumption occurred in the central part of the field and amounted to approx. 2.49 $kg \cdot h^{-1}$, while the highest values prevailed in the upper left part, amounting to approx. 3.4 $kg \cdot h^{-1}$. Six other smaller fuel consumption centers of similar values were created in the area of the tested field. Along the bottom edge there are the same averaged values at around 3 $kg \cdot h^{-1}$.

The second way to interpolate the real fuel consumption data is Nearest Neighbor method (NN). The principle of completing data, as in the case of classic interpolation methods, consists in choosing the technique of finding the nearest points. The most favorable solution is to adopt a radius suited to the model's resolution. GIS programs facilitate the automatic creation of the median, the maximum value, the raster model for the average, the minimum, the most and least characteristic (significant) for the subset of data allocated in the nearest neighborhood.

In models interpolated by these methods, the most significant impact is the local variance, or stationarity of the data set. In statistic distributions of subsets, a large local variance results in locally occurring differences. Specifying values in NN models for these types of areas can significantly differ. The decisive attribute is the range (most often the radius) of the subset selection: the extent of the analysis is larger, the more the interpolated size tends to be generalized. In cases where the ray is going to zero - the interpolated values to a greater extent reflect the local diversity of the interpolated feature. Analysis of local variance and geographic distribution analysis should take place before the interpolation starts with the statistical averaging method. Named studies are a sufficient criterion for choosing how to identify local subsets. Analyzes of the applications of local average usability to the creation of fuel consumption maps were carried out in terms of the selection of such parameter, in order that created model was generalized to the extent allowing the reduction of the "bandwidth" effect, and thus maintaining the correctness of the measured quantity (Fig. 7).

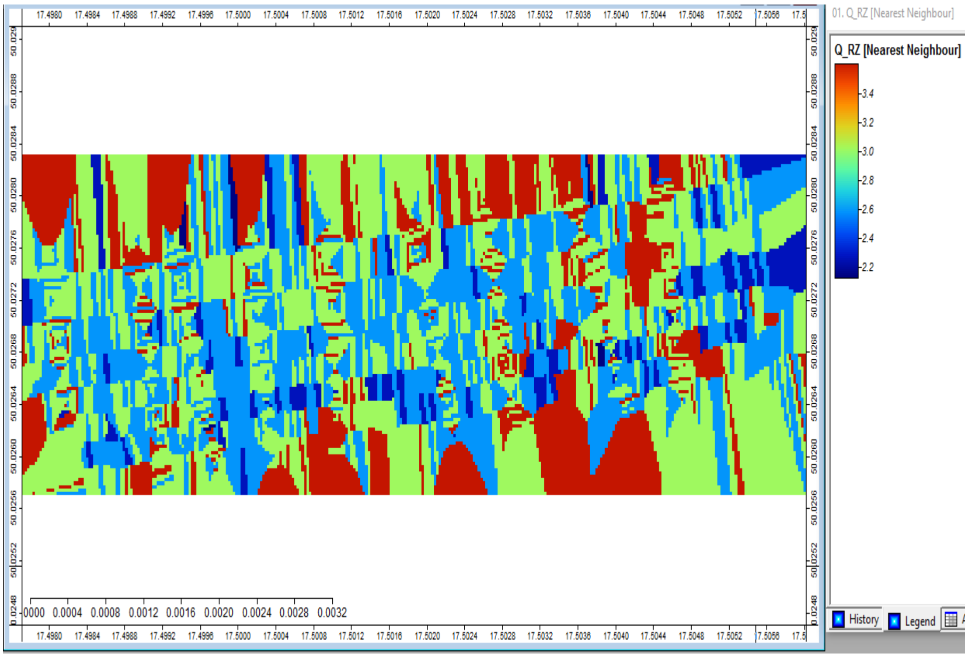

Figure 7. Window for visualization of interpolated variables of real fuel consumption using the NN method

The range of fluctuations in fuel consumption for the NN method ranged from 2.3 kg·h^{-1} to approx. 4.2 kg·h^{-1} and was much higher in relation to the range of fluctuations in the fuel consumption recorded in the case of Inverse Distance Weighted methode.

3.2. *Skid*. The second tested parameter was skid. Figure 8 shows the map made with the Inverse Distance Weighted method (IDW). Skid values oscillate between approx. 4.4% and 5.3%. The map analysis shows that the lowest slip occurred on the left upper field area. A few groups with the smallest value have been deployed all over the area, but they are incidental. High values of about 5.1-5.2% were recorded in the lower left part of the field.

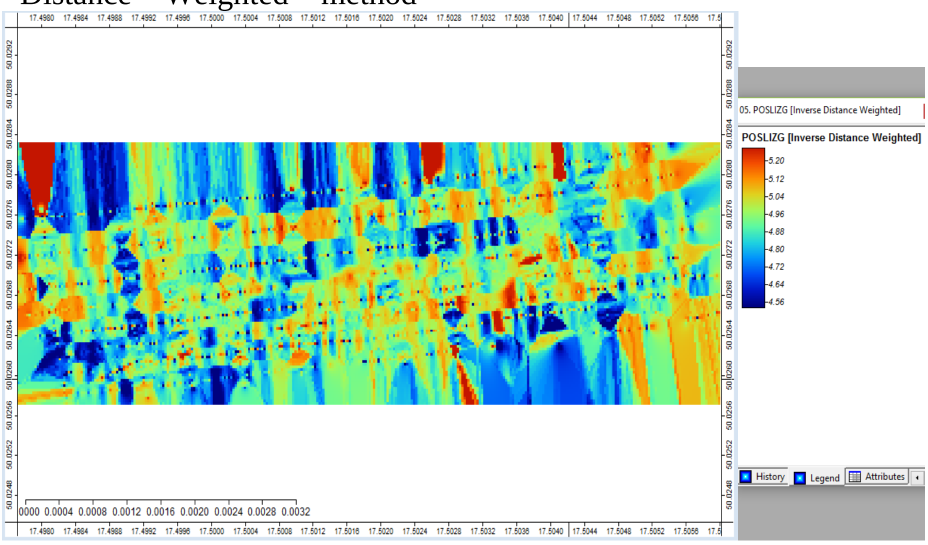

Figure 8. Window for visualization of interpolated skid variables using the IDW method

The map made by the NN method - the Nearest Neighborhood (Fig. 9) shows that the skid range is wider than in the model made with the Inverse Distance Weighted method and amounts to about 4.1% to 5.45%. The points with the lowest skid value are located in the left, lower part of the field, and they assume a value of about 4.1%. Similarly to the map generated by the IDW method, the largest skid was located in the right, lower part of the field, but local spike in the value of the tested parameter they are clearer.

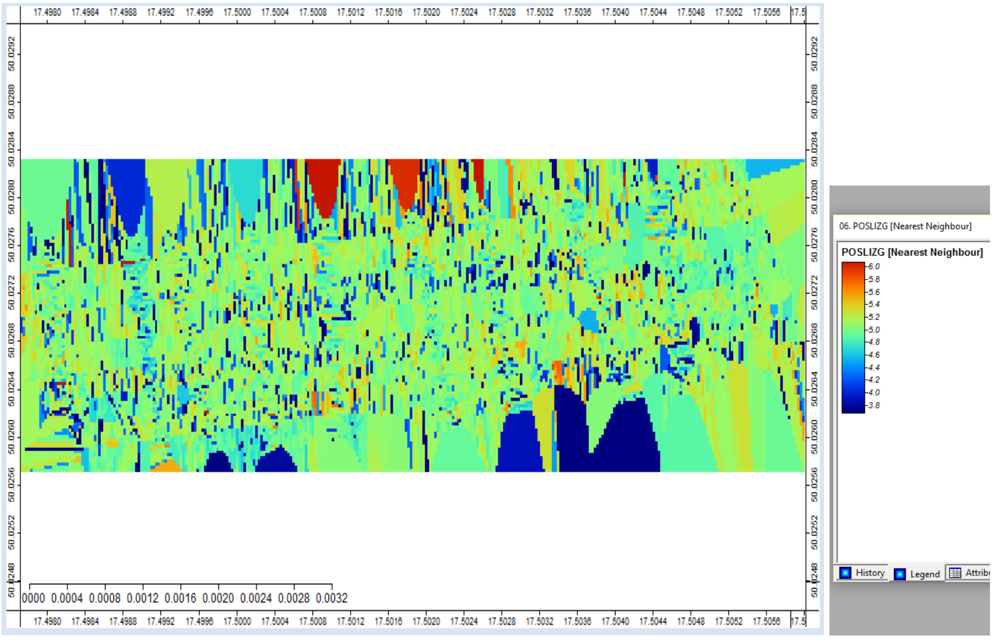

Figure 9. Visualization window of interpolated skid variables by the NN method

Discussion. The interpolation technique in empirical sciences is used primarily in the creation of maps allowing the estimation of the value of the previously unsampled feature, i.e. where the given value has not been measured before in the area covered by the existing measurements.

The commonly used maps are based on the interpolation method adopted by individual authors in an arbitrary way. The key, however, seems to be the choice of a method that allows the most accurate representation of the real state. An attempt to compare various interpolation techniques in relation to agricultural production parameters has so far been undertaken only in relation to the yield of plants (Pudełko, 2007). However, there are no studies showing the differences in the obtained digital maps (in relation to the exploitational aspects of agricultural production), depending on the interpolation method used.

CONCLUSION

1. When using interpolation methods from the deterministic group (Inverse Distance Weighted, Nearest Neighbor), be aware that they give satisfactory results when the interpolation parameters are correctly selected. In the case of the analyzed quantities, i.e. skid and fuel consumption by the tractor, it was observed that interpolation of the above-mentioned variables by the IDW method is sufficient for the implementation of processes related to precise production operations and conscious planning and implementation of the chosen technology. The NN method can be used for standardized sampling points whose coordinates are predetermined and do not result from the spatial variability of a given parameter. Summing up, it should be noted that both methods can be used in such data structures, but a better-quality fit of the map to real data was obtained using the IDW method.

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EXPERIMENTAL INVESTIGATIONS OF ECOLOGICAL EVOLUTION OF SOIL FERTILITY BY CONTROLLED ELECTROMAGNETISM FOR THE PURPOSE OF CULTIVATED CROP PRODUCTION

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Abstract. It is argued that transformation of the energy of electromagnetism, induced on seed material at the stage of its total homeostasis, into the life energy of crops according to the laws of nature, occurs by means of transition radiation, initiated by controlled electromagnetism, induced on seed, at the crossing of electric charge of the boundary, modelling the electromagnetism: air space – a plant cell. Experiments confirm that coherent interaction of the spectra of transition radiation with the spectra, which generate bio-electromagnetisms of cell organelles, sufficiently transform life energy conditions of a cell.

Keywords: ecological evolution, yields, induced electromagnetism, transition radiation, coherent interaction.

INTRODUCTION

The recent findings of agrarian science on the problems of maintenance of soil fertility (Kadiyevskyy *et al.* 2014, Vilkhova *et al.* 2016) provide the ground for solution of the most vital problems of humanity, particularly efficiency of cultivated crops production along with ecological recovery of the soil for their growing. However, it deals with the focus of crop growing on cease of soil degradation, which has currently got a catastrophic scale (Geletukha *et al.* 2014, Geletukha *et al.* 2013, Golub *et al.* 2016, Zinchuk *et al.* 2017). Moreover, nowadays, transfer of Ukrainian crop production to the advanced level of productive and ecological progress is an important component of food and ecological safety of humanity (Chaikin, 2014, European Commission, 2012, Dankevych *et al.* 2016).

The analysis of recent findings of the sciences, engaged in determination of crop production progress (Zinchuk *et al.* 2017, Ec. Europa, 2016, Dankevych *et al.* 2017), confirms that the actual problem can be solved by transformation of the energy of controlled electromagnetism into the life energy of plants according to the regularities of a revolving process of crops evolution. It considers electromagnetic origination of the standard varieties of agricultural crops by transition radiation (Grundas, 2004, Krasowski, 1997, Miroshnyk *et al.* 2018).

The issue of progress in crop production is studied in the works and publications, which argue the nature of the present investigations. The scientific novelty of means and methods of such research performance can be substantiated by analysis of the works, presenting results of fundamental and applied investigations (Miroshnyk *et al.* 2018, Paranjuk, 2015, Fertilization, 1997, Vasylieva *et al.* 2015).

Actuality of the new hypothetical fundamentals of the mentioned researches is confirmed in the works (Ronald, 2003, Xavier *et al.* 2016, Inozemtsev, 2012). Generally, the scientific discovery was declared at the previous stage of those investigations (Paranjuk, 2015).

Theoretical investigations, presented in the work (Miroshnyk *et al.* 2018), create a theoretical basis for experimental investigations. The most important results of those investigations are described in the current work.

MATERIALS AND RESEARCH METHODS

Working hypothesis of electromagnetic recovery of a genotype. Electromagnetic recovery of a genotype of the recognized variety of an agricultural crop is reasonable to be performed according to the following regularities:

– induced electromagnetism is actually an electric corona discharge at the stage of its ignition with a possible reveal of plasma discharge, which is produced by a difference of potentials between corona needle electrode in the form of electrically conducting plane, set parallel to the plane. The plane contains edges of needles of the corona electrode at a pre-determined permanent inter-electrode distance, which is taken as necessary one for performance of a corona process and intensity of the electric field, relating to the value of high voltage, connected to the electrodes;

– regulation of electric potential at a corona needle electrode (electric voltage between electrodes) maintains continuous electric current between electrodes, which is revealed in a move of bulk charge at a permanent speed in the form of “avalanche of electrodes” and air atoms, ionized by them, flowing down from needles;

– on its way to a settling electrode, electric current (mobile bulk electric charge) deposits a surface electric charge on the surface of a treated seed in the stage of total homeostasis. The charge moves into the space of a seed bud in the form of a seed surface electric current;

– in the process of move to a seed bud, current carriers, i.e. electrodes, arouse life electromagnetism in cells and cell environment of a seed, according to the law of electromagnetic induction;

– having reached the membrane of a cell at the stage of its total homeostasis, electric current in the form of electrode flows onto the surface of the seed cover up to a pore in the cover and, having achieved it, focuses its move inside the cell, perpendicular to an elementary lot of the surface of cytoplasmic (cellular) membrane within its pore;

– flow of elementary electric current in the form of an electron from outside of a cell and onto its surface up to a pore, as well as in the pore inside the cell up to its intersection with the plane of external surface of membrane, according to the law of electromagnetic induction for material environment, generates the same charge in the cell with opposite polarity, and the charge generates electromagnetic waves in it;

– collision of the electromagnetism induced in air environment in the form of mobile elementary electric current and generated electric waves with biological charge, induced in a cell, and biological electromagnetic waves, produce transition radiation on the surface of a cell (plasmatic) membrane. Spectra of that radiation enter coherent interaction with spectrograms, which are radiated by cell organelles and can recover life energy in cells, tissues and seed concerning the cell quantity and quality characteristics, which have been expected by selection of a genotype of the recognized variety of an agricultural crop.

Technical and technological system of study of electromagnetic recovery of genotypes of the recognized varieties of agricultural crops. A principal scheme of the ungraded version of technical and technological system of study of electromagnetic recovery of genotypes of the recognized varieties of agricultural crops is demonstrated at the Fig. 1. Creation of the scheme has its historical ground and serves as a basis for a new scientific direction concerning improvement of the technology of seedbed treatment of seed material. The mentioned investigation can be taken as one of the stages of that scientific direction of research.

A more detailed construction and principle of operation of an electric frictional separator of seed EFS-01m are described in the monograph (Paranjuk, 2015). One should stress that a previous version of the separator in Russia was introduced into the system of seed-processing machines for selection stations. It is currently still used there.

The flat settling electrode 9 (Fig. 1, *b*) is made of foil-clad paper-based laminate with a removed foil edge in order to prevent threshold effect, and with an under-set vibration device 8 with a frequency of oscillations, which is equal to the frequency of its own oscillations of an average seed 7 (Fig. 1, *b*) of a selection of quality certified seeds. In a model scheme of the process of receiving of electromagnetic effects by seed material (Fig. 1, *b*), dielectric partitions 13 (Fig. 1, *c*) are not depicted under the condition of correction of their absence while developing theoretical fundamentals by means of the values of regulated parameters of electromagnetic treatment of seed material, which enables logical and comprehensive building of theoretical fundamentals of the process.

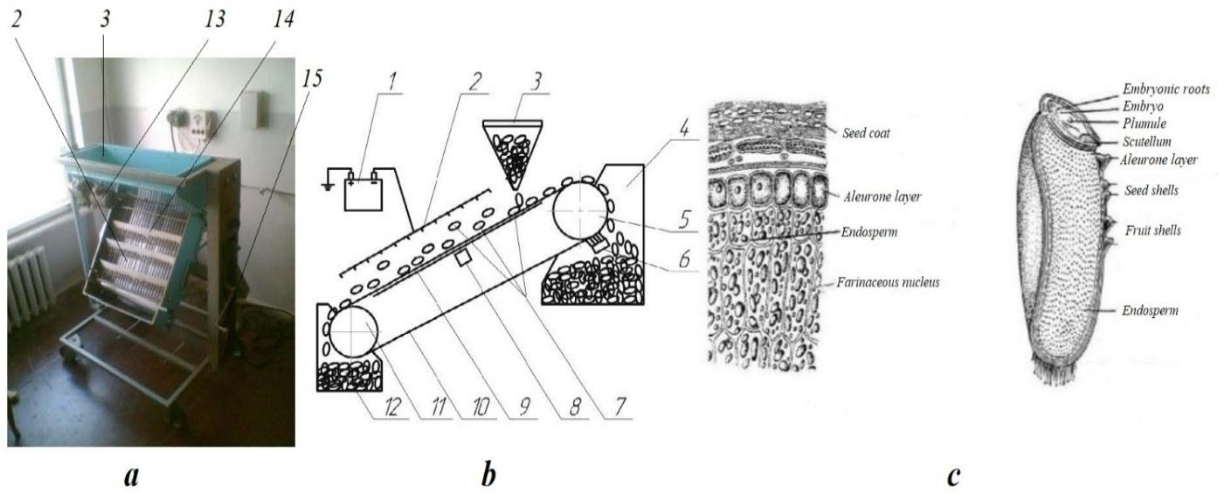

Figure 1. Technical and technological system of investigation of electromagnetic effects on seed material
a – production experimental sample of an electric seed-treating machine for inducing of electromagnetic effects on seeds of seed material in the system of its preparation – an electric frictional separator of seed EFS-01m; *b* – a model scheme of the process of receiving of induced electromagnetic effects by seed material; *c* – a universal model of a seed of seed material with an open bud for receiving of induced electromagnetic effects; 1 – a unit of high voltage; 2 – a corona needle electrode; 3 – a container of seed supply; 4 – a receiving bin for seed wastes; 5 – a leading roller of a conveying separating belt; 6 – a brush for cleaning of a conveying belt from dust; 7 – seeds; 8 – a vibration device; 9 – a flat settling electrode; 10 – a separating conveying belt; 11 – a led roller of a conveyer; 12 – a receiving bin for certified seeds; 13 – a regulated electric driver of a conveying belt; 14 – a dielectric partition in the operating zone of electromagnetic effects on sowing material for polarization of inter-electrode space and seeds of seed material; 15 – a handle to regulate angle of the conveying belt inclination to the horizon.

Parameters of generation of the controlled electromagnetism induced on the seed material at the stage of corona ignition are demonstrated in the Table 1. It is a new, patented technical and technological system (Paranjuk, 2015), which reveals possibilities of the new approach to production of new, objectively reliable, and reproductive knowledge about transformation of electromagnetism into the evolution according to the natural laws of life processes in a plant and soil of its growing.

Table 1. Parameters of generation of the controlled electromagnetism, induced on the seed material of cultivated crops at the stage of corona ignition

№	Parameters of electromagnetic effects			Argumentation of parameters
	Parameter	Unit of measurement	Value	
	1	2	3	4
1.	Needle diameter	mm	0,3	Theoretically studied and experimentally approved
2.	Needle length	mm	30	
3.	Distance between needles	mm	30	
4.	Inter-electrode distance	mm	60	By the experiment
5.	Electric field intensity	Kw/cm	2,8-3,0	By conditions of corona ignition
6.	Period of laying away	day	5	According to the existing methods of electric stimulation and laying away before sowing
7.	Exposition of treatment	second	3	

Table 2. Results of the productive experiment concerning effect of stimulation of the seed material of fodder perennials by means of induced electromagnetism

№	Recognized variety of an agricultural herbaceous crops in soil-climatic zones			Growth of fodder and seed productivity of perennial grasses as compared to the control by zones, %				
				Herbage	Hay	Seed yield by years		
	Species	Sort	Zones	Average for in three years		First year	Second year	Third year
1	Legume grasses	Pre-Carpathian red clover 6	Forest Steppe	110	116	129	112	141
			Pre-Carpathian	118	137	116	120	118
2		Pre-Carpathian small white clover 25	Forest Steppe	128	130	150	144	165
			Pre-Carpathian	119	126	121	117	119
3		Lishnianska small white clover	Forest Steppe	126	135	125	111	145
			Pre-Carpathian	120	124	115	125	120
4		Prydnistrovska hybrid clover 2	Forest Steppe	112	108	130	104	132
			Pre-Carpathian	114	118	116	112	114
5	Grasses	Drohobytskyi perennial ryegrass 2	Forest Steppe	107	107	118	117	109
			Pre-Carpathian	125	125	118	122	120
6		Drohobytskyi perennial ryegrass 19	Forest Steppe	116	126	116	114	125
			Pre-Carpathian	119	119	121	128	125
7		Peredhirna common timothy 3	Forest Steppe	128	102	130	102	116
			Pre-Carpathian	145	145	104	136	120

Results of the three-year productive experiment concerning effect of stimulation of the seed material of fodder perennial herbs by means of induced electromagnetism are presented in the Table 2. The research first substantiates the possibility of full reproduction of the effect of three-second stimulation of seed in the growing generations. It supplies credible argumentation of the scientific assumption that the controlled electromagnetism is capable to develop the evolution of life process of plants, according to the laws of nature. The evolution happens relating to the plants' conditions, set by selection of the genotype of a definite standard variety of agricultural crop for the soil and climate zone.

These grounded facts bear the following scientific novelty:

1. The controlled electromagnetism, induced on the seed, transforms its energy into the energy of plant life by provoking transition radiation in its cell in case, when its spectra include the ones, which are capable to enter a coherent interaction with the spectra of intercellular radiations at the stage of homeostasis.

2. Absorption of the induced electromagnetism by a plant cell for awakening of transition radiations in the cell and cellular environment of the seed occurs within the embryo.

CONCLUSION

Results of data of experimental researches have first argued the regularity, which confirms that electromagnetic recovery of the genotype of the recognized variety of agricultural crops by means of controlled electromagnetism, induced on seed material, is possible with consideration of the following regulations of the process:

1. ionic activity of the cell organelle in the stage of its total homeostasis of a seed has symmetric harmonious character and electromagnetic radiations, produced by it, are capable to enter coherent interaction with the transition radiation, generated in the cell;

2. a plant cell, tissue and seed at the stage of a total homeostasis enables application of the findings of mathematic physics concerning the spreading and effect of radiation in complicated stochastic dielectric environments;

3. detected regularities of controlled evolution of the plant-soil system in primary seed study, according to the laws of the nature, and adaptive crop production, which is new-established on the basis, are able to secure solution of the most actual food and ecology problems of human civilization;

4. ecological evolution of productivity of the soil for cultivated crop production, forced by controlled electromagnetism, along with improvement of growing efficiency of standards varieties of agricultural crops, which are developed by the agrarian science.

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NUTRITIONAL VALUE AND OIL CONTENT OF HAZELNUT

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Abstract. Sciencetific name of Hazelnut is Corylus avellana. The total amount of world production of hazelnut is mainly around 800.000 tons/year. About 65% of world's hazelnut production is harvesting in Turkey. Besides its economic importance, the high nutritional value of hazelnut makes it a special food. Hazelnut is a crucial and non-equivalent material for praline production, which is semi-finished product of chocolate industry. The hazelnut is a small deciduous tree originated in southern Europe and Turkey. It is now being cultivated in many regions of the world, as a major commercial crop. Hazelnuts are rich in unsaturated fats (mostly oleic acid), protein, complex carbohydrates, dietary fiber high in magnesium, calcium, zinc and vitamins B and E. Hazelnuts are good for your heart, help reduce the risk of cancer, and aid in muscle, skin, bone, joint and digestive health. This study has focused on Fatty acids content and nutritional effect of hazelnut.

Keywords: Hazelnut, content, nutritional effect, fatty acids

INTRODUCTION

High nutritional value of hazelnut is significant. Nutritional analyses of hazelnut present a high protein content (16.9%). Moreover, its protein quality (66.6%) is also high in comparison to many proteins of plant origin. It appeared to be one of the best sources of plant origin for iron (5.8 mg/100g), calcium (160.0 mg/100g), and zinc (2.2 mg/100g), which are the most important minerals for growth and development. Hazelnut were also found to be rich in potassium(655 mg/100g), which is necessary for nerve stimulation and functioning of muscle tissue. Hazelnuts were found to be good sources for vitamins B1 (0.33 mg/100g), and B2 (0.12 mg/100g), and very good sources for vitamin B6 (0.24 mg/100g) and Vitamin E (31.4 mg/100g), vitamins B2 and B6 are especially important nutrients for the schoolage children. The hazelnut is also the second best source of vitamin E after plant oils. This vitamin is essential for the normal functioning of muscle tissue and the reproduction system. It protects the organism agains cancer. Vitamin E also prevents the hemolysis of erythrocytes, and thus protects the body against anemia. The fat content of important varieties of Turkish hazelnuts is around 61%. Because of their chemical and nutritional compositions, hazelnuts have potential benefical health effects (Alphan *et al.* 1997).

The main fatty acids in hazelnut varieties were oleic (79.4%), linoleic (13.0%) and palmitic acid (5.4%). The ratios of polyunsaturated/saturated and unsaturated/saturated fatty acids of hazelnuts varieties were found to be between 1.23 and 2.87, and 11.1 and 16.4, respectively.

The average niacin, vitamin B1, vitamin B2, vitamin B6, ascorbic acid, folic acid, retinol and total tocopherol contents of hazelnut kernels were 1.45 mg/100 g, 0.28 mg/100 g, 0.05 mg/100 g, 0.5 mg/100 g, 2.45 mg/100 g, 0.043 mg/100 g, 3.25 mg/100 g and 26.9 mg/100 g, respectively. The amount of the essential amino acids, mostly as arginine (2003 mg/100 g) and leucine (1150 mg/100 g), and the non-essential amino acids, mostly as glutamic acid (2714 mg/100 g) and aspartic acid (1493 mg/100 g) were also determined in the hazelnut varieties. Mineral compositions of the hazelnut varieties, e.g., K, Mn, Mg, Ca, Fe, Zn, Na and Cu were (averagely) measured as 863 mg/100 g, 186 mg/100 g, 173 mg/100 g, 5.6 mg/100 g, 4.2 mg/100 g, 2.9 mg/100 g, 2.6 mg/100 g and 2.3 mg/100 g, respectively (Koksal *et al.* 2006).

Hazelnut contains saturated and unsaturated fatty acids. Saturated fat is one of the two main classes of fat, the other being unsaturated fat. These groups differ slightly in their chemical structure and properties. For instance, saturated fat is generally solid at room temperature, while unsaturated fat is liquid. The amount of these and their ratio to each other are important in healthy nutrition. In this study, nutritional contents of hazelnut were examined, especially some important unsaturated fatty acids contents and their influences were presented in detail. In addition, hazelnut nutritional effect on healthy diet in other important issues has been tried to give.

MATERIAL AND METHODS

Fat content and fatty acid composition of Turkish hazelnut are given in Table 1 (Mehmet Ali Koyuncu, 2004). The hazelnut cultivars, Tombul, Palaz and Kalınkara, contained 60.88%, 60.40% and 61.55% fat, respectively. There were no significant differences in fat content among cultivars. The saturated fatty acids found in the hazelnut kernels were palmitic acid as the predominant one followed by stearic acid. Also traces of palmitoleic acid were identified. Among the varieties, the main unsaturated fatty acid was oleic acid, 79.37% to 80.86%. While linoleic acid ranged from 10.41% to 11.86%, linolenic acid was detected only at trace levels. Significant differences were found among the cultivars for the saturated fatty acids palmitic and stearic. No significant differences were found for the unsaturated fatty acids. The total fat content of the varieties increased from 58.68% to 62.48% during storage. The difference was statistically significant. The palmitic and oleic acid content of the stored nuts were found higher whereas linoleic acid was lower compared with fresh nuts. Differences in palmitic and linoleic acid contents during storage were statistically significant. No significant differences were found for other fatty acids, palmitoleic, stearic, oleic and linolenic (Table 2) (Mehmet Ali Koyuncu, 2004). The fat content of the hazelnuts stored unshelled and shelled differed significantly. They were, respectively, 60.05% and 62.58%. However, there were no significant differences for each of the fatty acids. At the end of storage period, the total saturated fatty acid content of the three hazelnut cultivars was a little higher (8.30%) compared with the beginning of storage (8.14%); the total unsaturated fatty acid content changed from 92.12% to 90.88%. There were no significant differences at the beginning of the test period, 6 months or 12 months of storage. The unsaturated fatty acid content of nuts makes them nutritional products, but also makes them more susceptible to autoxidation. It is necessary to know the chemical and fatty acid composition of hazelnuts and the change of these parameters during the storage because of their relationship with nutrition and oxidation. The total fat, palmitic and linoleic acid contents of hazelnut changed during the storage at 21 C and 60–65% relative humidity. No significant differences were found for other fatty acids. The change of fat content of cultivars depending on whether nuts were shelled or unshelled was found to be statistically significant. While the total saturated fatty acid content increased from 8.14% to 8.30%, the total unsaturated fatty acid content changed from 92.12% to 90.88% in the storage period.

Fat content of roasted Turkish hazelnut (Tombul variety) has been investigated by Lviv National Agrarian University. The results are presented in Table 3 (Kambur *et al.* 2013). Roasting process makes additionally drying effect on samples. It is important the temperature and duration of roasting process. In that context, it seems to be changed some fat content of roasting hazelnut samples comparing with raw samples, Table 3.

In a study performed by Arslan et al., fat contents of 7 different Turkish hazelnut varieties were examined, Table 3. Moreover, polyunsaturated/saturated and unsaturated/saturated fat ratios were investigated in the same study, Table 4, 5.

Table 1. Fat content and fatty acid composition of hazelnut varieties (%)

Variety	Fat	Palmitic	Palmitoleic	Stearic	Oleic	Linoleic	Linolenic
Tombul	60.88^{ns}	6.07 b	0.08^{ns}	2.24 b	79.37^{ns}	11.86^{ns}	0.17^{ns}
Palas	60.40	6.45 a	0.05	2.34 a	79.80	10.41	0.37
Kahnkara	61.55	5.65 c	0.12	1.64 c	80.86	11.48	0.15

Any two values in a column with the same letters are not significantly different.
^{ns} Not significant.

Table 2. The chance of fat content and fatty acid composition of hazelnut varieties during the storage (%)

Period	Fat	Palmitic	Palmitoleic	Stearic	Oleic	Linoleic	Linolenic
Beginning	58.68 c	6.04 ab	0.10^{ns}	2.00^{ns}	79.62^{ns}	12.41 a	0.09^{ns}
6^{th} month	60.55 b	5.89 b	0.11	2.17	79.96	11.57 a	0.28
12^{th} month	6.23 a	6.23 a	0.05	2.01	80.27	10.35 b	0.25

Any two values in a column with the same letters are not significantly different.
^{ns} Not significant.

Table 3. Fatty acid composition of roasted hazelnut by cold pressing method

Fatty acids and code	Fattyacidscontentinpercentages		
	Crushed nut (large fraction)	Crushed nut (small fraction)	Whole hazelnut
Capric, 10:0	0,1	0,1	0,1
Lauric, 12:0	0,8	0,7	0,7
Myristic, 14:0	1,6	1,6	1,5
Pentadecylic, 15:0	0,8	0,8	0,7
Palmitic,16:0	5,8	5,7	5,6
Palmitoleic,16:1	0,4	0,4	0,4
Stearic, 18:0	3,4	3,2	3,1
Oleic, 18:1	70,7	71,7	70,8
Linoleic, 18:2	14,2	13,8	14,7
α-Linolenic, 18:3	1,9	1,7	2,1
Arachidic, 20:0	0,2	0,2	0,2
8-Eicosenoic, 20:1	0,1	0,1	0,1

Table 4. Fatty acid compositions of hazelnut oils of seven Turkish varieties (Kambur *et al.* 2013)

Variety	Palmitic	Miristic	Palmitoleic	Stearic	Oleic	Linoleic	Saturated	Unsaturated
Ham	5.70±0.91 a	0.18±0.01 a	0,22±0.07 a	0.73±0.05 a	85.47±1.4 c	7.63±0.53 e	6.61±0.22 a	93.30±2.37 e
Tombul	4.95±0.76 c	0.15±0.02 c	0,15±0.02 d	0.59±0.06 e	85.12±1.37 d	9.07±0.39 c	5.69±0.39 c	94.22±3.95 c
Kara	4.71±0.54 e	0.15±0.01 c	0,21±0.01 b	0.68±0.09 c	84.27±1.01 f	9.98±0.48 b	5.54±0.23 d	94.37±1.95 b
Sivri	4.75±0.98 d	0.13±0.01 d	0.22±0.08 a	0.66±0.03 d	86.53±2.55 b	7.71±0.97 d	5.54±0.14 d	94.37±3.23 b
Kan	4.71±0.82 e	0.15±0.02 c	0.21±0.03 b	0.69±0.06 b	84.27±2.11 f	9.98±0.41 b	5.54±0.47 d	94.37±2.86 b
Badem	4.52±0.79 f	0.16±0.00 b	0.21±0.04 b	0.51±0.02 f	84.51±0.97 e	10.09±0.65 a	5.19±0.26 e	94.72±1.60 a
Palas	5.19±0.70 b	0.16±0.01 b	0.18±0.01 c	0.44±0.04 g	87.38±2.30 a	6.65±0.67 f	5.79±0.15 b	94.12±2.57 d

Table 5. The ratios of polyunsaturated/saturated and unsaturated/saturated fatty acids of hazelnuts oils from seven Turkish varieties (Kambur *et al.* 2013)

Variety	polyunsaturated/saturated	unsaturated/saturated
Ham	1.16	14.11
Tombul	1.59	16.56
Kara	1.80	17.03
Sivri	1.39	17.03
Kan	1.80	17.02
Badem	1.94	18.25
Palas	1.15	16.26

CONCLUSİON

1. Hazelnuts are is rich in unsaturated fats (mostly oleic acid), significantly high in magnesium, calcium and vitamins B, E, and folic acid. They are good for your heart, help reduce the risk of cancer, and aid in muscle, skin, bone, joint and digestive health. Monounsaturated and polyunsaturated fats have a beneficial effect on your heart by lowering the bad cholesterol levels in your blood. The omega-3 and omega-6 fatty acids in hazelnuts are important components of cell membranes and are involved in the regulation of inflammation and prevention of hypertension. A major type of monounsaturated fat in hazelnuts is oleic acid. Oleic acid has beneficial effects on your health and may have a positive role in reducing cholesterol levels and blood pressure.

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BIOMASS UTILIZATION POSSIBILITIES AND CONVERSION METHODS

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Abstract. Energy use is increasing and the negative effects of intensive energy consumption on the environment are known. It is important to ensure and sustain a sustainable life cycle. Renewable energy use and dissemination is one of the important parameters that will be useful for this purpose. Biomass energy is at the first places in renewable energy. It is also suitable for local supply and local solutions. Appropriate assessment to the requirements is crucial with local approaches. If this is done, it will serve the purpose more effectively. In this study, biomass energy utilization methods are presented including comprehensive classification. These methods are classified in three main groups; physical, thermochemical, and biochemical conversion methods. Information about these groups is detailed in subdivisions.

Keywords: Sustainability, renewable, biomass, conversion, classification

INTRODUCTION

Due to the depletion of fossil fuels and their harmful environmental effects, it is becoming compulsory to seek alternative energy sources and to search for equivalent fuels. Therefore, exploring alternative energy resources is gaining growing importance on international scale and one of favorite topics for researchers (Jiang *et al.* 2016). Among renewable energy resources, biomass is an energy source that does not pollute the environment and has a wide range of applications especially for developing countries. Easy availability of biomass in the environment and having a low CO_2 emission relative to fossil fuels makes the biomass among the demandable energy resources. Bioenergy is taking the second place among the renewable energy resources in the market. Small-scale investment for bioenergy systems is increasing day by day due to its low cost. In 2012, 1.5% (370 TWh) of total electricity generation in the world was generated by using biomass resources. Currently, approximately 10% (50 EJ) of energy supply in the world is provided from biomass converted energy (Moka 2012). Although biomass materials have low energy densities comparing with coal, chemical properties make it higher-ranking in many ways. Moreover, the ash content of biomass materials is less than fossil fuels and generally free of toxic elements and other contaminants. This makes the utilization of residual ash of biomass as a soil fertilizer during agricultural applications (Zobaa *et al.* 2012). Additionally, planting and growing of biomass and their utilization for energy production causes reducing global warming effects because CO_2 released from combustion processes is converted by growing biomass through photosynthesis (Balat, 2005).

Biomass is an organic material that comes from plants and animals and can be found naturally all around the world at high amounts. There are approximately 4 billion tons of biomass in the ocean and 1,8 billion tons on the ground, and a proportional quantity in the soil. Agricultural residues, energy crops, forest resources, organic waste (such as municipal and industrial), sewage sludge and marine biomass (algae), etc. can be classified as a biomass (Yokoyama *et al.* 2008).

In general, biomass can be categorized in two ways:

1. Nature of biomass
2. Utilization/application area

The first categorization is based on the ecology or the type of biomass and can be entitled as biological categorization. Categorization is done by nature of existing biomass. The second categorization is based on its application such as energy resources (Yokoyama *et al.* 2008).

In line with the objective of this review paper, the second categorization based on the use and application of biomass was considered and biomass was classified in three groups:

1. Conventional biomass resources [agriculture, forestry (woody), fishery, livestock farming, food, materials, medicine, timber, pulp, chip, etc.]
2. Biomass wastes and its derivatives [agricultural, forestry, fishery, livestock residues (wastes), rice straw, cattle manure, lumber mill, sawdust, sewage sludge, black liquor, etc.]
3. Plantation biomass [forestry (eucalyptus, poplar, willow, oil palm), herbaceous (sugarcane, switchgrass, sorghum, corn, rapeseed), aquatic (giant kelp, water hyacinth, algae)] (Yokoyama *et al.* 2008).

Every kind of biomass can be utilized in various applications for heating purposes, obtaining electricity, production of fine chemicals (methanol, ethanol, etc.), polymeric materials and also biofuels (ethanol fuel, biomass-based biodiesel, biogas, etc.) (Jiang *et al.* 2016; Zobaa *et al.* 2012). However, some part of the biomass belongs to food chain. Therefore, the type and quantity of biomass which can be used as energy resources should be considered carefully before application processes (Yokoyama *et al.* 2008). Moreover, the variety of biomass source makes the use of diversified and innovative technologies, which are based on the separation of components at the first stage, inevitable to obtain high-value products (Chen *et al.* 2017; Kumar *et al.* 2017; Gravalos *et al.* 2016).

Generally, biomass emerges in solid, liquid and gas phase. It can also be found as a multi-phase structure in the form of combinations, such as in municipal wastes and animal wastes. Main components in biomass structure are cellulose, hemicellulose, lignin, starch, proteins, and some organic and inorganic components (Yokoyama *et al.* 2008). In addition to these, lignocellulosic structures known as single-phase (solid) have non-structural moisture. It is necessary to remove this moisture at a certain amount from biomass beforehand. Also, separation of main components in biomass structures should be considered during utilization processes. In this context, biomass conversion systems should take all these factors into consideration and provide the optimum solution (Yokoyama *et al.* 2008).

The widespread use of renewable energies requires global thinking and local approaches. It is important to bring solutions in close proximity to local needs. For this purpose, biomass conversions constitute one of the most significant instruments. Biomass is confronted in a wide variety of structures. Therefore, the conversion targets and intended usage purposes are also different, and the issue of how to reach the target and with which methods is gaining importance. By adopting the systematic approach mentioned in this study, classification and examination of the methods and explanations of the various sides are explained respectively. Information supported with some comprehensive and distinctive information on the subject additionally is provided as well.

2. Conversion methods. Biomass materials can be modified and proceed to different valuable and marketable products such as biofuels, biogas and some industrial chemicals through conversion technologies. The conversion process of biomass materials into energy encloses biomass type, biomass source, conversion process conditions, general requirements for processing including infrastructure and utilization area. There are various classifications similar to each other in the literature and present only small differences. However, it is difficult to distinguish the methods used in conversion systems and developing reactions with very precise lines. In this context, conversion methods for biomass utilization can be basically classified in three groups:

1. Physical conversion methods.
2. Thermochemical conversion methods.
3. Biochemical conversion methods.

2.1. Physical conversion. Physical conversion methods are applicable to solid biomass in terms of their structure. Generally, it is conducted with processes such as cutting, drying, reshaping, reducement, and condensation. Biomass materials can be converted into the main products including sheets, construction materials, and lignocellulosic composites by using physical conversion technologies (Kumar *et al.* 2017). The use of solid biomass with physical conversion methods can be examined in three parts: firewood, pelletizing and particle board production.

2.1.1. Firewood. Biomass as energy resource constitutes an important place in developing countries. Utilization of biomass for energy by direct burning is a classical way. In this process, materials such as wood, husk, agricultural wastes, etc. are directly burnt to obtain heat or process heating without being processed too much. The main stage in this method is cutting of raw materials in to the desired length and thickness which can be vary depending on furnace properties and utilization purposes (Balat, 2005). In addition, decreasing of humidity of biomass, in other words drying, is important to be suitable for direct burning.

Biomass materials used as fuel can be compared in terms of their thermal values. Thermal values of various agricultural residues are given below in Table 1 (Gravalos *et al.* 2016).

Table 1. Gross calorific values (GCV) of some biomass materials (La Villetta *et al.* 2017)

Biomass	Mean GCV ($MJ.kg^{-1}$)
Rice husk with moisture content 8.30%	15.972
Rice husk without moisture (dried at 105˚C for 24 h)	16.643
Rice straw with moisture content 12.19%	15.092
Rice straw without moisture (dried at 105˚C for 24 h)	16.475
Pistachios shells	17.320
Leaves of Pistachio trees	16.120
Dark red sweet cherry seeds	19.870
Apricot kernels	18.562
Peach kernels	18.995
Watermelon fruit seeds	24.473
Grape seeds	20.388
Olive pits	17.970
Almont husks	18.176
Sunflower husks	18.674
Sunflower seed cake with moisture content 12.72%	21.231
Rapeseed cake with moisture content 11.17%	21.569
Cotton (Gossypium hirsutum L.) plant root	17.707
Cotton plant main stem	17.733
Cotton plant terminal bud	16.396
Cotton plant vegetative branches	17.376
Cotton plant fruiting branches	17.368
Cotton plant leaves	16.059
Cotton plant (25 weeks/harvest) bur	17.141
Cotton plant (25 weeks/harvest) locks	16.679
Cotton plant seeds	22.933

The values given in the Table 1 shows that various biomass resources have different calorific values that depend on the source, moisture content and structure of biomass. It is obvious from the table that seeds and kernels have higher calorific values than leaves due to their higher unit mass and higher lipid contents. The moisture content also effects the thermal values. The biomass materials with low moisture have higher thermal energy values.

2.1.2. Pelletizing. Pelletizing is a kind of process during which various biomass materials such as agricultural residues, solid fuels, feed, ore etc. are compressed into the form of pellet. Pelletizing can also be defined as a condensation process during which fine powders or granules of a biomass materials are converted to small spherical particulates called pellets (Balat, 2005; Muley *et al.* 2016). A diameter of a pellet is generally between 6 to 12 mm. The larger ones are called as briquettes which have a diameter of 50-80 mm (Balat, 2005).

Lots of biomass materials can be utilized in their original form however the heating values per unit volume is generally low and handling and transportation is relatively high. Densification of biomass materials is an alternative way to get rid of this kind of problems. Moreover, the calorific value of biomass can be improved during densification process by decreasing moisture level. The pellets obtained after densification process are more convenient biofuel for the use in urban area where the conversion does not need any special conditions such as utilization of pellets in automatic furnaces requiring low care (García-Maroto *et al.* 2015). The regular geometric shape after densification makes the biomass easy to feed automatically into the boiler and handle maintenance issues. In addition, biomass pellets have low heating costs, can be obtained from naturally available abundant raw materials and do not pollute the environment as much as fossil fuels.

Densification of a biomass to produce pellet and briquette comprises following manufacturing stages (Balat 2005):

1. Drying.
2. Pulverizing.
3. Pelletizing.
4. Cooling.
5. Screening.

Wood is the most used raw material for the production pellets in the world. However, the increasing demand for pellet utilization as an energy and non-energy resources requires the use of other biomass materials such as bark, agricultural residues, energy crops, etc. as an alternative to wood (Puig-Arnavat *et al.* 2016).

2.1.3. Particleboard. Raw material requirements of forest industry are increasing year after year. Due to the fact that decreasing amount of obtained products from the natural environment, manufacturer tends to find alternatives sources like agro-residues, lignocellulosic biomass materials to use for industrial manufacturing (Guler *et al.* 2011).

Particleboards can be promising raw materials for forest industry. They can be produced from wood residues or other biomass like lignocellulosic agricultural wastes and can be acceptable as a renewable raw material. In general, particleboard is a composite panel in the form of separated pieces or particles. These pieces or particles are combined under heat and pressure by adding resin, adhesive or other appropriate binder to obtain panels. Particleboards have higher stability which makes them convenient for the productions of special materials like countertops, door cores, floor underlayment, furniture, etc (Balat, 2005).

Wood or woody material engineered boards (particleboard) are categorized as plywood, fibreboard (wet), fibreboard (dry), chipsboards, OSB boards and blockboards. Among these boards, fibreboards are important in the sense that they can be made of fully or partially lignocellulosic materials. They can be manufactured by using heat and pressure with a thickness of 1.5 mm or higher. The classification of fibreboards depends on their production methods: dry or wet produced fibreboards. While fibreboard (wet) has more than 20% moisture at the stage of forming, fibreboard (dry) has less than 20% moisture at the stage of forming and obtained by addition of synthetic adhesive.

According to density, fiberboard (wet) can be classified as follows:

Hard boards (HB) ≥ 900 kg/m^3,

Semi-hard boards (MB) 400 and 900 kg/m^3.

Porous boards (SB) 230 kg/m^3 ÷ 400 kg/m^3.

According to density, fiberboard (dry) can be classified as follows:

Low-density fiberboard (LDF) - less than 650 kg/m^3.

Middle density fiberboard MDF - from 650 to 800 kg/m^3.

High density fiberboard HDF - over 750 kg/m^3 (Hajjari *et al.* 2017).

2.2. Thermochemical conversion. Thermochemical conversion is a process includes controlled heating or oxidation of biomass to obtain products. These conversion methods can be categorized in three traditional ways; combustion, gasification and sulphurs, which have different intermediate products. These products, can be converted to final products such as electricity, heat, power, H_2, alcohols, gasoline, diesel, chemicals, etc. Complicated physicochemical processes such as multiphase hydrodynamics, thermal decomposition, and chemical reactions take place during thermochemical conversion of biomass Additionally, the physical and thermal properties effect the selection of thermal conversion methods (Overend *et al.* 2004). Besides traditional methods, carbonization, torrefaction, liquefaction, carbonisation and biodiesel production are another thermochemical conversion method.

2.2.1. Combustion. Combustion is a process during which an exothermic chemical reaction occurs. High amount of heat generation and glow is followed by this reaction. Solid, liquid or gas fluids can be used as a feedstock during combustion processes. However, combustion of solid fuel is more complicated than liquid or gaseous one (Balat, 2005).

The combustion of biomass as a fuel is a heat-generating oxidation reaction (Balat 2005). During this process, biomass is burned with oxygen to get heat at high temperatures without any intermediate products. However, 56 sulphur burners and boilers are needed to directly burn the biomass. Surplus oxidizer is generally preferred in order to get high conversion efficiency. Some chemical products such as carbon dioxide (CO_2), nitrogen oxides (Nox), water (H_2O), volatile organic compounds (VOCs), carbon monoxide (CO), hydrocarbons, ash and polycyclic aromatic hydrocarbons (PAH) are obtained at the end of the burning process of biomass (Hupa *et al.* 2016; Sahu *et al.* 2014).

The direct combustion of biomass includes four direct combustion forms: evaporation combustion, decomposition combustion, surface combustion and smoldering. Evaporation combustion is a process during which fuel evaporates by heating and reacts with oxygen in gas phase. During decomposition combustion, gas is produced by thermal decomposition and reacts with oxygen in gas phase. Generally, chars remain as a residual after these types of combustion forms and burns by surface combustion. When the fuel component contains only carbon with little volatile portions, burning occurs by surface reaction. Smoldering combustion is a kind of thermal decomposition reaction proceed at lower temperature than ignition temperature of volatile components of fuels such as wood. Decomposition combustion and surface combustion are two main combustion forms during direct combustion of biomass as a fuel (Balat, 2005).

The combustion of biomass has some advantages than the ordinary fossil fuels. Biomass has minor constituents, such as chlorine, sulphur, phosphorus, nitrogen, and several ash-forming metals and generation of nitrogen oxides, sulphur oxides, hydrochloride and dioxin are low. (Balat, 2005; Hupa *et al.* 2016).

2.2.2. Pyrolyses. Pyrolysis is a partial gasification where degradation process contains no or limited amount of oxidizing agent. The process is carried out under the temperatures between 500 to 800 °C (Kumar *et al.* 2013.). There is no necessity to get direct energy from pyrolysis process. Main goal of pyrolysis is to get energy forms such as oil, gas, charcoal forms from biomass feedstocks under controlled conditions of oxygen and temperature.

In pyrolyses, heating detracts moisture from biomass feedstocks around 100 ^{o}C, then decomposition of hemicellulose is occurred between 200-260 ºC. Cellulose (between 240-340 ºC) and then lignin (between 280-500 ºC) decomposition follows the hemicellulose. Lignocellulosic biomasses are proper materials to take under pyrolyses. The main organic components of lignocellulosic biomasses are hemicellulose, cellulose and lignin. The amount of these materials in biomass depends on the type of biomass and the part of the plant sampled (Yu *et al.* 2017.).

Pyrolysis can be classified by two ways; allothermal and aotuthermal. While eternal agents generate heat in allothermal pyrolysis, fuel source itself generates heat in aotuthermal pyrolysis. Also, different heat generating procedures present different types of pyrolysis in process rate: conventional-slow, fast and ultra fast. Different features of these pyrolyses methods are shown in Table 2.

Another extensive classification is given below in Table 3. Here, the information on final product is provided in the last column (Panwar *et al.* 2012).

Table 2. Classification of pyrolysis methods (Ndaba *et al.* 2015)

Method	Temperature (^oC)	Process time (min)	Heating rate ($^oC/s$)	Major products
Slow pyrolysis	400-500	5-30	10 (low)	Gases, Char, Bio-oil (tar)
Fast pyrolysis	400-650	0,5-2 s	100 (high)	Bio-oil (thinner), Gases, Char
Flash pyrolysis	700-1000	<0,5 s	Very high>500	Gases, Bio-oil

Table 3. Extensive classification of pyrolysis methods (Levin *et al.* 2004)

Method	Residence time	Temperature (°C)	Heating rate	Products
Carbonation	Days	402	Very low	Charcoal
Conventional	5-30 min	602	Low	Oil, gas, char
Fast	0.5-5 s	925	Very high	Bio-oil
Flash-liquid[a]	< 1 s	<652	High	Bio-oil
Flash-gas[b]	< 1 s	<652	High	Chemicals, gas
Hydro-pyrolysis[c]	< 10 s	<502	High	Bio-oil
Methano-pyrolysis[d]	< 10 s	>702	High	Chemicals
Ultra pyrolysis[e]	< 0.5 s	1002	Very high	Chemicals, gas
Vacuum pyrolysis	2-30 s	402	Medium	Bio-oil

a: Liquid obtained from flash pyrolysis accomplished in a time of <1 s
b: Gaseous material btained from flash pyrolysis within a time of <1 s
c: Pyrolysis with water
d: Pyrolysis with methanol
e: Pyrolysis with very high degradation rate.

When the biomass is thermally degraded, the actual behavior is governed by complex factors; distinctive stability and reactivity of components in biomass, the probability of interaction between these components, and finally reaction of the pyrolysis products with each other and with the pyrolysis bed, which will be affected by reactor configuration (Yu *et al.* 2017). Recent studies showed that changing the rate of heating, temperature and process time of pyrolysis mechanisms lead to considerable changes in the proportions of gas, liquid and solid products. Feeding type, biomass itself, pyrolysis temperature, catalyst, sweeping gas velocity, particle size, reactor geometry and ratio of heating can be enumerated as pyrolysis parameters (Uzun, 2017).

2.2.3. Gasification. The gasification can be defined as the process of obtaining fuel gas or syngas from biomass solid material. Gasification pressure, temperature, agent, and temperature zone formation are some of the conditional parameters that can be used to classify the gasification individually or combined. Some of the gasifier can be listed as: twin tower, moltrn furnace, fixed bed, flow bed, entrained bed, mixing bed, etc.

Biomass gasification units exhibit differences in various forms of large-scale gasification processes, which are predominantly used in large industrial installations such as power plants, refineries and chemical plants. There are five thermal stages of gasification named as Drying, Pyrolysis, Combustion, Cracking, and

Reduction. Syngas, wood gas, producer gas, town gas and such names are used to define the gas produced from gasification. Syngas is the most used one refers to gas mixture contents carbon monoxide (CO), hydrogen (H_2), methane (CH_4) and other hydrocarbons at different proportion (La Villetta *et al.* 2017).

Gasification is an incomplete combustion process during which solid fuels like wood or coal are burnt under insufficient air. A combustible output gas is transferred to somewhere else to burn. Gasification can convert energy held in biomass to other products such as electricity, ethanol, methanol, fuels, fertilizers and chemicals. However, the moisture content of the biomass is important for the productivity of gasifier. High levels of moisture content in the biomass decreases the temperature inside the gasifier, and then reduces the gasification efficiency. Hence, drying and reducing the moisture level of biomass before gasification process becomes inevitable. In addition, processing of biomass into a standard size or shape before feeding to a gasifier will be provided high productivity.

In most large-scale industrial plants and air-cooled power gasification plants, air is preferred instead of oxygen during gasification reactions. Because, oxygen usage requires an air separation unit in order to get gaseous/liquid oxygen which increases cost.

Gasification converts organic portions of biomass and solid wastes into syngas. Mostly used industrial gasification reactors are fluidized bed and fixed bed. Design of each system is different and specific to biomass raw material properties and also feed rates. The produced syngas from each system has different qualities. The two types of fixed bed gasifiers are shown in Figure 1.

In the Updraft fixed bed gasifiers, the feedstock enters the system from the top and goes downwards through the zones of pyrolysis, reduction and carbon oxidation. The air is supplied from the bottom of the system in such a way as to form a bed for the feedstock and char. The produced syngas flows upward and exits the gasifier from the top of the system while the biomass feedstock flows downwards. In a downdraft gasifier, feedstock, air and syngas streams flow in the same direction, which is particularly advantageous in reducing tar production.

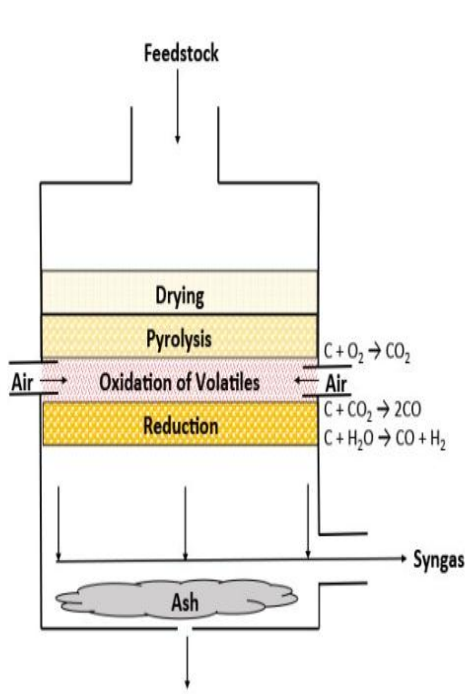

Figure 1. a) Updraft fixed bed gasifier b) Downdraft fixed bed gasifier (Onwosi *et al.* 2017).

In the pyrolysis zone, volatile gases are oxidized moderately by air-injection, which provides the heat necessary for the gasification reactions. The tar is thermally decomposed in this zone which has 815-1093 °C temperature and is therefore partially oxidized. The tar, which is converted to a ratio higher than 99%, also cleans the syngas by creating a filter effect before the syngas left the gasifier. In the reduction zone, CO_2 and H_2O in the syngas are converted to CO and H_2 which are the main constituents of Syngas. Syngas leaves the system at a temperature between 593-815 ^oC.

The general restrictions of feedstock properties for both downdraft gasifiers and updraft gasifiers are same. The fact that the biomass has a fine and uniform particle size distribution is necessary to preserve the physical properties of the bed and to minimize channelling. The moisture content of the raw biomass feedstock must be below 20%, since it is very high in moisture content, it would be difficult to get the high temperatures required for tar cracking. In order to avoid slagging, the biomass needs low ash content and high ash fusion temperatures.

In a fluidized bed gasifier, the gas velocity is kept high enough to be able to divide the biomass particles in a large way and to allow free circulation throughout the bed. The syngas flows upward through solid containing channels while solid masses flow downward during bed circulation. Fluidization of the bed is provided by using air, oxygen or steam. The biomass is introduced into the bed through a feeder channel at the top of the bed. While syngas is leaving the gasifier, the unreacted biomass, char and fluidizing sand are returned to the bed with the help of a cyclone. The ash formed at the end of the process is appropriately disposed. System conditions, stability, gas quality and pressure losses of the system directly effects gasifier performance (Samiran *et al.* 2016). A typical fluidized bed gasifier is shown in Figure 2 (Khan *et al.* 2012).

The operating temperature range of bed is between 593-871 ^oC. The bed temperature is arranged so that the biomass is completely devolatilized while keeping the bed temperature below the ash fusion temperature. After feeding the biomass into the bed, most of the organic contents are volatilized and partly oxidized. The exothermic oxidation reactions taking place in the bed provides appropriate amount of heat in order to keep the bed at the required temperature and to volatilize more biomass. Good mixing and high heat transfer are the main advantages of fluidized bed gasifiers which provides inform bed conditions yields to efficient gasification process with carbon conversion percent of 95%-99%.

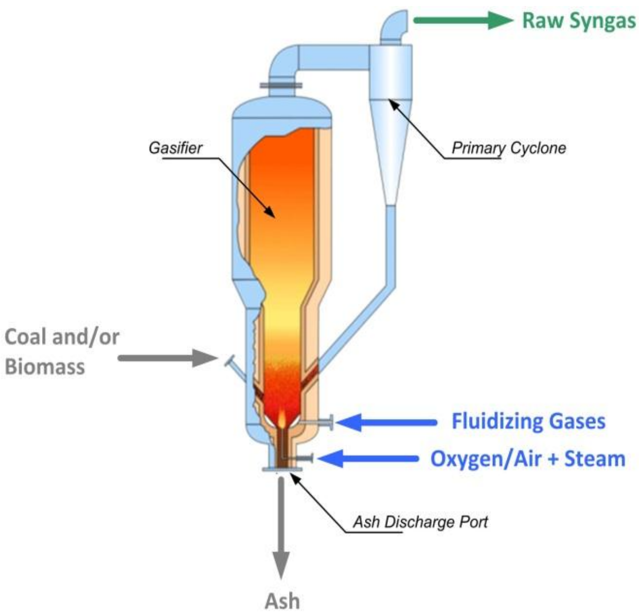

Figure 2. Fluidized bed gasifier configuration

Bubbling and circulation beds are the most preferred ones used for biomass gasification in fluidized bed. Both systems differ from each other by fluidizing velocity and gas path. Bubble beds have relatively low gas velocities and low solids. However, in circulation beds, the velocity is high as pneumatic velocity and the added solids are recycled after passing through a cyclone.

2.2.4. Torrefaction. Torrefaction is a thermochemical process in which the biomass is applied in an inert or limited oxygen environment, typically at a temperature of 200 ºC - 300 ºC. This method includes drying and incomplete pyrolysis processes. Torrefaction process allows the biomass to be heated slowly to a specified temperature range, so that the hemicellulose content is almost completely degraded and can be held there for a certain period of time to maximize the mass and energy output of the solid material. It is also a kind of pyrolysis operating at mild conditions that can be used as a preliminary treatment for increasing the heating value of biomass while decreasing its moisture content (Chen *et al.* 2015).

In torrefaction process, about 30% of biomass is transformed to torrefaction gases which include only 10% of the energy of the original biomass, thus increasing the energy density by a factor 1.3. In torrefaction, the quality of biomass increases at a point which results the change in the combustion behavior of the gases and thus, efficient use of the process in cofiring power plants (Nhuchhen *et al.* 2014). Torrefaction method can be applied in different reactor styles such as; belt drier, rotary drum, screw conveyor, multiple hearth furnace, compact moving bed, rotating fluidized bed, microwave hybrid, conventional fluidized bed (Batidzirai *et al.* 2013).

The main parameters effecting the process are reaction temperature, heating rate, oxygen amount, residence time, ambient pressure and feedstock characteristics (moisture content, particle size, etc.). For example, high temperature or long residence time increase the torrefaction degree (Strandberg *et al.* 2015).

The main outputs during this process are:

1. Solid biomass which can be used for production of bioenergy
2. Condensable volatile organic compounds such as water, acetic acid, aldehydes, alcohols, and ketones
3. Noncondensable gases such as CO_2, CO, and small amounts of methane.

2.2.5. Carbonization. Carbonization is the method or technology applied in temperature range of 400-600 ºC during which charcoal is obtained as the main product by heating solid biomass such as wood, shell, bamboo, rice husk. In other words, carbonisation is the term for the conversion of an organic substance into carbon or a carbon-containing residue through pyrolysis or destructive distillation.

The first step in this process is to dry out the wood in the furnace at 100 °C or below to get zero moisture content. Then the temperature of the oven is increased up to about 280 °C. The energy used in these steps is obtained from partial combustion of some of the wood fed into the furnace or pit and it is an energy absorbing or endothermic reaction. The wood begins to produce charcoal, water vapour, methanol, acetic acid, more complicated chemicals mainly in the form of tars and non-condensable gas primarily consisting of hydrogen, carbon monoxide, and carbon dioxide when it is dried and heated up to 280 ^{o}C (Strezov *et al.* 2007).

During carbonization, at first, the wood is dried in the oven at a temperature of 100 °C or below until the moisture content is fully removed. After that, the increase in temperature up to 280 °C is provided by endothermic combustion reaction of the wood fed into the furnace. When the wood is dried and reached to 280 ºC temperature, the products charcoal, water vapour, methanol, acetic acid, tars and non-condensable gas contains hydrogen, carbon monoxide, and carbon dioxide are obtained (Strezov *et al.* 2007). Since carbonization is specifically used to obtain charcoal, the effects of temperature on charcoal production and its composition is given in Table 4 (Strezov *et al.* 2007).

Table 4. Effects of temperature on charcoal production

Carbonization tempereture	**Chemical analysis of charcoal**		Charcoal yield based **on oven dry wood**
^oC	% of fixed charcoal	% volatile material	% moisture
300	68	31	42
500	86	13	33
700	92	7	30

Sub-products, biogas and bio-liquids, which are occurred during the carbonization process can be used in thermal conversion process for self-sustaining while the excess amount can be recovered for further uses. Charcoal is generally used as an energy resource. However, recent studies focused on the use of charcoal in different application such as activated carbon in adsorption processes, electrode material, fertilizer, carbon nanotubes, etc. (Strezov *et al.* 2007).

2.2.6. Liquefaction. Liquefaction is a thermochemical process in which biomass is converted into liquid fuel with common products of gas, liquid and char. Liquefaction can be classified into two groups: direct or indirect. Direct liquefaction is a process in which organic materials are converted directly into a liquid biocrude and co-products by the addition of a reducing agent, usually hydrogen and CO, at a temperature range of 300-400 ºC and a pressure of 10-20 MPa. During this process, products of bio oil, liquid tar and condensable organic vapour are obtained by rapid pyrolysis of biomass. When the biomass used in the direct liquefaction is wet or in sludge form, the process generally named as hydrothermal processing (He *et al.* 2017). When pyrolytic liquefaction or catalytic liquefaction processes are used for the conversion of biomass, liquid biocrude is produced as an initial step. However, in indirect liquefaction, catalyst is used for the conversion of non-condensable products and other gases coming from pyrolysis or gasification into liquid products (Raheem *et al.* 2015).

2.2.7. Biodiesel production. When a vegetable oil or animal fat chemically react with an alcohol (such as methanol or ethanol), biodiesel, an alternative fuel for diesel vehicles, is obtained as a product. Raw materials for biodiesel production are generally classified in three groups; edible, non-edible and others. Nowadays, oils manufactured from typical fuel crops which are harvesting solar energy and store it as chemical energy are used for biodiesel production. Among them, canola, soy and palm oils are widely used raw materials. (Schenk *et al.* 2008). However, it is not convenient to use vegetable oils directly for the production of biodiesel due to their viscosity. Their viscosity should be decreased before feeding to the engine. Several ways can be used for the converting of vegetable oils ino biodiesel, such as direct blending (dilution), micro-emulsion, catalytic cracking and trans esterification (Verma *et al.* 2016).

Although, biodiesel production has become an alternative energy source, it has started debates on many issues. The debates are focussed in areas such as greenhouse gas emissions, land use changes (LUC) and availability of raw materials and cost. However, the use of non-crop raw materials such as waste-oriented oils/fats can be an effective solution to these problems. But, cost of collection and recycling of these materials should be taken into account (Hajjari *et al.* 2017).

2.3. Biochemical conversion. Biochemical conversion is environmentally friendly process, which depends on the use of enzymes, microorganisms and catalysts to obtain fuels and chemicals. During this process, breakdown product of biomass, sugar, is converted into valuable fuels and chemicals by fermentation. Biochemical conversion process has a potential for large scale applications since agricultural wastes, energy crops, pulp and paper mill residues can be used as a feedstock (Kaushik *et al.* 2007).

Biochemical conversion can be carried out in bioreactors which differ from conventional chemical reactors. A bioreactor has a convenient environment and provides necessary conditions to obtain desired output (Singh *et al.* 2014). Anaerobic decomposition and anaerobic fermentation are the main processes occur during biochemical conversion. In comparison to thermochemical processes, biochemical conversion process occur at low temperatures and the reaction rates are slow (Kumar *et al.* 2015). High moisture content of the input material is desirable in biochemical processes. The main outputs of biochemical conversion reactions are generally biogas and ethanol. Biogas can be utilized for the production of electricity, fuel or natural gas. Besides biogas and bioethanol, biobutanol and dimethyl ether are other biofuels which should be investigated during conversion processes (Kumar *et al.* 2015).

Biochemical routes of biomass conversion can be divided into 6 categories as biomethanation, ethanol fermentation, aceton-butanol fermentation, hydrogen fermentation, lactic acid fermentation, and silage.

2.3.1. Biomethanation. Biomethanation is an anaerobic process during which biogas is obtained by microbial conversion of organic material. Anaerobic process proceed under oxygen-free medium with the output of methane and carbondioxide. In general, obtained biogas constitutes about 65% methane and 34% carbon dioxide. However, conversion efficiency of biomass depends on the type of input biomass, degradation system and operating conditions. Therefore, operational conditions of the conversion system should be optimized in order to get high biogas output (Krishania *et al.* 2013). Anaerobic digestion includes four types of processes: Hydrolysis, acidogenesis, acetogenesis, and methanogensis. Hydrolysis step includes the hydrolysis of biomass which is catalysed by enzymes of hydrolytic and acidogenic bacteria. The products of the hyrolysis reaction are utilized by acidogenic bacteria to produce acetate, hydrogen, and carbon dioxide. These outputs can be directly converted to methane and carbon dioxide by methanogenic bacteria while alcohol and volatile fatty acids are further oxidized by acetogenic bacteria (Krishania *et al.* 2013). Conversion steps of complex biomass during biomethanation are shown in Figure 3.

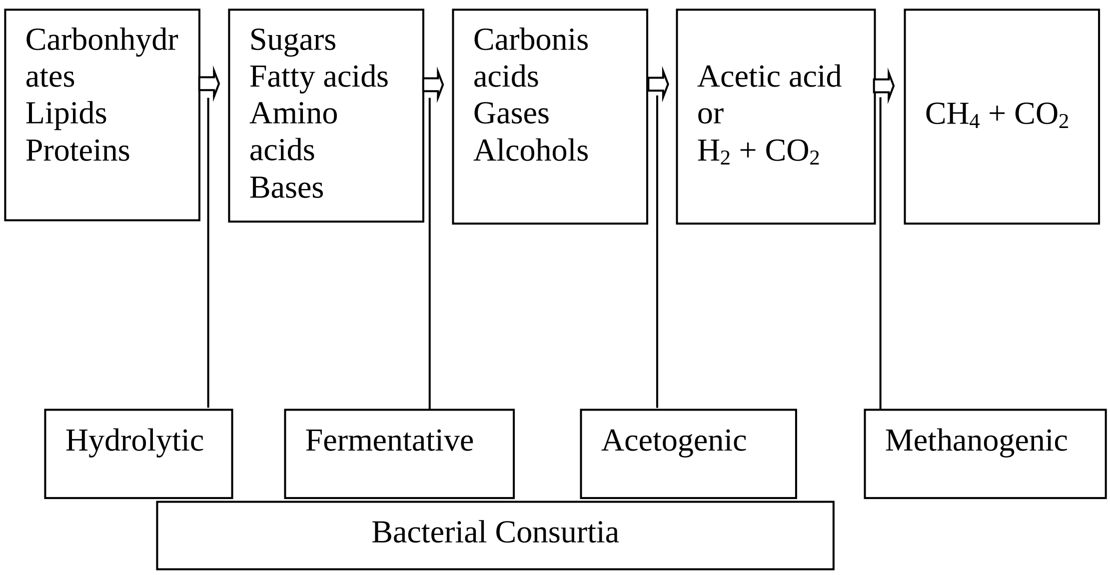

Figure 3. Biomethanation steps of complex biowastes

2.3.2. Ethanol fermentation. Many cellulosic biomass materials such as herbaceous and woody plants, agricultural and forestry residues, and municipal and industrial wastes can be used for the production of ethanol. There are different processes suggested by some researchers for conversion of lignocellulosic biomass to ethanol. While Mohammad and Keikhosro (Mohammad *et al.* 2009) mentioned four main processes; pretreatment, hydrolysis, fermentation, and product separation or purification (Zheng *et al.* 2009) stated different pretreatment techniques: chemical pretreatment (acid treatment, ammonia treatment, sulfuric acid treatment, alkaline wet oxidation and ozone pretreatment), physical pretreatment (steaming, grinding and milling, blending, thermal, and irradiation), biological pre-treatment, and the combine pretreatment. While chemical pretreatment overcome the lignin problem in the biomass structure, physical pretreatment increases the surface area of the biomass by decreasing its size. Acid/base catalysed and enzymatic hydrolysis are two main methods can be used for the degradation of cellulosic structure in biomass. It was investigated in a study that enzymatic hydrolysis is more convenient than the acid/base catalysed hydrolysis (Alexander *et al.* 2009).

Biological treatment includes fermentation processes. SSF (Simultaneous Saccarification and Fermentation) and SHF (Separate Hydrolysis and Fermentation) are two types of fermentation techniques. It is explored in a study that SHF is better than SSF (Kim *et al.* 2008). A raw material contains sugar could convert into ethanol by fermentation. The raw materials available for the production of ethanol can be classified into three groups: sugars, starches, and cellulose materials. While ethanol can be directly obtained from sugars (from sugarcane, sugar beets, molasses, and fruits), enzymatic hydrolyzation is required for the conversion of starches to fermentable sugars. Mineral acids are used for the conversion of cellulose (from wood, agricultural residues, waste from pulp, and paper mills) into sugar. When simple sugars are obtained, it is easy to obtain ethanol by microbial enzymes (Lin *et al.* 2006).

Ethanol production from a cellulosic biomass is a complicated and costly process. In the biochemical method, raw material should be pretreated in order to separate cellulose and lignin. Then, hydrolysis takes place for conversion of hydrocarbons to sugars. The process end up with ethanol by microbial fermentation of sugar. Figure 4 summarize the biochemical production of ethanol.

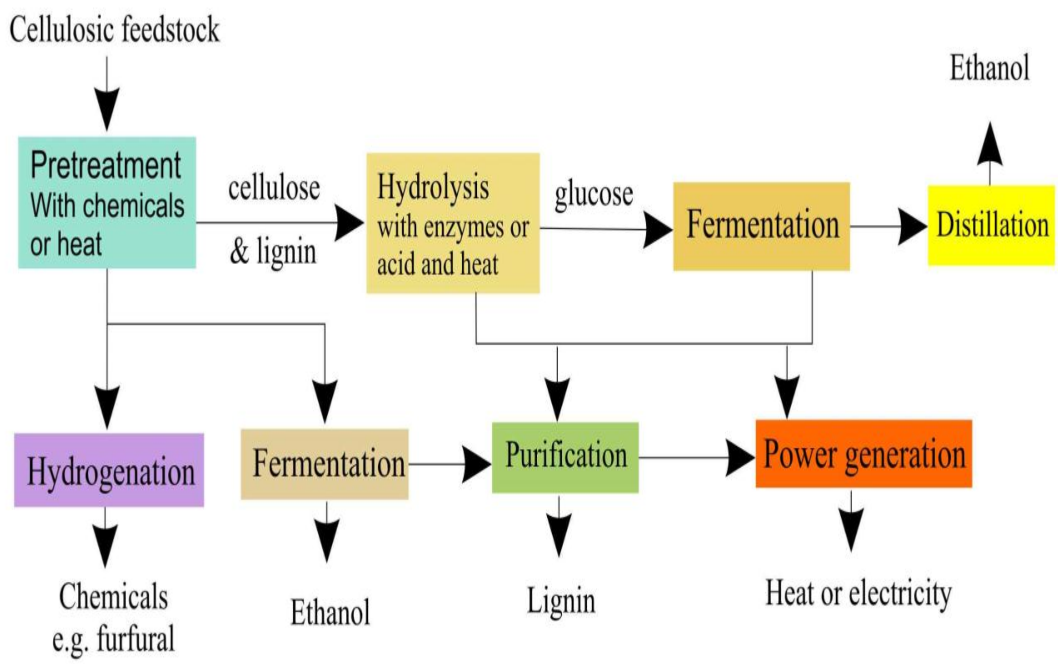

Figure 4. Biochemical production of cellulosic ethanol

The most used sugar for the production of ethanol is molasses, a dark-colored syrup, which contains half part sugar and the remaining half part organic and inorganic compounds. In ethanol fermentation process, molasses is sterilized before transferring to the fermentor. Then, mass fraction of molasses is decreased to 10-18% by dilution in order to overcome any viscosity problems in the pipeline. However, high concentration of sugar means long fermentation time with high ethanol yield but incomplete reduction of sugar. Fermentation process is operated under non-steril conditions at a temperature range of 20–32 °C for about 1-3 days following by pH adjustment to 4-5 by using mineral acid (Lin *et al.* 2006). Agricultural biomasses such as corn, wheat, oats, rice, potato, and cassava can be used as a feedstock in ethanol fermentation process due to their high starch content (Lin *et al.* 2006).

2.3.3. Aceton-butanol fermentation. This process includes the production of acetone and butanol with microbial reduction of glucose under anerobic conditions. Since ethanol is also obtained at the end of the fermentation, the process is called acetone, butanol and ethanol (ABE) fermentation. Fermentation process is carried out by using Clostridium species (Clostridium beijerinckii, Clostridium acetobutylicum) anaerobic bacterium which is available in the soil at high amounts and excretes extracellular enzymes; amylase, xylanase, protease, and lipase. Two types of acetone butanol fermentation processes are available. While buthanol formation by starch fermentation is called Weizmann-type, the other one is saccaro-type from sucrose fermentation.

Acetone, butanol and ethanol are produced in the proportions of 3, 6 and 1-part, respectively, during the ABE fermentation. The three common type processes for performing ABE fermentation are batch, fed-batch, and chemo-stat reactors. Fed-batch fermentation has drawn attentions since the continuous feeding of fresh medium dilutes the butanol toxicity while it provides more glucose for fermentation, Figure 5 (Lu *et al.* 2016).

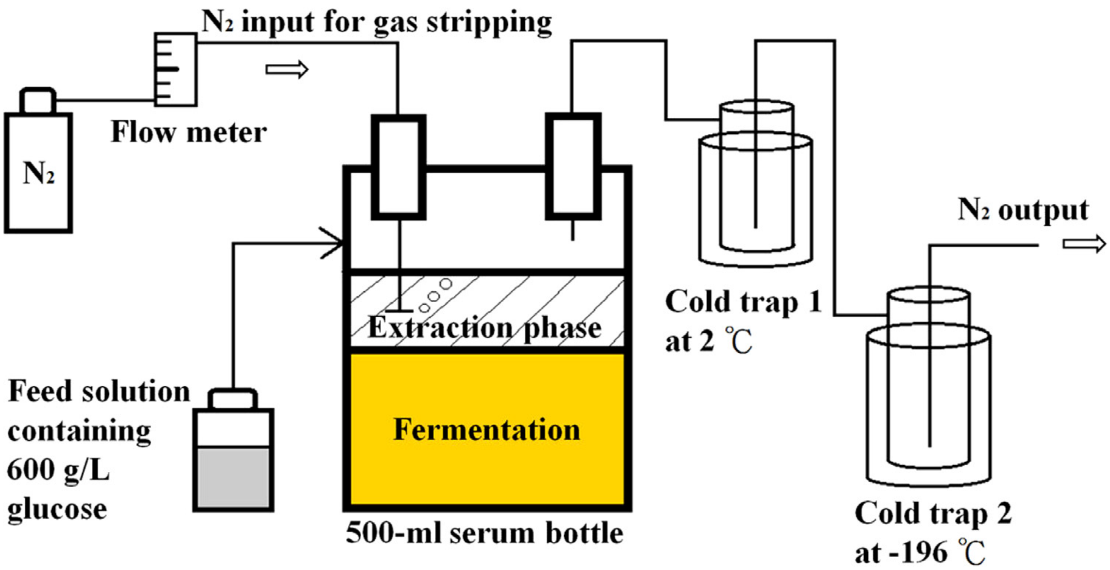

Figure 5. Schematic of integrated in situ extraction-gas stripping process for fed-batch ABE fermentation

The historical developments of ABE fermentation start with the production of acetone for military applications. However, nowadays, it is mostly used for the production of buthanol as an alternative energy source to fossil-based resources (Karimi *et al.* 2015). The metabolic pathway of ABE fermentation includes two main steps: Acidogenesis and solventogenenis. The acidogenic step starts during exponential growth phase of Clostridium species. The obtained products in this phase are transferred to solventogenic phase during spore formation phase of bacterial growth. Then, acetic acid can be converted to ethanol or acetone while butyric acid is turned to butanol. Buthanol is much more valuable fuel in comparison to ethanol due to its excellent fuel characteristics; such as, high calorific value, low volatility, less corrosive, etc. Butanol can be used in internal combustion engines (Li *et al.* 2016). It is also possible to produce hydrocarbons which are the main constituents of gasoline, jet and diesel fuels by catalytic reaction and hydrodeoxygenation processes. Simultaneous saccharification and fermentation (SSF) of lignocellulose and fermentation of biodiesel derived glycerol are the alternative ways fort he production of biobutanol (Ndaba *et al.* 2015).

A process using extracellular hydrolysis by enzymes or by chemical
or physical pre-treatment (as is presently under development for production of bioethanol) could be applied to furnish lignocellulosic substrates for microbial conversion to solvents a process using extracellular hydrolysis by enzymes or by chemical or physical pre-treatment (as is presently under development for production of bioethanol) could be applied to furnish lignocellulosic substrates for microbial conversion to solvents a process
using extracellular hydrolysis by enzymes or by chemical or physical pre-treatment (as is presently under development for production of bioethanol) could be applied to furnish lignocellulosic substrates for microbial conversion to solvents.

On the other hand, a process using extracellular hydrolysis by enzymes or by chemical or physical pre-treatment (as is presently under development for production of bioethanol) could be applied to furnish lignocellulosic substrates for microbial conversion to solvents.

2.3.4. Hydrogen fermentation. Hydrogen is one of the most plentiful element and can be available in different sources such water, hydrocarbon fuels, inorganic substances, etc. Different hydrogen production technologies can be used depend on the source of hydrogen. Among these methods; water electrolysis, thermo-chemical hydrogen production and biological hydrogen production are the main ones.

Biological hydrogen production is a biochemical reaction during which hydrogen is produced by using microorganism. There are three different microbial groups that can potentially produce hydrogen. While photosynthetic green algae and cyanobacteria take part in the first group, heterotrophs which are used organic substrates are the second group. The first group are autotrophic organisms and can directly reduce the water to hydrogen and oxygen under light. This process is called direct photolysis if green algae is used. When cyanobacteria are used, it is called indirect photolysis (Levin *et al.* 2004). The second group organisms produce hydrogen under oxygen-free environment. If the process is carried out under light, it is called photo-fermentation otherwise dark-fermentation. For example, organic acids are used as carbon source and light as an energy source during photo fermentation by purple non-sulphur bacteria (Levin *et al.* 2004). However, while photo fermentation is thermodynamically unfavourable without light, dark-fermentation does not need light and feedstock rich in carbonhydrates can be both used as carbon and energy sources.

Nowadays, while 88% of commercial hydrogen is produced from fossil fuels (natural gas, heavy oils or coal), 4% of hydrogen is obtained from water electrolysis. However, the energy comsumption of these methods are significantly high and researcher tends to find alternative ways, biological hydrogen production.

Agricultural wastes, animal wastes and even food wastes can be used as a source for biological hydrogen. Agroindustrial wastes and effluents can also be used for obtaining biological hydrogen by fermentation. However, hydrogen production is a quite complicated and expensive process. The main factor affects the operating cost of biohydrogen production is the structure of feedstock. The hydrolysis of cellulose to glucose is required the use of pure cellulose enzymes which is quite expensive. By the way, different pretreatment methods (mechanical, physical, chemical or biological techniques) of raw materials can be used for easy hydrolysis of cellulose-like structures. Thus, the most suitable and effective method should be chosen according to the biomass structure. The most used methods for the production of biohydrogen are direct/indirect bio-photolysis and dark and photo-fermentations. Fermentation process proceeds faster than bio-photolysis and can operate in batch, continuous and fed-batch reactors. However, dark fermentation of hydrogen steps forward which involves hydrolysis and acidogenesis steps (Jiang *et al.* 2017).

2.3.5. Lactic acid fermentation. Lactic acid is a valuable commercial material that can be used in various areas, such as, feedstock in pharmaceutical, cosmetic and textile industries, raw material for the production of polylactic acid, biodegradable polymers, oxygenated chemicals, plant growth regulators, solvents, etc. Fermentation process is the main method for the production of lactic acid. Maize, sugar cane and sugar beet are the main sugar resources during the lactic acid fermentation process. However, the costs of these agro-raw materials are relatively high and restrict the implementation for large-scale production. However, the use of wastes from agriculture, forestry and the organic fraction of municipal waste which are widely available at low-price can enable large-scale production. These biomasses mainly contain lignocellulose structure which is required physical/chemical or enzymatic techniques in order to release sugar content which will be transformed to lactic acid by fermentation process. Lactic acid fermentation can be carried out with fungi or lactic acid bacteria by using starchy or lignocellulosic biomass as a raw material with changing yields of product at the end of the processes (Abdel-Rahman *et al.* 2013). Besides fungi and lactic acid bacteria, yeast, cyanobacteria, and algae can also produce lactic acid. The main factors affecting the microbial growth and lactic acid production are ambient conditions such as pH, temperature, feed-stock concentration, etc. (Abdel-Rahman *et al.* 2013).

2.3.6 Silage. Silage is a common feed used for cattle and sheep all around the world. It can be produced by fermentation of crops having high water content under controlled medium which is called wet storage process (Balat 2005). During this process, the harvested biomass including more than 45% moisture is directly stored by ensilaging which may keep dry matter losses less than 5%. This provides easy decomposition of wet-biomass than dry-one. Wet storage process keeps the biomass under wet and air-insulated conditions and involves the microbial degradation of sugars to acids. The microbial growing is under limitations due to acidic and oxygen-free environment which provides the storage of feedstock for a long-period of time. A horizontal silo, a pit with air-insulated or a plastic wrapping can be used as a wet-storage place.

Wet storage process is a good alternative way for the storage of biomass because of the possibility of manufacturing a uniform product which is generally desirable for microbial hydrolysis processes. However, improvement studies of wet storage process and integration with other steps of entire process such as harvesting, transportation, storage and pretreatment, is needed in order to ensure yearly availability of biomass (Li *et al.* 2011).

2.3.7. Composting. Composting is a self heating (autothermic) process during which organic materials are decomposed by bacteria under aerobic conditions. The heat generated during decomposition can be used to decrease the moisture, to inactivate the harmful contents (microbes, weed seeds, etc.) and to keep compost mixture in safe and disinfected (Balat 2005). Composting process can be performed in three stages as pretreatment, pasteurization and stabilization. Product of composting process (organic manure rich in mineral nutrients such as nitrogen (N), phosphorus (P) and potassium (K) can be utilized as a land material for agricultural, horticulture or ecological purposes. (Onwosi *et al.* 2017).

DISCUSSION

Providing up to 14% of the world’s primary energy demand, biomass is the world’s fourth largest energy source today. It can be as high as 35% of the primary energy source in developing countries. Biomass is a multi-directional source of energy as it can be readily stored and converted into electricity and heat. It has also the potential to be used as a raw material for fuel and chemical feedstock production. Production units range from small scale up to multi-megawatt sizes (Onwosi *et al.* 2017).

The production of biomass for materials and energy may produce a variety of benefits, although energy from biomass is usually not cost competitive with fossil fuels under present technology and market conditions in many developed countries. These benefits vary depending on the case, but among others the followings come forward: it offsets greenhouse gas emissions from the combustion of fossil fuels, creates jobs and income through the development of a new industry and the utilization of locally produced raw materials, and enhances energy security by reducing dependence on imports. However, the values of these advantages are far less noticed than production costs of biomass and bioenergy. Evaluating these benefits may supply a more comprehensive picture about the general competitiveness of biomass and bioenergy, offering implications for bioenergy development and policy formulation (Balat, 2005).

Although the burning of biomass release carbon dioxide, it also captures carbon dioxide for its own growth. On the other hand, carbon dioxide emitted by fossil fuels is released into the atmosphere and is harmful to the environment. Most of the energy sources endeavour to control their carbon dioxide emissions since these can harm the ozone layer and increase the effects of greenhouse gases. Co-combustion is a promising development in combustion for efficient biomass conversion. This can be implemented in existing coal plants of a large capacity and allow high efficiency in electricity production (Veringa *et al.* 2004).

Solids (charcoal), liquids (pyrolysis oils) and a mix of combustible gases are the products generated by pyrolysis of lignocellulosic matter. Pyrolysis of biomass is a promising tool for providing bio-oil that can be used as an alternative for fuel oil or chemical feedstock. These liquids, referred to as bio-oils or biocrudes in this study, are intended to be used for direct combustion in boilers, engines or turbines (Veringa *et al.* 2004).

Activated carbon is obtained by a process of pyrolysis of the biomass source, followed by activation of the produced biochar with physical or chemical methods (Gonçalves *et al.* 2016). Gasification usually adopts the direct gasification method with partial combustion of raw material in order to raise the temperature. Most of the gasification furnaces use normal pressure and a direct gasification process. Air, oxygen, and steam are required for the gasification agent to keep the reaction temperature at 800 ^{o}C and above for direct gasification. The calorific value of product gas relies on the percentage of inflammable gas (CO, H_2, CXHY) (Balat 2005). Hydrothermal gasification is the hot compressed water treatment of biomass, generally above 350 ^{o}C and above 20 MPa pressure, to obtain combustible gas. Hydrothermal gasification is proper for wet biomass treatment (Balat, 2005).

Hydrogen production from biomass and bio-oils remarks a realistic renewable source. Additionally, the bio-diesel infrastructure development may enable hydrogen production from vegetable oil derived materials either through decentralised stationary reformers or through on-board fuel processors.

Torrefied biomass can be used for co-firing with coal in CHP (combined heat and power) plants and for industrial implementations as steel and cement production as well. Torrefied material is also better than non-pre-treated biomass for producing liquid biofuels in gasification processes.

Presently, the lignin fraction cannot be biochemically converted economically for biomass feedstock. The lignin and other stabilized residue from biochemical transformation may be suitable as a compost product or could be used for energy via thermochemical processes, perhaps for supplying the energy needs of the biochemical conversion plants. If the residue is of poor quality or highly contaminated (i.e., the feedstock coming from mixed waste rather than clean source separated material), it may not have a market value and most likely end up in the landfill.

In anaerobic digestion, the biomaterials go through a fermentation process converting the organic materials into biogas, mostly methane (60%) and carbon dioxide (40%). Transforming methane into

CO_2 and water by burning the gas is a net positive from a greenhouse gas (GHG) perspective, as methane is a much more powerful GHG than CO_2. To increase conversion enzymatic digestion and other catalysts are used. Appropriate fuels are organic materials with high moisture content like animal manure or food processing waste.

It is very important to determine the practical and theoretical methane potential for optimal process design, configuration, and effective evaluation of economic feasibility. A wide array of process implementations for biomethanation of wastewaters, slurries, and solid waste have been developed. In order to maximize the energy output from the waste and also to decrease retention time and to enhance process stability, these applications use different reactor types (fully mixed, plug-flow, biofilm, UASB, etc.) and process conditions (retention times, loading rates, temperatures, etc.). Biomethanation has a great potential for energy production from organic residues and wastes. It will help to

reduce fossil fuel use and thus reduce CO_2 emission. Bio-based product from biomass can be classified as given in Figure 6 (Tong *et al.* 2014).

The methods for obtaining bio-based products are given below in Figure 7.

These days, using biomass effectively has gained attention for the prevention of global warming and recycling society formation.

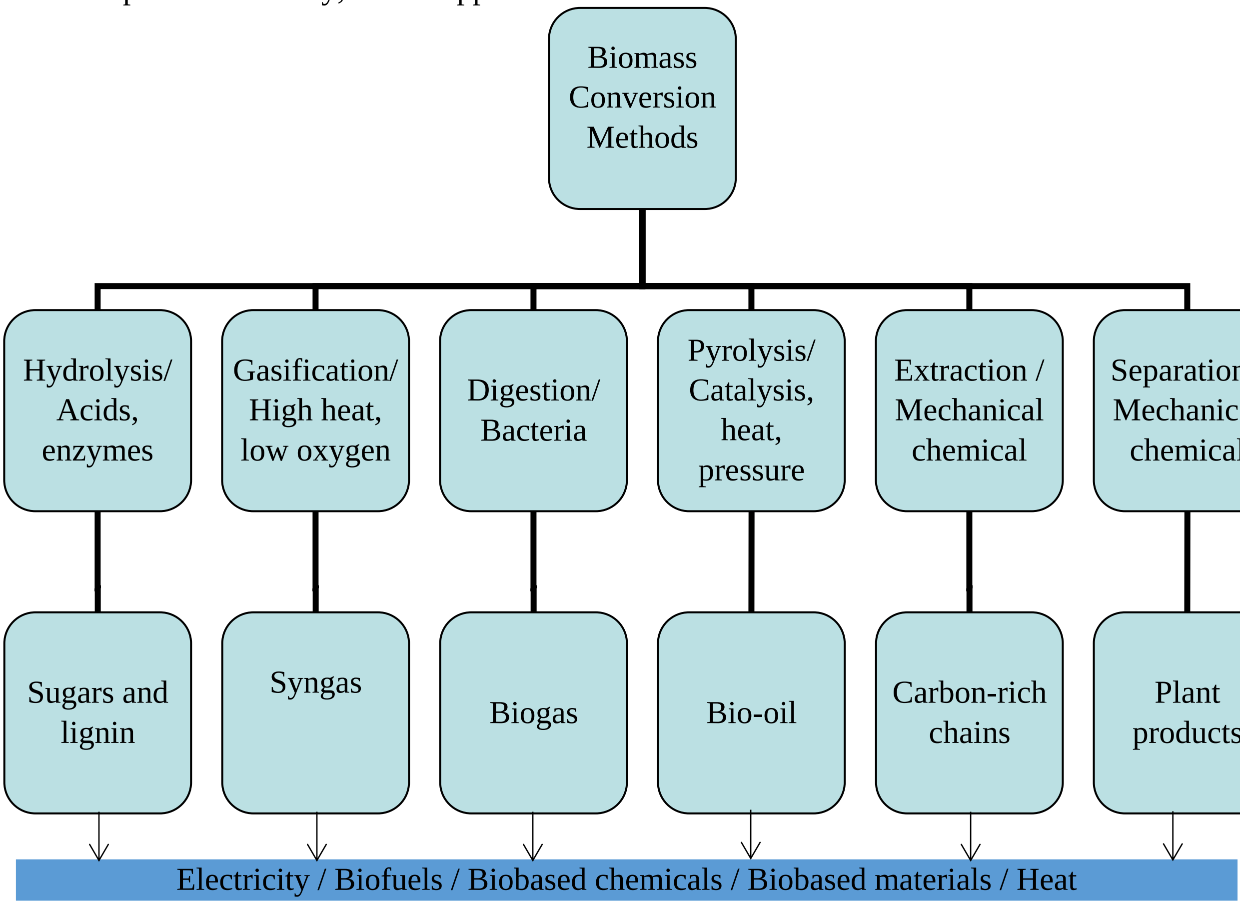

Figure 6. Summarization of biomass conversion methods

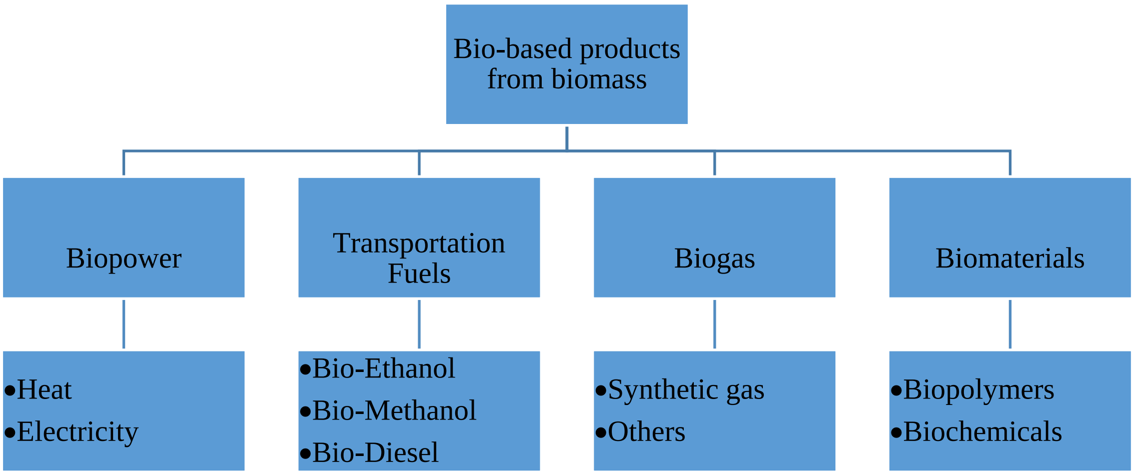

Figure 7. Classification of bio-based products

Some principles are mentioned below for the promotion of biomass utilization:

- Comprehensive, Uniform and Effective Utilization of Biomass
- Mitigation of Global Warming
- Development of Recycling--based Society
- Promotion of industrial Development and International Competitiveness
- Revitalization of Rural Areas
- Fully Utilization of Different Types of Biomass
- Diversification of Energy Sources
- Promotion of Community-based Voluntary Actions
- Raise of Social Awareness for Biomass
- Consistency between Stable Food Supplies and Biomass Utilization
- Considerations for Environment Preservation.

There are various difficulties in the maintenance and development of biomass-to-energy applications despite the potential benefits of biomass utilization.

Due to its bulkiness and degradation, the transportation and storage of biomass is difficult. Therefore, using biomass in the areas they are produced is more reasonable. To this respect, biomass is used in or nearby regions where a balanced biomass supply and demand exists. On the other hand, in the event that biomass is converted into more transportable forms like densified pellets or liquid fuels, it can be used in distant regions. Biomass can be used as materials or energy. Biomass can be used as diversified materials such as food, feed, fiber, feedstock, forest products, fertilizer and fine chemicals. Usage as energy in the biofuels form appears on the final stage and biomass is decomposed into carbon dioxide or methane and emitted in the air (Balat 2005).

Biomass is the world's fourth largest energy source today corresponding up to 14% of the primary energy demand of the world. In developing countries, it can be as high as 35% of the primary energy supply. Biomass is a multi-purpose source of energy as it can be readily stored and transformed into electricity and heat. It has the potential to be used as a raw material for production of fuel and chemical feedstock. Production units range from small scale up to multi-megawatt sizes (Veringa *et al.* 2004).

Today, the main biomass sources are wastes, either in the form of wood wastes, agricultural wastes, municipal or industrial wastes, and consequently, they are the primary fuels for energy production. Using residues such as municipal solid waste and slurry as feedstocks has also an additional environmental benefit as these are withdrawn from polluting land filling (Veringa *et al.* 2004).

CONCLUSION

Biomass such as organic material, plant or animal wastes is a renewable energy sources that can be used for the production of energy in the form of heat or electricity.

Various technologies are used for the conversion of biomass into energy. These methods can be grouped into three classes:

1. Physical conversion methods: firewood, pelletizing and particle board production.
2. Thermochemical conversion methods: combustion, pyrolyses, gasification, carbonization, torrefaction, liquefaction and biodiesel combustion.
3. Biochemical conversion methods: biomethanation, ethanol fermentation, aceton-butanol fermentation, hydrogen fermentation, lactic acid fermentation, and silage.

The advantages of biomass utilization can be enumerated as follows:

- Widely available and naturally distributed
- To be a renewable fuel
- Generally low-cost inputs
- Abundant supply
- Can be domestically produced for energy independence
- Low carbon, cleaner than fossil fuels
- Can convert waste into energy, helping to deal with waste

The challenges and disadvantages of biomass utilization can be enumerated as follows:

- Energy intensive to produce. In some cases, with little or no net gain.
- Land utilization can be considerable. Can lead to deforestation.
- Requires water to grow
- Not totally clean when burned (NOx, soot, ash, CO, CO_2)
- May compete directly with food production (e.g. corn, soy)
- Some fuels are seasonal
- Heavy feedstocks require energy to transport.
- Overall process can be expensive
- Some methane and CO_2 are emitted during production
- Not easily scalable

We come across biomasses in various phases and components. Based on physical and chemical structure of biomass appropriate conversion methods are used. Biomass conversions and usages have many advantages; however, they include some disadvantages as well. While choosing any of these methods, one should consider its environmental effects, too. It come forward as an alternative to chemical materials as fossil fuels and oil products and they can be substitute for them. Yet they need to become cost competitive compared to their present technologies. Moreover, there is a need for compact systems of small scale biorefineries for local needs. This is predicted to be one of the most important study areas of future.

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STUDY OF HEAT INFLUENCE ON MICROSTRUCTURE OF ALUMINUM WIRE (FOR FIRE EVALUATION)

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Abstract. The problem of fire hazard in old buildings with electric aluminum wiring has been analyzed. To establish the temperature influence on the microstructure of aluminum wire, they were experimentally heated gradually up to 650 ^{o}C. Based on the local X-ray spectral analysis, the differences in the microstructure of aluminum wire, depending on the heating mode are shown. The results of the research provide an opportunity to determine the cause of the fire due to electric current.

Keywords: aluminum wire, microstructure, temperature, influence.

INTRODUCTION

After analyzing statistics as to the number of fires that have taken place over the past years, we can conclude that electric conductors were the most fire hazard elements of electrical installations. Wiring and electric cables of electrical apparatus were the reasons for about 61 % of all fires concerned with electrical installations for industrial and domestic use (Tymochko *et al.* 2019; Smelkov 2009). Thus, the issue of fire safety in electrical installations, as well as the search for methods of detecting the causes of fires, are important and relevant and need to be decided.

There is a tendency in Ukraine that, in the majority of cases, conflagrations arise from electrical installations periodically in buildings of old construction. This is explained by the fact that the old normative technical and building regulations allowed to use aluminum wiring, which have much worse electrical characteristics than copper ones in modern constructions. The natural increase in the number and power of electricity consumers leads to overloading of electrical networks, which leads to rapid aging of insulation, its destruction, and, accordingly, the reduction of the life of the wiring. As evidenced by the statistics – 42 % of all fires were connected with the electrical networks of industrial and household purpose (Babrauskas *et al.* 2006).

The statistical data also argue that the 23–25 % of fires causes were the violation of the rules of installation and operation of electrical apparatus (Boniardi *et al.* 2015). This indicates that every fifth fire occurs due to the burning of a variety of electrical products, overloads and short circuits in electrical conductors, electrical installations of buildings and the internal electrical grids of buildings in particular. Aluminum wiring was used in public and residential buildings until the mid-1990s. Taking into consideration that aluminium has a low melting point of 923-943 K, the melting points of wire are often mistakenly considered to be short-circuited when determining the causes of a fire (Nazarovets *et al.* 2015). It should be noted that the melting of conductors may also be caused not only by short-circuit currents but by external high-temperature heat sources and long-term overload current, which can heat the aluminum wire in places of weak contact and to cause the melting.

During the investigation of fire places almost every fact of the reveal of wires and cables remnants with molten cores, burnt metallic cable shell of wiring is put forward with version of the involvement in the emergence of fires the breakdown modes in electrical installations.

Therefore, in this paper the task is to analyse the microstructures of aluminium wire after it heating by various sources that simulate the conditions of fires. The wire microstructures were analysed with the help of physicochemical methods in order to substantiate the method of research of damaged wires during the examination of the reasons and consequences of fires.

To achieve these aims, the following tasks were set:
- to prepare the aluminium wire section in order to detect the microstructure of the wire;
- to reveal the chemistry of section of the aluminum wire;
- to compare the changes in the quantity (mass content) of chemical elements in the studied aluminum wire.

RESEARCH METHODOLOGY AND RESULTS

Physicochemical methods are based on the ability to record structural transformations that occur under the influence of high temperatures and directly flames in fires, so they can be used for the study of aluminium wires (Nazarovets et al. 2015). During examinations, most aluminum fusion conductors are studied by the method of metallographic analysis, and X-ray phase and coulometric methods for analyzing aluminum wire are used to detect carbon content (Lindsay *et al.* 2006).

During the researches of wires the temperature modes were created by the "MP-2UM" muffle furnace with the power of 2.6 kW and temperature limits of 273-1273 K. The current load of the conductors was created by a welding transformer of P = 5 kW nominal power, the I_1 = 23 A current of the primary winding, and the U = 220/50 V voltage of the primary and secondary windings of transformer. The welding transformer provides a maximum current load of 110 A. After the short circuit (SC), wires are removed from the temperature medium and cooled to the room temperature for further research. Temperature is controlled by the temperature converter of CA "chromel-aluminum" connected to the secondary device and the temperature regulator of RT-0102 on semistor (Jones and Michael *et al.* 2011).

The experimental study consisted of revealing the certain changes in the microstructure of the wires in which the SC was occurred, with further heating of the medium and wire cores by another source of heat to the melting point. For this purpose, aluminum wires with a cross-sectional area of 2.5 and 4 mm^2 with PVC insulation and length of 200 mm were placed in a muffle furnace.

Experiments are carried out according to the following order of table 1.

Table 1. Conditions of experimental study

№	The ambient temperature [T, K]	Comment
1.	423	Time of stay of the wire in the muffle furnace is Tm = 7 min. Conditions: gradual cooling by air (T = 293 K).
2.	523	Tm = 12 min. Conditions: gradual cooling by air (T = 293 K).
3.	623	Tm = 17 min. Conditions: gradual cooling by air (T = 293 K).
4.	723	Tm = 27 min. Conditions: gradual cooling by air (T = 293 K).
5.	823	Tm = 38 min. Conditions: gradual cooling by air (T = 293 K).
6.	923	Tm = 51 min. Conditions: gradual cooling by air (T = 293 K).
7.	293	The SC of wire was occurred at a temperature of 293 K. Conditions: gradual cooling by air (T = 293 K).
8.	523	After the SC, the wire was heated in a muffle furnace to a temperature of 523 K and gradually cooled by air (T = 293 K).
9.	723	After the SC, the wire was heated to 723 K in a muffle furnace and gradually cooled by air (T = 293 K).
10.	923	After the SC, the wire was heated in a muffle furnace to a temperature of 923 K and gradually cooled with air (T = 293 K).

After the experiments, segments of wire with melting in the size of 50-100 mm are removed, and later the microsections are made from them. In the process of sections making, the part of wire with melting in the size of 7-12 mm is placed in a metal mandrel and with the low-melting and fast-hardening "Wuda" alloy is poured (fig. 1). After hardening of the "Wuda" alloy, the samples are polished on a rotating circle with abrasive paper of different grain size. After changing the graininess of the abrasive paper, it is necessary to change the direction of grinding by 90° and to polish to the complete disappearance of the lines from the previous operation. The surface roughness after grinding should not exceed of 0.08 microns.

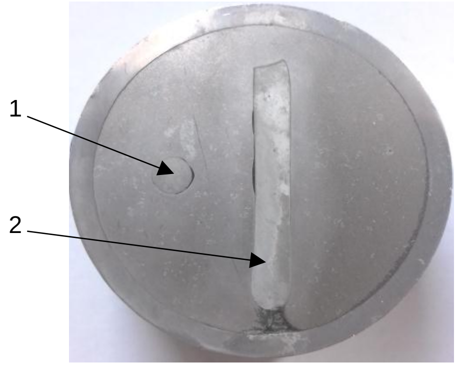

Figure 1. Overview of the aluminum wire section: 1 – cross section, 2 – longitudinal section

To detect the microstructure of the wire under study, the sections were etched by applying a special reagent on the polished surface.

The chemistry of wires was studied by the method of local X-ray spectral analysis using a ZEISS EVO 40XVP scanning electron microscope with the INCA Energy system of X-ray microanalysis.

To determine the dependence of the change in the chemistry of the aluminum wire structure, the following samples were selected: 1) standard (wire was heated by a short-circuit current), 2) wires were heated in a muffle furnace to temperatures of 523, 723 and 923 K, and 3) wires were preheated with SC currents and then heating in the muffle furnace to temperatures of 523, 723 and 923 K.

The structure of the section and the area of the aluminum wire of the standard sample (spectrum 1) were showed on figure 2.

Spectral analysis of the studied section of the aluminum wire revealed the mass content of 10.3 % *ω(O)* oxygen and 89.7 % of *ω(Al)* aluminum.

The structure of the section of aluminum wire after SC was showed on figure 3 and the chemistry of this section was showed in table 2 and on figure 4 according to analyse.

Analysis of the section (Fig. 5), which was heated in a muffle furnace to a temperature of 523 K with following air cooling, showed the content of *ω(O)* oxygen was 38.87 %, aluminum *ω(Al)* = 42.92 %, carbon *ω(C)* = 12.81%, silicon *ω(Si)* = 2.59% and chromium *ω(Cr)* = 2.81 % (table 3).

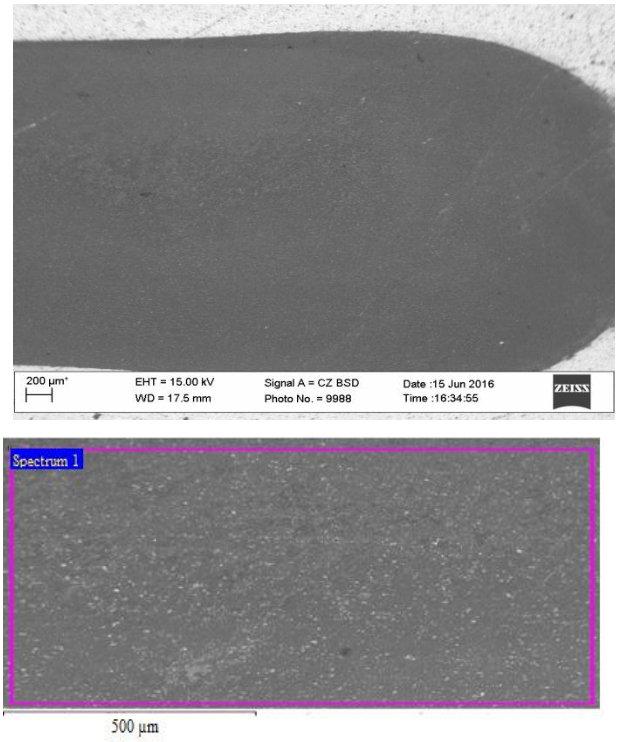

Figure 2. The section of the aluminum wire of the standard sample

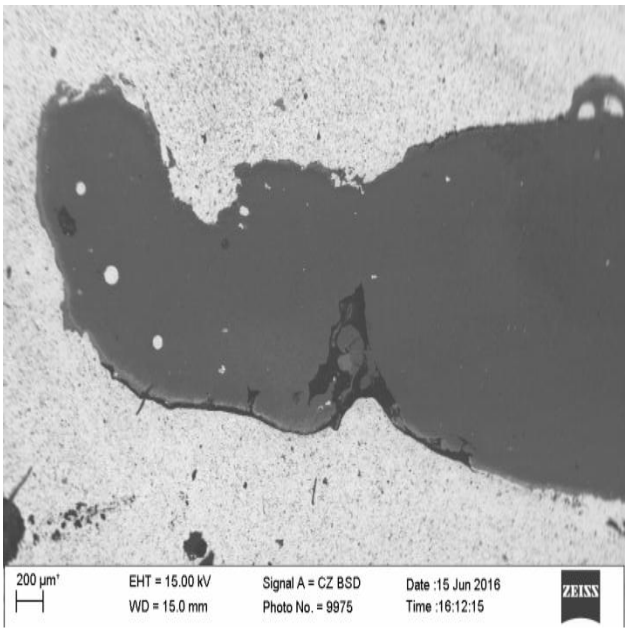

Figure 3. The section of the aluminum wire after short circuit heating and cooling by air

Table 2. The chemistry of the aluminum wire section

Element	Mass (ω), [%]	Atomic (χ), [%]
O K	14.09	22.07
Al K	74.6	69.29
Si K	7.78	6.94
Cr K	3.53	1.7
In all	100	

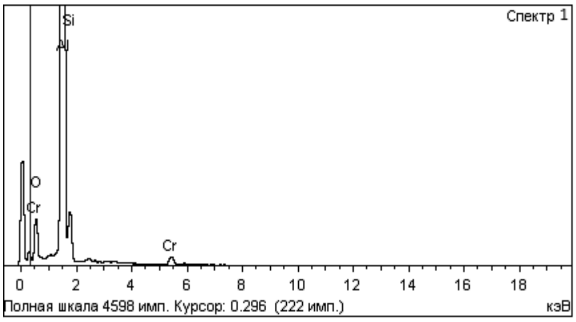

Figure 4. The chemistry of the aluminum wire after short circuit heating and cooling by air

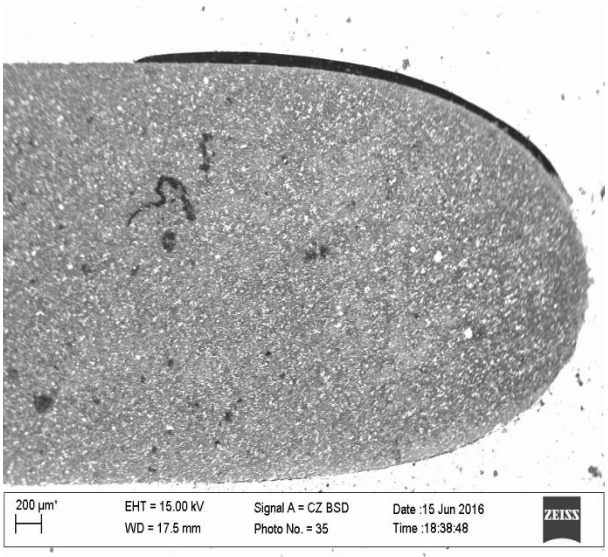

Figure 5. The section of the aluminum wire after heating to 523 K, and cooling by air

Table 3. The chemistry of the aluminum wire section

Element	Mass (ω), [%]	Atomic (χ), [%]
O K	38.87	46.43
Al K	42.92	30.4
C K	12.81	20.38
Si K	2.59	1.76
Cr K	2.81	1.03
In all	100	

According to analysis the structure of the section of aluminum wire after SC preheating was showed on figure 6 and the chemistry of this section was showed in table 4.

Analysis of the section (Fig. 6), which was preheated by short circuit and then heated in a muffle furnace to a temperature of 523 K with following air cooling, showed the content of *ω(O)* oxygen was 27.76 %, aluminum *ω(Al)* = 63.86 % and silicon *ω(Si)* = 8.38% (table 4) with appropriate atomic percentage.

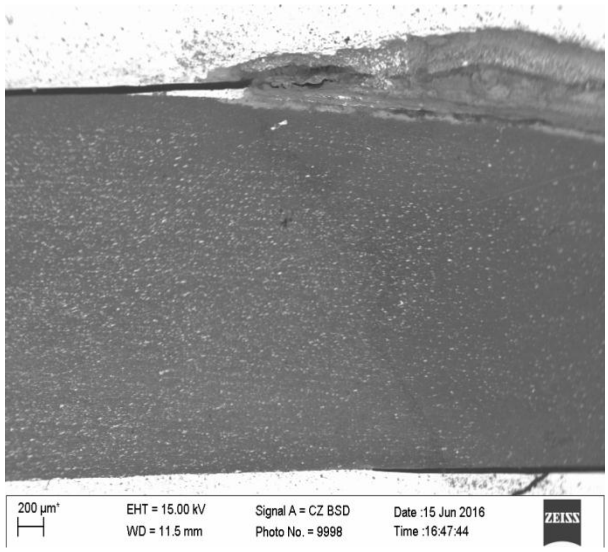

Figure 6. The section of the aluminum wire after short circuit preheating with following heating in muffle furnace to 523 K and cooling by air

Table 4. The chemistry of the aluminum wire section

Element	Mass (ω), [%]	Atomic (χ), [%]
O K	27.76	39.5
Al K	63.86	53.7
Si K	8.38	6.8
In all	100	

To compare the changes in the quantity of chemical elements in the studied aluminum wire of the internal electrical network tables were formed. The table 5 represents mass content of chemical elements in microstructures of aluminum wires heated in a muffle furnace and table 6 represents the mass content of chemical elements in microstructures of aluminum wire preheated with short-circuit currents according to test conditions and with subsequent heating in the muffle furnace.

The data in the table 5 shows that in the studied sections of the main metal zone, metal abscess zone and impurities zone the mass content of *ω(O)* oxygen was increased with the rise of temperature, and the mass content of *ω(Al)* aluminum was decreased as a result of heating of aluminum conductors in the muffle furnace. When the melting point of aluminum was reached, the oxygen content was decreased sharply, and the content of aluminum was increased. It should be noted that when the conductors were heated to a temperature of 523 K, the content of oxygen was increased by almost 3 times compared with the standard, while the *ω(C)* carbon was appeared in the sections of conductors.

Figure 7 shows graphic presentation (as curves) of the changes of the mass content of *ω(O)* oxygen in the sections of the main metal, metal abscess and impurities in accordance with the temperature of the heating of the aluminum conductor.

Table 5. The mass content of chemical elements in microstructures of wires after heating in a muffle furnace

№	Test conditions for aluminum wires	O, %	Al, %	Si, %	C, %
1	Etalon Spectrum №1	10.30	89.70	-	-
2	T – 523 K, air cooling. Spectrum №1	38.87	42.92	2.59	12.81
3	T – 723 K, air cooling. Spectrum №1	43.62	49.84	1.92	-
4	T – 923 K, air cooling. Spectrum №1	26.55	70.21	2.05	-
5	Etalon Spectrum №2	11.27	85.45	3.28	-
6	T – 523 K, air cooling. Spectrum №2	39.45	34.54	-	20.45
7	T – 723 K, air cooling. Spectrum №2	55.04	32.23	12.73	-
8	T – 923 K, air cooling. Spectrum №2	44.67	55.33	-	-
9	Etalon Spectrum №3	9.50	76.20	18.86	-
10	T – 523 K, air cooling. Spectrum №3	31.89	62.60	-	5.51
11	T – 623 K, air cooling. Spectrum №3	44.31	55.69	-	-
12	(T – 923 K), air cooling. Spectrum №3	27.39	72.60	-	-

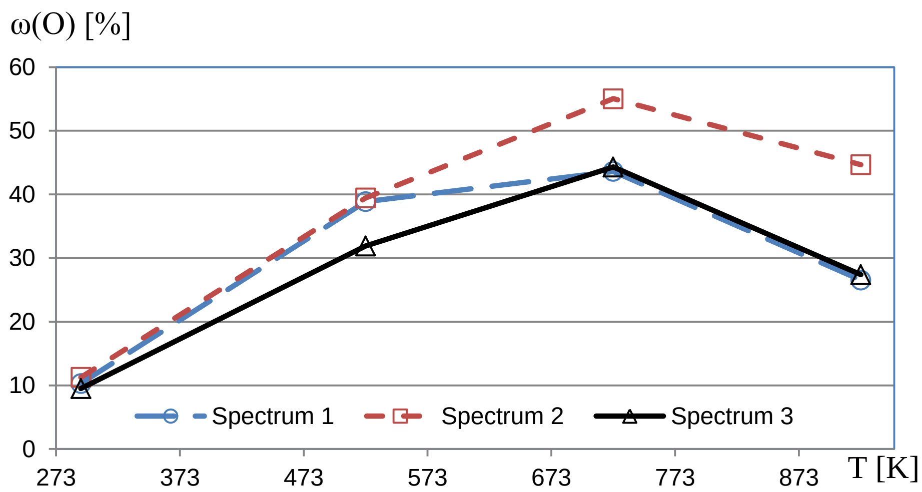

Figure 7. The curves of changes of the mass content of oxygen in the studied sections: spectrum 1 – the main metal zone; spectrum 2 – the metal abscess zone; spectrum 3 – the impurities zone

Table 6. The mass content of chemical elements in microstructures of wires after preheating by short-circuit currents with subsequent heating in a muffle furnace

№	Test conditions for aluminum wires	O, %	Al, %	Si, %	C, %
1	SC – (T – 293 K), air cooling. Spectrum №1	14.09	74.60	7.78	-
2	SC – (T – 523 K), air cooling. Spectrum №1	27.76	63.86	8.38	-
3	SC – (T – 723 K), air cooling. Spectrum №1	19.13	76,08	4.42	-
4	SC – (T – 923 K), air cooling. Spectrum №1	21.44	67.54	7.65	-
5	SC – (T – 293 K), air cooling. Spectrum №2	9.28	61.42	28,00	-
6	SC – (T – 523 K), air cooling. Spectrum №2	31,20	48.52	-	20.28
7	SC – (T – 723 K), air cooling. Spectrum №2	15.78	79.63	-	4.6
8	SC – (T – 923 K), air cooling. Spectrum №2	30.91	58.00	-	11.09
9	SC– (T – 293 K), air cooling. Spectrum №3	9.76	75.71	10.74	-
10	SC – (T – 523 K), air cooling. Spectrum №3	18.81	77.44	3.75	-
11	SC – (T – 723 K), air cooling. Spectrum №3	14.38	84.68	0.94	-
12	SC – (T – 923 K), air cooling. Spectrum №3	19.76	40.74	-	25.59

Table 3 demonstrates some content of carbon *(C)* in impurity zones as a result of alumina wire sample heating to temperatures of 523 K, 723 K and 923 K with preheating by SC currents.

When the conductor (aluminium wire) was preheated by the current of the short circuit and then was heated up to 523 K the mass content of *ω(O)* oxygen in the area of the base metal are increased by 1.7 times, in the metal abscess zone the mass content of oxygen is increased by 2.3 times and in the impurity zone it was increased by 1.7 times in comparison with the model in which the SC current was at the room temperature. After further heating in the muffle furnace, the mass content of oxygen was decreased significantly and at the temperature of 723 K the content of oxygen was increased again.

Fig. 7 shows the graphs of the change in the mass content of oxygen in the zone of the base metal, in the metal abscess zone and in the impurity zone in accordance with the mode of heating temperature of the aluminum conductor sample which was previously heated by the SC current.

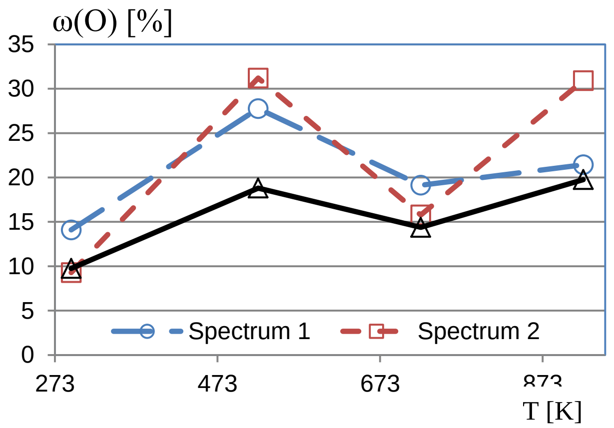

Figure 8. The curves of changes of the mass content of oxygen in the studied sections: spectrum 1 – the main metal zone; spectrum 2 – the metal abscess zone; spectrum 3 – the impurities zone

Figure 7 shows that for all spectra, the highest content of oxygen is in the zones of the main metal, the metal abscess and the impurity at a temperature of 523 K, and subsequent heating reduces the oxygen content of the main metal zone almost by 2 times at 723 K.

CONCLUSIONS

1. On the basis of the experimental study, it was found that for the analysis of the microstructure of aluminum wires, the etchant was most effective when based on the solution of 0.5% hydrofluoric (etching) acid. The etchant on the basis of 5-10 % sodium hydroxide heated to a temperature of 343 K was less sensitive to the microstructure of an aluminum conductor and was more time-consuming.
2. The use of the method of local X-ray spectral analysis of transverse and longitudinal sections of aluminum wires of internal electric networks (after the fire conditions) showed following peculiarities.
3. When aluminum wire was heated, the mass content of oxygen was increased with the temperature increase, and the content of aluminum was decreased in the zones of the main metal, the metal abscess and the impurities. When the temperature reached the melting point of aluminum, the content of oxygen was decreased sharply, and the content of aluminum was increased. It should be noted that when the conductors were heated to a temperature of 523 K, the content of oxygen was increased by almost 3 times compared with the standard, while the $\omega(C)$ carbon was showed up in the sections of conductors.
4. Experimental studies revealed the heating of aluminum wires by convective heat transfer method make it possible to find the carbon in model sections heated to the temperature of 523 K. At the conditions of aluminum wires preheating by SC with subsequent heating in muffle furnace the carbon was showed up in all models samples heated to a temperature of 523 K, 723 K, 923 K.
5. The study revealed that the SC is the reason of the oxygen content increase in the surface layer of the conductor. The highest content of oxygen was in the zones of the metal abscess and the impurities and also in the conversion zone from solid to liquid metal. These peculiarities can confirm that the short-circuit current was the root cause of fire.

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APPLICATION OF THE LAPLACE TRANSFORM TO CALCULATE THE VELOCITY OF A TWO-PHASE FLUID MODULATED BY THE MOVEMENT OF CUTTINGS OF AN ENERGY WILLOW (SALIX VIMINALIS)

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Abstract. In order to create automatic systems for planting energy willow, it is important to study the process of gravitational unloading of cuttings. When constructing a mathematical model of this process, planting material was characterized as a pseudo-fluid consisting of a discrete component (cuttings) and a gaseous medium (air), and the gravity unloading itself was considered from the point of view of hydrodynamic multiphase systems using the corresponding general equations for characterizing the motion. By applying the Laplace transform to determine the Fourier coefficients, we obtain a system of linear algebraic equations of the velocity of motion of such a pseudo-fluid.

Keywords: energy willow (salix viminalis), planting automation, mathematical model, Laplace transform, multiphase system

INTRODUCTION

As theoretical studies, in the direction of unloading bulk materials, show, this problem is far from solved. Numerous studies of the process of gravitational outflow of materials made it possible to establish only some dependencies that explain the essence of this process (Bagnold, 1954; Bohomiahkih, Pepchuk, 1985; Gyachev, 1992; Savage, Cowin, 1999; Zenkov *et al.* 1966). It is due to the complexity of ensuring uniform continuous movement till now, there is no universal power device that works effectively with any bulk material, and the variety of material requiring unloading contributes to a further search for justifications for the movement of a particular material. So in this study, such material is cuttings of plants. The need to study this issue is dictated by the increasing popularity of fuels from bioenergy crops, which require fast and efficient machines to create the so-called energy plantations to increase their volumes. The most common energy willow in Ukraine is vegetatively propagated by cuttings 20-25 cm long and 5-20 mm in diameter (Frączek, Mudryk, 2005; Dziedzic *et al.* 2017; Hutsol *et al.* 2018; Yermakov *et al.* 2018).

Today, such material is planted with planters in which planting material is supplied exclusively by hand, which significantly limits the possibility of increasing the efficiency of the units. A theoretical study of the cuttings' movement and the implementation of the results in practice can be of help in creating a planting machine.

Figure 1. Planting material of energy willow

In accordance with the scientific direction at the State Agrarian and Engineering University in Podilia “Research on workflow and parameters of the feeling mechanism for cuttings in energy willow planting” (state registration number 0119U100945), an automated system for feeding and selecting planting material for wood energy crops is being developed.

One of the first steps in this work is the construction of a mathematical model of the process of gravitational flow of rod-shaped materials from slot hoppers (Yermakov, Hutsol 2018; Yermakov *et al.* 2019).

MATERIALS AND METHODS

In previous works, we have already worked out general principles for constructing a mathematical model of the process of unloading cuttings from the hopper, determined the boundary conditions and characteristics of their movement (Yermakov *et al.* 2018; Yermakov, Hutsol, 2018; Yermakov *et al.* 2019).

The model of the hopper was taken as the basis (Fig. 2), in which the consideration of the process is limited to the two-dimensional model (in the plane x_1x_2), since it is assumed that the movement of cuttings in the hopper is independent of the coordinate x_3, due to the presence of walls parallel to the plane x_1x_2 that restrict movement cuttings along the axis x_3.

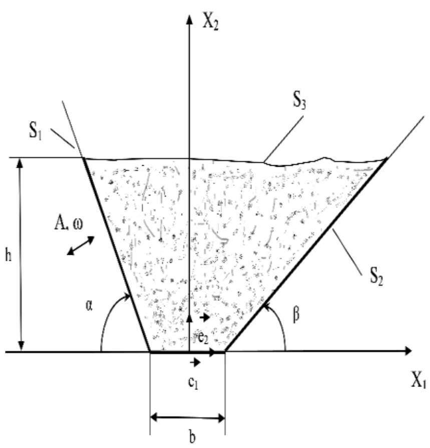

Figure 2. The design scheme of the hopper with cuttings

Moreover, based on an analysis of existing solutions, a number of assumptions were made, which made it possible to consider the gravitational unloading of cuttings from the point of view of hydrodynamic multiphase systems. In accordance with this approach, the set of cuttings is considered as a pseudo-fluid consisting of two phases: a discrete, formed by cuttings and a continuous phase (gas-like medium between the cuttings) (Yermakov *et al.* 2019). Each of these phases is considered as a continuous medium, which allowed us to consider unloading as the motion of a viscous incompressible pseudo-fluid, the equations of motion of which were presented in the following form (Sous 1971; Nyhmatulin 1978).

$$\rho\left(\frac{\partial\vec{V}}{\partial t}+\left(\vec{V}_1,\nabla\right)\vec{V}\right)=-\nabla P+\mu\Delta\vec{V}+\vec{F}-\rho g e_2\,, \tag{1}$$

$$\rho_1\left(\frac{\partial\vec{V}_1}{\partial t}+\left(\vec{V}_1,\nabla\right)\vec{V}_1\right)=-(1-\delta)\nabla P_1+\mu_1\Delta\vec{V}_1-\vec{F}-\rho_1 g e_2\,, \tag{2}$$

$$div\vec{V}=0\,, \tag{3}$$

$$div\vec{V}_1=0\,, \tag{4}$$

where e_1, e_2, e_3 are the unit vectors of the Cartesian coordinate system,

$\vec{V},\vec{V}_1$ - velocity field of discrete and continuous phases,

P, P_1 - pressure of discrete and continuous phases,

g - acceleration of gravity.

RESULTS AND DISCUSSION

Basic assumptions about the nature of the motion of a two-phase pseudo-fluid. In the previous works of the authors (Yermakov *et al.* 2019), the formulation of the initial-boundary-value problem of the motion of a two-phase pseudo-fluid is given, which simulates the process of unloading cuttings from the hopper. The equation of motion of this pseudo-fluid is nonlinear integrodifferential equations. This significantly complicates the solution to these equations. However, under certain assumptions about the nature of the motion of the pseudo-fluid, these equations can be simplified. This made it possible to obtain their solutions in an analytical form.

Let us formulate these assumptions. To do this, we introduce dimensionless variables by the formulas

$$\begin{aligned} &t = T\cdot\bar{t},\, x_1 = L\cdot\bar{x}_1, x_2 = L\cdot\bar{x}_2,\\ &\vec{V}_1 = V_0\cdot\vec{U}_1, \vec{V} = V_0\cdot\vec{U} \end{aligned} \tag{5}$$

where T is the characteristic time, L is the characteristic length size, V_0 is the maximum velocity of the pseudo-fluid.

In these variables, the equation of motion (1) - (4) will take the form

$$\begin{aligned} &\frac{\partial\vec{u}}{\partial\bar{t}} + \frac{V_0T}{L}(\vec{u},\nabla)\vec{u} = -\frac{T}{V_0\rho L}\nabla\rho + \frac{\nu T}{L^2}\Delta\vec{u} +\\ &+0.5\frac{\bar{\rho}_1}{\bar{\rho}}\left[\begin{matrix}\frac{\partial}{\partial\bar{t}}(\vec{u}_1-\vec{u}) + \frac{V_0T}{L}\times\\ (\vec{u}_1-\vec{u},\nabla)(\vec{u}_1-\vec{u})\end{matrix}\right] +\\ &+\frac{4.5\bar{\rho}_1\sqrt{\nu_1 T}}{\sqrt{\pi}a\bar{\rho}}\int_0^{\bar{t}}\left(\begin{matrix}\frac{\partial}{\partial\bar{\tau}}(\vec{u}_1-\vec{u}) + \frac{V_0T}{L}\times\\ (\vec{u}_1-\vec{u},\nabla)(\vec{u}_1-\vec{u})\end{matrix}\right)\times\\ &\times(\bar{t}-\bar{\tau})^{-1/2}\,d\bar{\tau} +\\ &+3.75\frac{\bar{\rho}_1\delta\nu_1 T}{\bar{\rho}a^2(1-\delta)^2}(\vec{u}_1-\vec{u}) - g\frac{T}{V_0}\vec{e}_2. \end{aligned} \tag{6}$$

$$\begin{aligned} &\frac{\partial\vec{u}_1}{\partial\bar{t}} + \frac{V_0T}{L}(\vec{u}_1,\nabla)\vec{u}_1 = -\frac{(1-\delta)T}{V_0\rho_1 L}\nabla\rho_1 + \frac{\nu_1 T}{L^2}\Delta\vec{u}_1 -\\ &-0.5\frac{\delta}{1-\delta}\left[\frac{\partial}{\partial\bar{t}}(\vec{u}_1-\vec{u}) + \frac{V_0T}{L}(\vec{u}_1-\vec{u},\nabla)(\vec{u}_1-\vec{u})\right] -\\ &-\frac{4.5\delta\sqrt{\nu_1 T}}{\sqrt{\pi}a(1-\delta)}\int_0^{\bar{t}}\left(\frac{\partial}{\partial\bar{\tau}}(\vec{u}_1-\vec{u}) + \frac{V_0T}{L}(\vec{u}_1-\vec{u},\nabla)(\vec{u}_1-\vec{u})\right)\times\\ &\times(\bar{t}-\bar{\tau})^{-1/2}\,d\bar{\tau} - 3.75\frac{\delta^2\nu_1 T}{a^2(1-\delta)^3}(\vec{u}_1-\vec{u}) - g\frac{T}{V_0}\vec{e}_2. \end{aligned} \tag{7}$$

$$\operatorname{div}\vec{u} = 0, \quad \operatorname{div}\vec{u}_1 = 0. \tag{8}$$

From (6), (7) it follows that if the quantity V_0T/L is sufficiently small

$$\frac{V_0T}{L} << 1, \tag{9}$$

then in equations (6), (7) we can neglect nonlinear members of the type $(\vec{u},\nabla)\vec{u}$, $(\vec{u}_1-\vec{u},\nabla)(\vec{u}_1-\vec{u})$. As the quantities V_0, T, L we choose the following; $V_0 = \omega A$ - maximum speed of vibrations, $T = 2\pi/\omega$ - period of vibrations, $L = 2\pi a$ - circumference of the cross-section of the cutting. Then inequality (9) takes the form

$$\frac{A}{a} << 1. \tag{10}$$

Thus, if the amplitude of the vibrations is sufficiently small, then in equations (6), (7) the nonlinear terms are small. In what follows, we will assume that inequality (10) holds.

Further, since $\vec{\rho}_1$ is the density of air, $\bar{\rho}$ is the averaged density of cuttings, the quantity is

$$\frac{\bar{\rho}_1}{\bar{\rho}} << 1. \tag{11}$$

Therefore, the third and fourth terms on the right side of equation (6) can be neglected.

In addition, since the volume concentration of the cuttings $\delta \approx 1$, and the coefficient of kinematic viscosity of the air (continuous phase) ν_1 is small ($\nu_1 \approx 10^{-5}\, m^2/s$), the first and second terms on the right side of equation (7) can be neglected.

Thus, based on the assumptions made about the nature of the motion of the two-phase pseudo-fluid, equations (6) - (8) are simplified and take the form

$$\frac{\partial\vec{u}}{\partial\bar{t}} = -\gamma\nabla\rho + \bar{\nu}\Delta\vec{u} + \Phi(\vec{u}_1-\vec{u}) - \bar{g}\vec{e}_2, \tag{12}$$

$$\begin{aligned} &\frac{\partial\vec{u}_1}{\partial\bar{t}} = -0.5\frac{\delta}{1-\delta}\frac{\partial}{\partial\bar{t}}(\vec{u}_1-\vec{u}) -\\ &-\Phi_1\int_0^{\bar{t}}\frac{\partial}{\partial\bar{t}}(\vec{u}_1-\vec{u})(\bar{t}-\bar{\tau})^{-1/2}\,d\bar{\tau} -\\ &-\Phi_2(\vec{u}_1-\vec{u}) - \bar{g}\vec{e}_2, \end{aligned} \tag{13}$$

$$\operatorname{div}\vec{u} = 0, \quad \operatorname{div}\vec{u}_1 = 0. \tag{14}$$

The notations are introduced here.

$$\gamma = \frac{T}{V_0 \rho L}, \quad \bar{g} = g\frac{T}{V_0}, \quad \bar{\nu} = \frac{\nu T}{L^2}, \tag{15}$$

$$\Phi = 3.75\frac{\bar{\rho}_1 \delta \nu_1 T}{\bar{\rho} a^2 (1-\delta)^2}, \tag{16}$$

$$\Phi_1 = 4.5\frac{\delta\sqrt{\nu_1 T}}{\sqrt{\pi} a (1-\delta)}, \tag{17}$$

$$\Phi_2 = 3.75\frac{\delta^2 \nu_1 T}{a^2 (1-\delta)^3}, \tag{18}$$

Equations (12) - (14) are the basis for describing the process of unloading cuttings from the hopper. To these equations it is necessary to add initial and boundary conditions, which in the new notation have the form:

Initial conditions

$$\vec{u}\big|_{\bar{t}=0} = \vec{u}_1\big|_{\bar{t}=0} = 0, \quad \rho\big|_{\bar{t}=0} = 0, \tag{19}$$

Boundary conditions

if $\bar{x}_2 = h(\bar{t})/L$

$$-\rho + \frac{2\mu V_0}{L}\frac{\partial u_2}{\partial \bar{x}_2} = 0, \tag{20}$$

$$\frac{\partial u_1}{\partial \bar{x}_2} + \frac{\partial u_2}{\partial \bar{x}_{12}} = 0, \tag{21}$$

$$\dot{h} = V_0 T u_2, \tag{22}$$

if $\bar{x}_2 = -\operatorname{tg}\alpha\left(\bar{x}_1 + b/2L\right), /$ $-\operatorname{ctg}\alpha h_0 / L - b/2L < \bar{x}_1 < b/2L$

$$\sin\alpha u_1 + \cos\alpha u_2 = \frac{A\omega}{V_0}\sin 2\pi\bar{t}, \tag{23}$$

$$\cos 2\alpha\left(\frac{\partial u_1}{\partial \bar{x}_1} + \frac{\partial u_2}{\partial \bar{x}_2}\right) + 2\sin 2\alpha\frac{\partial u_1}{\partial \bar{x}_1} = \frac{gL\cos^2\alpha \quad h(\bar{t})}{2\nu V_0}, \tag{24}$$

if

$$\bar{x}_2 = \operatorname{tg}\beta(\bar{x}_1 - b/2L), \quad b/2L < \bar{x}_1 < b/2L + \frac{\operatorname{ctg}\beta h_0}{L}$$

$$\cos 2\beta\left(\frac{\partial u_1}{\partial \bar{x}_2} + \frac{\partial u_2}{\partial \bar{x}_1}\right) - 2\sin 2\beta\frac{\partial u_1}{\partial \bar{x}_1} = \frac{gL\cos^2\beta \quad h(\bar{t})}{2\nu V_0}. \tag{25}$$

*Application of the Laplace transform to the equations of motion of a two-phase pseudo-fluid.*The solutions of equations (12) - (14) can be found using the Laplace transform.

Before applying the Laplace transform, we determine the pressure ρ. To do this, we act by differential operation div on the left and right sides of equation (12). Then, taking into account equations (14), we have

$$\Delta\rho = 0. \tag{26}$$

Assuming that the pressure ρ is weakly dependent on the variable x_1

$$\left|\frac{\partial^2 \rho}{\partial \bar{x}_1{}^2}\right| << \left|\frac{\partial^2 \rho}{\partial \bar{x}_2{}^2}\right|$$

from (26) we obtain

$$\left|\frac{\partial^2 \rho}{\partial \bar{x}_2{}^2}\right| = 0. \tag{27}$$

Integrating (27), we have

$$\rho = C_1 \bar{x}_2 + C_2, \tag{28}$$

where $C_1$and C_2 are constant values independent of the variable $\bar{x}_2$. The constants

C_1 and C_2 can be determined from the boundary conditions on the free surface of the layer of cuttings and on the border of the discharge window of the hopper.

Neglecting the influence of the atmosphere and assuming that at the boundary of the discharge window the pressure coincides with the standard pressure $p_{cm} = \rho g h$, we obtain

$$p = \rho g\left(h - L\bar{x}_2\right). \tag{29}$$

Let us substitute (29) into (12). After a series of transformations, we have

$$\frac{\partial \vec{u}}{\partial \bar{t}} = \bar{\nu}\Delta\vec{u} + \Phi\left(\vec{u}_1 - \vec{u}\right). \tag{30}$$

We introduce the Laplace transform with respect to the time variable $\bar{t}$ for the velocity fields $\vec{u}$ and $\vec{u}_1$ of the discrete and continuous phases of the pseudo-fluid

$$\vec{U} = \int_0^\infty \vec{u}e^{-q\bar{t}}d\bar{t}, \quad \vec{U}_1 = \int_0^\infty \vec{u}_1 e^{-q\bar{t}}d\bar{t}. \tag{31}$$

Let us apply the Laplace transform to (30) and (13), (14). Then, taking into account (31), using the property of the Laplace transform and the formula

$$\int_0^\infty e^{-q\bar{t}}\int_0^{\bar{t}} U(\tau)\left(\bar{t} - \tau\right)^{-1/2} d\tau = \sqrt{\pi q}\int_0^\infty U\left(\bar{t}\right)e^{-q\bar{t}}\,d\bar{t}$$

we have

$$q\vec{U} = \bar{\nu}\Delta\vec{U} + \Phi\left(\vec{U}_1 - \vec{U}\right), \tag{32}$$

$$\vec{U}_1\Psi = \left(\Psi - q\right)\vec{U} - \frac{\vec{g}}{q}\vec{e}_2, \tag{33}$$

$$\operatorname{div}\vec{U} = 0, \tag{34}$$

where

$$\Psi = q\frac{1 - 0.5\delta}{1 - \delta} + \sqrt{\pi q}\Phi_1 + \Phi_2. \tag{35}$$

Excluding $\vec{U}_1$ from (32), (33) we have

$$\Delta\vec{U} = \frac{q}{\bar{\nu}}\left(1 + \frac{\Phi}{\Psi}\right)\vec{U} + \frac{\Phi\bar{g}}{q\bar{\nu}\Psi}\vec{e}_2, \tag{36}$$

$$\operatorname{div}\vec{U} = 0. \tag{37}$$

Having determined from (36), (37) the Laplace transform $\vec{U}_1$ of the discrete phase velocity, from (33) it is possible to determine the Laplace transform of the continuous phase velocity

$$\vec{U}_1 = \left(1 - \frac{q}{\Psi}\right)\vec{U} - \frac{\bar{g}}{q\Psi}\vec{e}_2. \tag{38}$$

Thus, to solve the problem, it is sufficient to determine the velocity of the discrete phase of the pseudo-fluid.

In addition to equations (36), (37), it is necessary to add boundary conditions (23) - (25), which, after applying the Laplace transform, are reduced to

if $\bar{\bar{x}}_2 = -\operatorname{tg}\alpha\left(\bar{x}_1 + b/2L\right)$

$$\sin U_1 + \cos U_2 = \frac{A\omega 2\pi}{V_0\left(q^2 + 4\pi^2\right)}, \tag{39}$$

$$\cos 2\alpha\left(\frac{\partial U_1}{\partial \bar{x}_1} + \frac{\partial U_2}{\partial \bar{x}_2}\right) + 2\sin 2\alpha\frac{\partial U_1}{\partial \bar{x}_1} = \frac{fgL\cos^2\alpha\bar{h}}{2\nu V_0}, \tag{40}$$

if $\bar{\bar{x}}_2 = -\operatorname{tg}\beta\left(\bar{x} - b/2L\right)$

$$\cos 2\beta\left(\frac{\partial U_1}{\partial \bar{x}_2} + \frac{\partial U_2}{\partial \bar{x}_1}\right) - 2\sin 2\beta\frac{\partial U_1}{\partial \bar{x}_1} = \frac{fgL\cos^2\beta\bar{h}}{2\nu V_0}, \tag{41}$$

where

$$\bar{h} = \int_0^\infty h\left(\bar{t}\right)e^{-q\bar{t}}d\bar{t}. \tag{42}$$

Let us find a solution to problem (36), (37). To do this, we pass from the vector form to the scalar one.

$$\Delta U_1 - \lambda U_1 = 0, \tag{43}$$

$$\Delta U_2 - \lambda U_2 = d, \tag{44}$$

$$\frac{\partial U_1}{\partial \bar{x}_1} + \frac{\partial U_2}{\partial \bar{x}_2} = 0, \tag{45}$$

where

$$\vec{U} = U_1\vec{e}_1 + U_2\vec{e}_2, \quad (46)$$

$$\lambda = \frac{q}{\bar{\nu}}\left(1+\frac{\Phi}{\Psi}\right), \quad (47)$$

$$d = \frac{\Phi\bar{g}}{q\bar{\nu}\Psi}. \quad (48)$$

Equations (43) - (45) must be satisfied in the volume of the hopper. Continue the functions U_1 and U_2 beyond the hopper to the rectangle

$$-\frac{h_0}{L}\operatorname{ctg}\alpha - \frac{b}{2L} \le \bar{x}_1 \le \frac{h_0}{L}\operatorname{ctg}\beta + \frac{b}{2L}, \quad (49)$$

$$0 \le \bar{x}_2 \le \frac{h_0}{L}$$

In the following way: U_1 will continue with zero, and U_2 with a constant $-d/\lambda$.

Then equations (43) - (45) will be satisfied on the entire rectangle (49).

We will seek a solution to these equations in the form of Fourier series in the variable $\bar{x}_1$

$$U_1 = \sum_{n=0}^{\infty} A_{1n}\cos\frac{2\pi}{M}n\bar{x}_1 + A_{2n}\sin\frac{2\pi}{M}n\bar{x}_1, \quad (50)$$

$$U_2 = -\frac{d}{\lambda} + \sum_{n=0}^{\infty} B_{1n}\cos\frac{2\pi}{M}n\bar{x}_1 + B_{2n}\sin\frac{2\pi}{M}n\bar{x}_1, \quad (51)$$

where $M = b/L + (\operatorname{ctg}\alpha + \operatorname{ctg}\beta)h_0/L$.

Here the quantities $A_{1n}, A_{2n}, B_{1n}, B_{2n}$ are unknown functions of the variable $\bar{x}_2$.

To find these functions, we substitute (50) and (51) into equations (43) and (44). Making the necessary calculations, we will have

$$\ddot{A}_{1n} - \lambda_n A_{1n} = 0, \quad \ddot{A}_{2n} - \lambda_n A_{2n} = 0, \quad (52)$$

$$\ddot{B}_{1n} - \lambda_n B_{1n} = 0, \quad \ddot{B}_{2n} - \lambda_n B_{2n} = 0, \quad n = 0,1,... \quad (53)$$

where

$$\lambda_n = \lambda + \left(\frac{2\pi n}{M}\right)^2, \quad (54)$$

and the dot denotes the operation of differentiation with respect to the variable $\bar{x}_2$.

Next, we substitute (50) and (51) into equation (45). We will obtain

$$\dot{B}_{1n} + \frac{2\pi n}{M}A_{2n} = 0, \quad \dot{B}_{2n} - \frac{2\pi n}{M}A_{1n} = 0. \quad (55)$$

The general solution of equations (52), (53) can be represented as

$$\begin{aligned} A_{1n} &= \bar{A}_{1n}e^{-\sqrt{\lambda_n}\bar{x}_2} + C_{1n}e^{\sqrt{\lambda_n}\bar{x}_2}, \\ A_{2n} &= \bar{A}_{2n}e^{-\sqrt{\lambda_n}\bar{x}_2} + C_{2n}e^{\sqrt{\lambda_n}\bar{x}_2}, \\ B_{1n} &= \bar{B}_{1n}e^{-\sqrt{\lambda_n}\bar{x}_2} + D_{1n}e^{\sqrt{\lambda_n}\bar{x}_2}, \\ B_{2n} &= \bar{B}_{2n}e^{-\sqrt{\lambda_n}\bar{x}_2} + D_{2n}e^{\sqrt{\lambda_n}\bar{x}_2}, \end{aligned} \quad (56)$$

where $\bar{A}_{1n}, \bar{A}_{2n}, C_{1n}, C_{2n}, \bar{B}_{1n}, B_{2n}, D_{1n}, D_{2n}$ are arbitrary constants.

Since λ_n depends on the parameter q of the Laplace transform (see (31)), which, generally speaking, is a complex number, for the root $\sqrt{\lambda_n}$ we choose the branch for which $\operatorname{Re}\sqrt{\lambda_n} \ge 0$.

As follows from (56), the sought quantities are the sum of two terms. One of them with the increase $n \to \infty$ increases exponentially, while the other decreases. For the convergence of infinite series (50) and (51), exponentially growing terms should be discarded. Therefore, exponentially decreasing terms should be left in (56).

$$\begin{aligned} A_{1n} &= \bar{A}_{1n}e^{-\sqrt{\lambda_n}\bar{x}_2}, \\ A_{2n} &= \bar{A}_{2n}e^{-\sqrt{\lambda_n}\bar{x}_2}, \\ B_{1n} &= \bar{B}_{1n}e^{-\sqrt{\lambda_n}\bar{x}_2}, \\ B_{2n} &= \bar{B}_{2n}e^{-\sqrt{\lambda_n}\bar{x}_2}, \end{aligned} \quad (57)$$

Now we substitute (56) into (57). Then we have

$$\begin{aligned} \bar{A}_{1n} &= -\sqrt{\lambda_n}\frac{M}{2\pi n}\bar{B}_{2n}, \\ \bar{A}_{2n} &= \sqrt{\lambda_n}\frac{M}{2\pi n}\bar{B}_{1n}. \end{aligned} \quad (58)$$

In particular, it follows from (58) that $\overline{B}_{10} = \overline{B}_{20} = 0$.

In view of the above, for solving equations (43) - (45), we obtain the following formulas

$$U_1 = \overline{A}_{10} e^{-\sqrt{\lambda}\overline{x}_2} + \sum_{n=1}^{\infty} \overline{\lambda}_n e^{-\sqrt{\overline{\lambda}_n}\overline{x}_2} \times \\ \times \left(\overline{B}_{1n} \sin \frac{2\pi n}{M} \overline{x}_1 - \overline{B}_{2n} \cos \frac{2\pi n}{M} \overline{x}_1 \right), \quad (59)$$

$$U_2 = -d/\lambda + \sum_{n=0}^{\infty} e^{-\sqrt{\overline{\lambda}_n}\overline{x}_2} \times \\ \times \left(\overline{B}_{1n} \cos \frac{2\pi n}{M} \overline{x}_1 + \overline{B}_{2n} \sin \frac{2\pi n}{M} \overline{x}_1 \right), \quad (60)$$

where

$$\overline{\lambda}_n = \sqrt{\lambda \left(\frac{M}{2\pi n} \right)^2 + 1}. \quad (61)$$

Formulas (59), (60) give a general solution to the system of equations (43) - (45).

CONCLUSIONS

1. The construction of a mathematical model of the motion of cuttings of energy willow will automate the planting process. To date, planters are known exclusively with manual laying of planting material.

2. The easiest way to move material during unloading is to move it under the action of gravitational forces. The theoretical justifications for such a movement do not have a single approach, and the specifics of the material for planting energy willow create additional difficulties for the development of a mathematical model of this process.

3. Taking a number of assumptions, it is proposed to consider the gravitational unloading of cuttings from the point of view of hydrodynamic multiphase systems. In accordance with this approach, the set of cuttings is considered as an incompressible pseudo-fluid consisting of two phases: a discrete, formed by cuttings and a continuous phase (gas-like medium between the cuttings).

4. The basic assumptions about the nature of the motion of a two-phase pseudo-fluid were considered and substantiated, due to which some of the composite equations could be neglected, and the existing equations of motion were significantly simplified.

5. By applying the Laplace transform to determine the Fourier coefficients, a system of linear algebraic equations of the pseudo-fluid velocity has been obtained (see (59), (60)).

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APPLICATION OF ELECTRICAL TECHNOLOGIES IN THE MANUFACTURING, RESTORATION AND REPAIR OF ELECTRIC EQUIPMENT IN THE CONDITIONS OF THE AGRICULTURAL COMPLEX

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Abstract. Modern electro-technologies used in the processes of manufacturing, restoration and repair of electrical equipment have been considered and analyzed. The use of such technologies can improve the performance of such equipment and improve the quality and reliability of its operation.

The use of electro-technology based on the direct action on the object of various forms of electrical energy (DC and AC energy, electromagnetic and electric field energy, etc.) in the manufacture, restoration and repair of equipment allows to increase its efficiency, profitability and competitiveness in comparison with other technologies, used in similar technological processes, such as mechanical treatment of structural materials with special physical and mechanical properties, heat treatment, enameling and painting, as well as repairing worn assemblies and parts.

Keywords: electrical technologies, electrical equipment, electrostatic method, coatings, ultrasonic treatment.

FORMULATION OF THE PROBLEM

The efficiency of operation of modern agricultural equipment is largely determined by the quality and reliability, which does not always meet modern requirements. This can to some extent be attributed not only to current agricultural machinery, but also to the processes of its production, especially in the stages of restoration and repair, which in most cases are outdated, energy-consuming technologies, carried out in manual, which causes considerable labor costs and low productivity. Such outdated methods include such technological processes as cleaning parts from greasing, dust, mechanical contamination, especially in complex configuration details, with deep holes and cavities, removal of scale, corrosion products, deposits, etc., and to outdated and inefficient technological processes can be referred: mechanical treatment of structural materials with special physical and mechanical properties, thermal treatment, enameling and painting, repairing of worn assemblies and parts, etc.

ANALYSIS OF RECENT RESEARCHES

Studies conducted in a number of Western countries (USA, Germany, Canada, UK, etc.), Russia, Ukraine, as well as their widespread implementation, demonstrate the high efficiency of the use of electro-technology, their considerable potential, including in the manufacture, restoration and repair of agricultural machinery and electrical equipment for it. Increased interest in electro-technology in these countries is confirmed by an increase in annual investments, for example in the USA, from $ 8 to $ 35 million, an increase in the number of electro-technical installations, for example in Japan by 43% (Borodin, 1986; Inozemtsev *et al.* 2016; Voloshyn, 2015; Radko, 2013).

According to the calculations of some of the leading companies in the field of electrical technology, in many cases, their implementation is much cheaper than the classic ones. For example, the electrostatic method of coating production including (powder, liquid paints), and the method of electro-deposition by volume of sales in various industries is about 82 - 85% of the volume of production of all coatings. Today, it can be argued that, in some cases, due to the increasing modern requirements for product quality and technical and economic indicators, electrical technologies, in general, cannot be replaced by other technologies, such as in the areas of economical use of fuel and energy resources, energy costs, the creation of clean technologies and environment protection, etc. (Inozemtsev *et al.* 2010).

FORMULATION OF THE PROBLEM. THE GOAL

The purpose of the study is to analyze and develop modern electrical technologies for the manufacture, restoration and repair of agricultural machinery and electrical equipment and to develop proposals for their use in agricultural production.

THE MAIN MATERIAL PRESENTATION.

Electro-technology is a technology that is based on the application of electro-physical processes to obtain the final products, that is, on the direct action on the object of various forms of electricity. In such technologies, different forms of electrical energy in the processing are used, such as direct and alternating current energy, electromagnetic field energy, and so on.

Such technologies, first of all, include: the use of ultrasonic vibrations for cleaning, washing and disinfection; for mechanical processing of structural materials; application of electrostatic method of production of coatings on surfaces and objects of different configuration; technologies of welding, heat treatment with the use of electro-contact heating, high-frequency and over high-frequency fields, etc. In the repair of agricultural machinery and electrical equipment, control methods are also used in testing processes based on electromechanical, acoustic, optical, and other measurement principles.

The use of ultrasound for cleaning allows us to accelerate the process by 3…15 times while reducing the cost of chemicals more than 1.5…2 times. This treatment not only accelerates the removal of dirt with high productivity and quality, but also solves environmental problems by replacing the use of different solvents. Numerical studies show that the optimal frequency range for cleaning ranges from 16…60 kHz at an intensity of 0.5…5 W/cm^2 (Inozemtsev *et al.* 2010; Bergman, 1956; Inozemtsev, 2006).

Cleaning of parts of tractors, cars, agricultural machines by ultrasonic treatment 3… 4 times reduces processing time. Thus, cleaning of engine parts and transmissions under normal methods is carried out for 8… 15 minutes, with ultrasound for 3… 5 minutes.

For high-quality cleaning of dirt, grease in the conditions of small agricultural enterprises and workshops it is possible to use ultrasonic small-size installations of the UM-60-0,2 type. This unit has an output power of 60 W, an operating frequency of 25 kHz, a radiation intensity of 5 W / cm^2. And when cleaning large parts, it is proposed to use ultrasonic modular units of UZUM type with the power 130, 250 and 400 watts. The technical characteristics are given in Table 1.

Table 1. Technical characteristics of ultrasonic cleaners

Parameter	Type of unit		
	UZU-0,1	UZU-0,25	UZU-0,4
P_{in}, kW	0,1	0,25	0,4
P_{out} , kW	18	18	18
$P_{cons.}$, kW	0,15	0,4	1,0
$V_{res.}$, dm^3	1,0	5	5
Type of converter	piezoelectr.	piezoelectr.	piezoelectr.

The most common are 2 methods of ultrasonic cleaning: contact and immersion in detergent solution. The contact method is used to clean the inner cavities of thin-walled parts. The small and large parts are cleaned by the immersion method. Fig. 1 shows an ultrasonic cleaner for cleaning and washing parts.

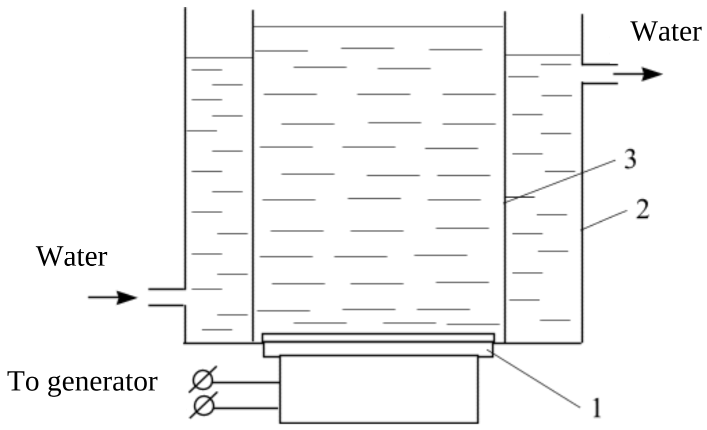

Figure 1. Schematic diagram of an ultrasonic bath for cleaning and washing parts:
1 - ultrasonic converter; 2 - water bath; 3 - bath with working fluid

Cleaning of parts of tractors, cars, agricultural machines by ultrasonic treatment 3… 4 times reduces processing time.

For example, cleaning of engine parts and transmissions under normal methods takes 8… 15 minutes, with ultrasound 3… 5 minutes. During ultrasonic treatment, the parts are immersed in a bath in grids that are lowered directly to the diaphragms of the transducers.

The availability of a wide range of ultrasonic generators, including small-sized generators, enables them to be used for cleaning and degreasing small batches of products, which facilitates the use of such technologies in agricultural and farm environments.

The idea of using ultrasound to clean materials has been successfully implemented in the cleaning of various working, cutting tools (Frelich, 1960). For example, ultrasonic cleaning is very effective in restoring the sanding belt - cleaning it from wood, metal and paint, oiling, etc. The application of such treatment causes the restoration of the sanding belt to 60 ... 70%, that is, promotes secondary use, use in finishing, etc. Such technology can be implemented at any enterprise, including agricultural repair shops. The basic scheme of installation is shown in Fig. 2.

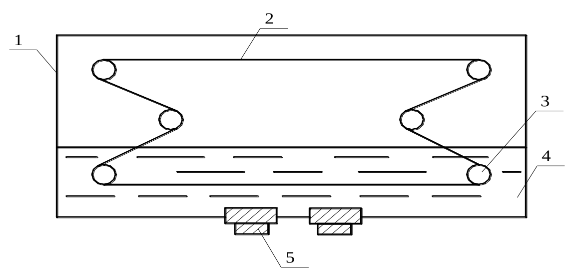

Figure 2. Scheme of installation for restoration of a sanding belt
1 - technological capacity; 2 - sanding tape; 3 - rollers; 4 - working solution; 5 – oscillators

Cleaning the sanding belt can be combined with other operations, such as washing and cleaning small parts, relay contacts, switching devices, brushes of electric machines, and the like.

For cleaning and washing glass and metal containers, such as oil, different installations can be used - rotary, through type, bath, etc. Today such technology is being implemented at a number of enterprises.

It is known that transformer oil is a liquid insulating material that is widely used in electrical appliances. Its most important characteristic is the electrical strength, which is extremely sensitive to moisture and pollution, which contributes to the conditions of electrical breakdown.

In Fig. 3 a schematic diagram of an installation of a quality measurement (electrical strength) of transformer oil is performed. This parameter is one of the most important both in the operation of electrical equipment and in the processes of its repair (Inozemtsev *et al.* 2010; Elperer, 1983; Radko *et al.* 2016).

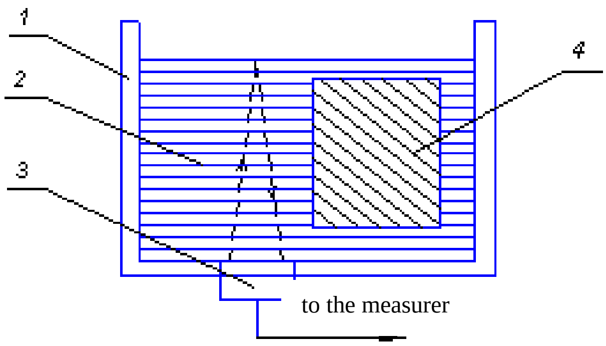

Figure 3. Schematic diagram of rapid analysis of the electrical strength of transformer oil in electrical appliances:
1 - the appliance's body; 2 - transformer oil; 3 - acoustic emitter-receiver; 4 - electric appliance

Speed measurement is carried out by the method of determining the time of passage of the acoustic pulse ($T_{pass.}$) through the transformer oil according to the formula (Popkov, 1971; Inozemtsev *et al.* 1974):

$$T_{pass} = T_1 + T_2 + 0{,}4 \cdot N_P \ , \qquad (1)$$

where T_1, T_2 - delay start scan; N_p is the number of calibration voltage periods.

The speed is determined by the formula:

$$C_x = \frac{L_{AC}}{T_{pass} - T_{AC}} \cdot 10^3 \ , \qquad (2)$$

where L_{AC} is the acoustic base (the distance between the emitter and the receiver); $T_{pass.}$, T_{AC} - respectively the time of passage of the acoustic pulse and the time of acoustic delay.

Fig. 4 shows the dependence of the electrical strength of the transformer oil on the speed of propagation of ultrasound at different humidity and contamination.

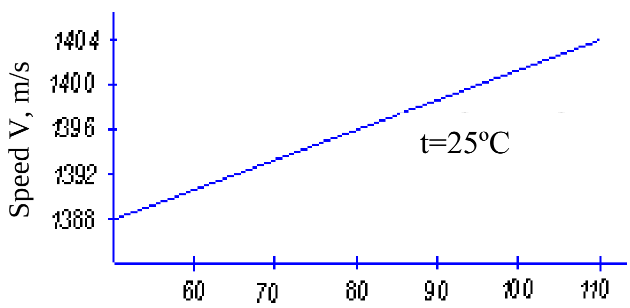

Figure 4. Dependence of the speed of propagation of ultrasonic vibrations on the electrical strength of transformer oil

In the process of repairing agricultural machinery, electro-technology for the purification of technical liquids is used, and, first of all, oils and fuels from ferromagnetic impurities, which are formed by the actuation of interacting parts, etc. For example, in motor and transmission oils, such impurities are 25-35% (Radko *et al.* 2017; Inozemtsev *et al.* 2013).

This technology is carried out with the use of a magnetic field, the effect of which helps to extend the life of the oils by 3 - 5% and to solve the problem of their recovery, the possibility of secondary or repeated use.

The so-called “finishing” operations, especially in the process of repair and restoration of agricultural machinery, play a special role in solving the problems of improving efficiency and resource conservation as well as in the production of protective and decorative coatings, the quality and durability of which greatly affects the increase in terms and conditions of use and reliability of the equipment.

Many years of experience and achievements in the field of electro-technology show that the solution of these issues is achieved through the widespread use of electrostatic dyeing (electro-dyeing), which today is the most advanced method, primarily due to technical and economic indicators.

The widespread use of the electrostatic method, since the second half of the last century, in almost all developed countries of the world, its unsurpassed qualitative and quantitative indicators, led to the possibility of creating highly productive and highly efficient technological processes in various industries, which, above all, provided saving of paint up to 65 - 95%, high quality of coatings (serviceability increases in 1,2 - 1,3 times), possibility of mechanization of labor-intensive processes, improvement of ecological conditions due to reduction of emissions of solvents into the environment. The Table 2 shows the main technical and economic indicators that characterize this method.

Table 2. Technical and economic indicators of the electrostatic method

Functional	Economic	Ergonomic
Physical grounds	Economy of paint, quality of a covering	Increasing environmental performance. Improving working conditions
Specified thickness	Increase productivity	
Process Automation	Reduction of technological process	

Electro-painting equipment, in the first place, high-voltage sources (generators and rectifiers), paint sprays based on the use of centrifugal forces in the electrostatic field, pneumoelectric sprays and paint systems are successfully produced in many countries (USA, Canada, Japan, Germany, Russia, Belarus, etc.). The Table 3 shows the technical characteristics of a number of high-voltage sources used by different companies for electro-dyeing. This equipment is used not only to equip high-performance automated and robotic lines of electro-dyeing, but also with success in the electro-dyeing of small batches of products in the conditions of small

Table 3. Technical characteristics of high-voltage sources

Type of the source	U_{max}, kV	I_{load}, μA	U_{in}, V
Cascade	85	150 – 250	220 – 240
Classic	100	150 – 250	220 – 240
LEPS	140	150 – 250	220 – 240
Micropack	100	–	220 – 240

Table 4. Specifications of electro sprayer

Technical characteristics	Units of measurement	NO-2-701
Input voltage	V	110/220
Power Output	kW	0,1
Output voltage	kV	90
Loss of paint	%	<1-2
Max performance	ml / min	<200
Weight (sprayer)	kg	1,25
Type of high voltage source		RGV-90

farms in the form of mobile small-sized installations or directly in the form of manual electro-dye sprayers (Table 4). Despite their considerable diversity, the electrical dyeing equipment of these countries has no significant differences, except for the structural ones, which is related to the applications (Radko, 2017).

Electro-technology of coatings of metal constructions of 35 - 110 kV transmission lines is one of the most promising and effective solutions to the problem of corrosion control, which affects the durability, mechanical stability, duration of operation of the supports.

The nature of operation, especially of electrical networks of agricultural purpose (considerable time of their work - 30 - 40 years, uneven loading, application for repair of separate units and elements of supports of imperfect and inefficient methods, etc.) contributes to their damage, and in the first place, due to corrosion action, all of which requires the replacement or restoration of individual units directly in place, ie in the field. The current state of such networks shows that the annual need for reconstruction works only for 35 - 110 kV transmission lines is 110 - 150 supports (without taking into account individual elements), each of which constitutes 130 - 250 m^2 of the metal surface depending on the class of voltage and type of supports.

One of the advantages of the electrostatic method that solves the problem above is its versatility, which is especially important for solving problems related to the restoration of coatings during the reconstruction and repair of metal supports directly in the field.

A serious positive effect of the electrostatic method is that it not only reduces losses of paints and varnishes (by 1,5 - 1,75 times), but also promotes increase of operational stability of a covering (in 1,2 - 1,5 times), improvement of ecological conditions and reduction of technological cycle of production of coatings.

Figures 5 and 6 show the dependences of the change in the service stability (adhesion) of the coating, depending on the modes (high voltage, inter-electrode distance) and method of application (Kozyrsky, 2015).

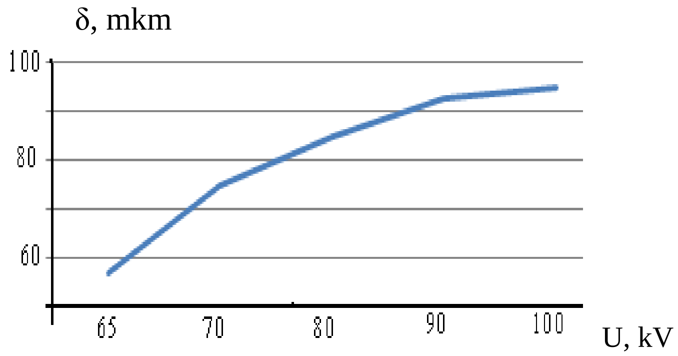

Figure 5. Dependence of coating thickness on high voltage

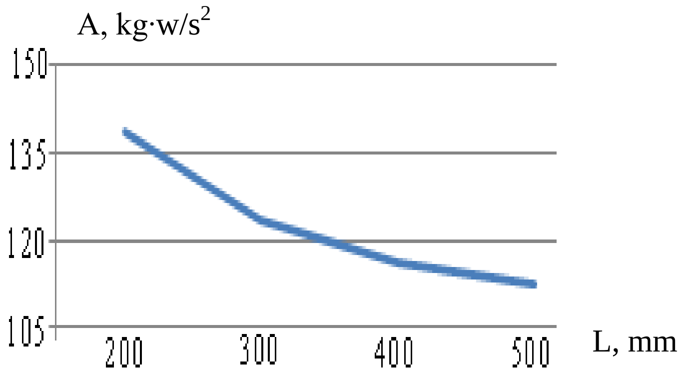

Figure 6. The dependence of the adhesion resistance of the coating on the inter-electrode distance

It should be emphasized that the use of manual and mobile electro-dyeing installations, which prove their economic and technological feasibility especially in the field, is especially effective. Field tests show that with the volume of repair work (10 - 12 supports per month) it is possible to save 170 - 210 kg of paint (organo-silicon OS, pentaphtale PF), to reduce the number of repair and restoration works by increasing the service life of such coatings, reducing the corrosive effect on elements of structures and their fastening (1,2 - 1,5 times) (Inozemtsev *et al.* 2009; Okushko *et al.* 2018).

One of the most effective methods of electro-technology for the production of coatings in order to create high quality protective and decorative coatings is to use an electrostatic field with the use of powder paints. Not only is this technology economically pure and waste-free, it also has several advantages over the use of liquid paint materials. First of all, minimal losses of powder paints (3 - 5%), savings on the cost of solvents, the possibility of obtaining thick single-layer coatings (instead of multilayers in the case of the use of liquid paints), increased durability of coatings, etc.

Today, this technology is widely used in practically every developed country in the various industries for painting metal products, wood (mechanical engineering, construction and agricultural machinery, aviation and shipbuilding, various parts and components for tractor and household appliances, etc.).

The painting equipment involves the use of various powder paints, first of all, thermoplastic and thermosetting based on polyvinyl butyryl, polystyrene, epoxy, polyester resins, polyurethane and the like. The Table 5 shows the Start sprayer specifications.

Table 5. Specifications of Start sprayers

Parameter	Start 50	Start 50-1	Start 50 vibro
Supply voltage (V / Hz)	220/50	220/50	220/50
Corona Electrode Voltage (kV)	60	60	60
Power Consumption (W)	2	2	
Short-circuit current (mA)	100	100	100
Compressed air pressure (MPa)	0,02-0,1	0,15-0,20	0,02-0,2
Painting speed (m^2 / min)	1,2	1,2	3,0

A special place, especially in the processes of application of water-dispersed and water-soluble materials is electro-deposition, which is widely implemented in automotive production, mechanical engineering, etc. Electro-deposition is widely used in the processes of obtaining galvanic coatings, corrosion protection, for the restoration of worn-out parts of agricultural machinery and the like. For example, about 75% of all coatings in automotive production are produced today by electro-deposition.

The advantages of dyeing by electro-deposition are:

- high productivity in painting units and components of complex configuration, obtained by welding (arc, point) and which are difficult to access for painting places;
- obtaining the same thickness during painting of the paint film and increasing the corrosion resistance of the treated material;
- high adhesion of the paint film to the metal surface and subsequent layers of paint. Improve product appearance.

Electro-deposition dyeing technology can be referred to as so-called "clean technology" due to the fact that it: provides protection against corrosion at the minimum consumption of paint and varnish material per unit of surface to be painted and has a minimal amount of waste; provides minimal evaporation of volatile components during drying due to the minimum thickness of the paint film.

These advantages are reflected in operating costs, which are sometimes lower than the costs of powder coating (for example, the thickness of the paint film during electro-deposition is 15… 30 μm, and for powder coating 50… 70 μm, with the same corrosion resistance) (Inozemtsev *et al.* 2009; Okushko *et al.* 2018).

The disadvantages of the method include the need for large production areas and higher than other methods of capital costs for equipment.

This method is effectively used to obtain primer layers overlapping with other coating layers, as well as to apply single-layer protective and decorative coatings with minimal loss of paint and varnish materials.

Gas-plasma spraying is a method that can be used to repair parts, such as pumping equipment, covers and shafts of electric motors, as well as various non-standard equipment in the conditions of repairing agricultural workshops. With this method, durable and corrosion-resistant coatings of iron, nickel, copper, aluminum, zinc alloys, conductive, insulating coatings and the like are obtained.

Certainly the given directions of application of electro-technologies do not comprise all possibilities at repair and production of agricultural machinery, electrical equipment, demonstrate expediency and efficiency of application, cause increase of qualitative-quantitative indicators and increase of labor productivity.

CONCLUSIONS

1. Practical implementation of the above-mentioned electro-technology in the conditions of agriculture can help to improve the quality of repair and renewal works of electrical equipment and to solve energy-saving issues, as well as to increase the qualitative-quantitative characteristics and increase labor productivity.
2. The availability of the above technologies and modern facilities of the so-called "small mechanization" gives every reason for their implementation, which will help to increase the profitability and competitiveness of agricultural products.

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RESEARCH OF REAL INDICATORS OF LED LAMPS, REPRESENTED IN THE MARKET OF LVIV REGION IN THE SECOND HALF OF 2018

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Abstract. Electricity production in the state in 2017 decreasedby 10.2% compared to the previous year by 163.3 billion kWh . At the same time, the saving of electric energy is of interest not only to the state and business owners, but also to the representatives of ordinary house holds.

Every year the issue of energy saving and energy efficiency is becoming more and more relevant. There are a number of reasons for this, among which one can distinguish:

- short age of energy resources in Ukraine;
- reduction of natural resources;
- rising prices for energy imports;
- annual increase in electricity consumption.

Nuclear power plants, which today produce almost 60%, in 2017 reduced electricity productionby 0.9% compared to the previous year to 87.6 billion kilowatt-hours.

So the problem of energy conservation has a global scale. Upto 20% of the total electricity consumption in the industry falls on electric lighting. One of the ways to increase energy efficiency is to modernize the lighting.

A few years ago, the introduction of LED-type lamps was too expensive, so it's not effective. There fore, we decided to experiment experimentally with the introduction of different types of lamps, and to compare their economic expediency in time. But the situation in the marketis changing, the cost of LEDs is reduced, as well as their electricity consumption.

Keywords: LED lamps, economy lamps, energy saving lamps, LED lamps composition.

THE FORMULATION OF THE PROBLEM

The problem of energy conservation has a global scale. Up to 20% of the total electricity consumption in the industry falls on electric lighting. One of the ways to increase energy efficiency is to modernize the lighting.

Our experiments indicate that many LEDs are poorly-matched, but not always consistent with the characteristics of manufacturers.

ANALYSIS OF THE LAST RESEARCHES AND PUBLICATIONS

Having analyzed the available modern light sources, the main generalized characteristics of light sources.

After analyzing the above information and taking into account the problems of energy saving, it can be argued that one of the effective ways to reduce consumption (EC) for lighting is the replacement of incandescent lamps (IL) for compact fluorescent lamps (CFLs), whose light output is 4-5 times higher than in LR (Hoshko, 2014; Goshko *et al.* 2015a; Goshko *et al.* 2015b) , and light-emitting diode (LED) lamps with light output of 5-8 times higher than LR, both in the illumination of the production complex, (Goshko, 2015; Goshko, 2016; Goshko *et al.* 2016) and in the housing and communal services. Street lighting is considered more economically - advantageous when using sodium lamps of high pressure with light output of 100 - 130 lm / W. (Hoshko, 2017).

FORMULATION OF THE PROBLEM

The purpose of the study is to investigate the influence of design and LED lamps manufacturing technologyon their lighting characteristics.

MAIN MATERIAL

When choosing LED lamps before we bought them, we were only observing one parameter, all LEDs should have only one power, and for a more illustrative example, they would purchase for their experiments about 10 pieces in a different price category.

Actually all parameters were respected. The largest selection of available lamp bulbs E-27 was 10 Watts of all brands.

After completing the research on each of the representatives of our lamps formed dependencies of various parameters to better compare them among themselves.

The total volt-ampere characteristic is given in Figure 1.

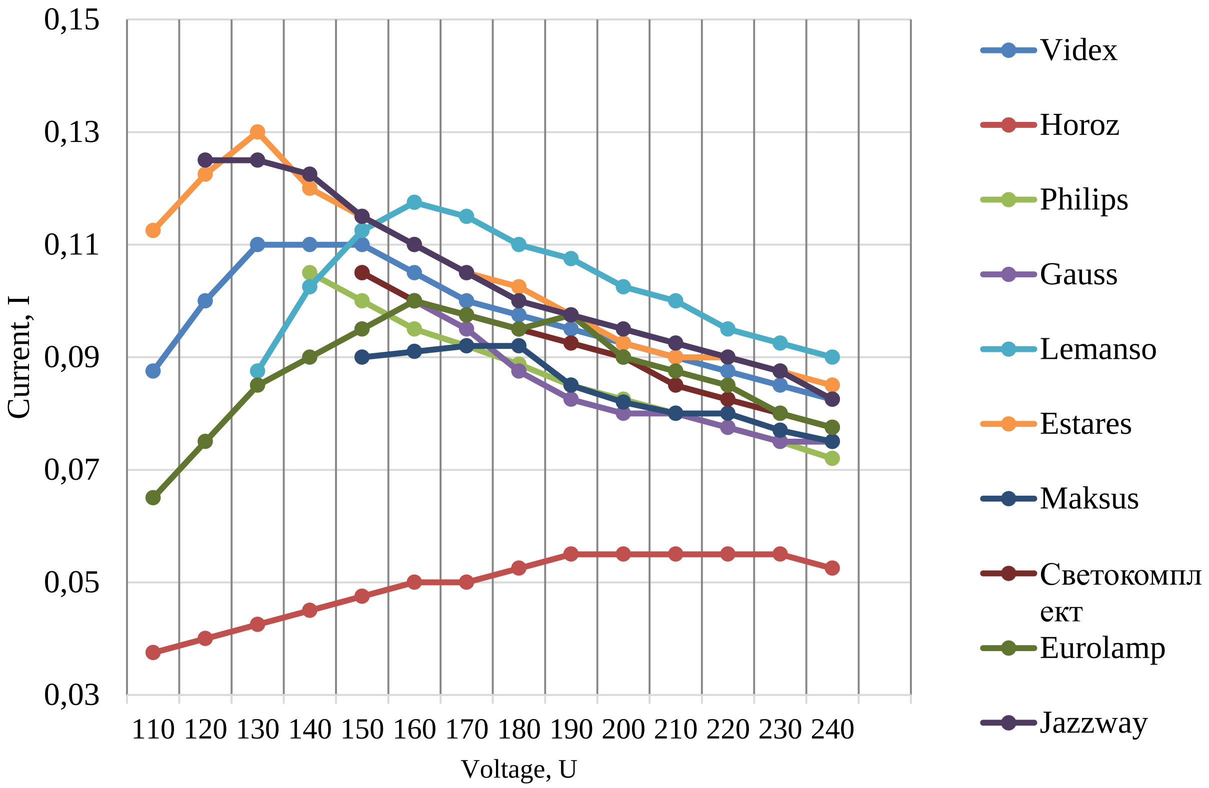

Figure 1. Voltage and ampere characteristics

With the help of this dependence, we observe the volt-ampere characteristic and using the data given on it, we calculate the total power and on this graph it is clearly stated which bulb consumes more and which is smaller.

Horoz - produces the smallest currents, therefore it is the most economical in terms of consumption, at 220V, only 0,055A. Lamps that are left at times worse, Gauss and Eurolamp - 0.075A, all the subsequent in geometric progression increase, Lemanso brand has the largest consumption - 0.095A.

According to preliminary data, a diagram graphically depicting the dependence of the light flux on the voltage in Figure 2 was constructed.

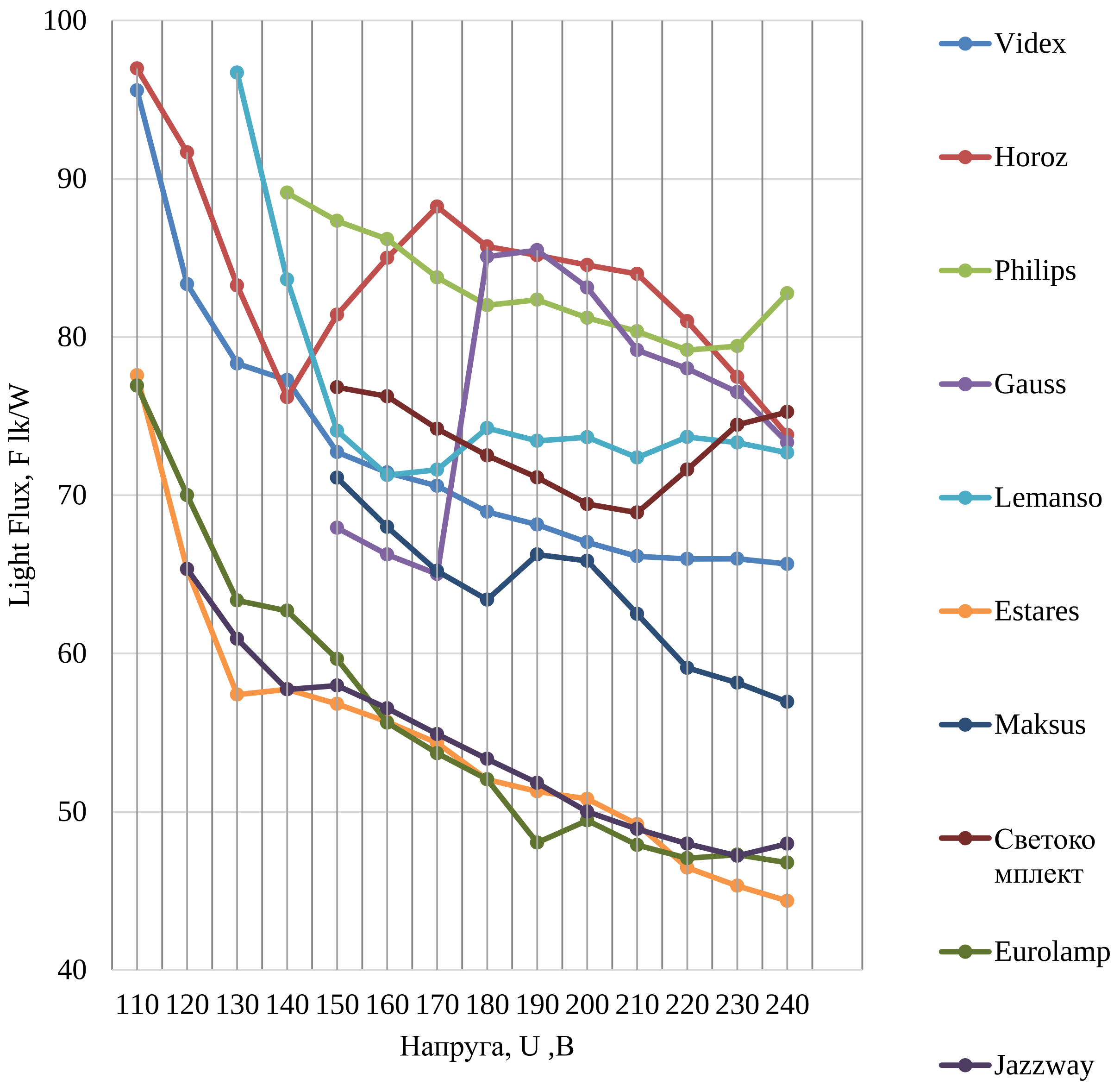

Figure 2. Dependence of the light fluxon voltage

The larger and more stable the light flux, the more efficient and stable the light level and the more energy-efficient light bulb, that is, if the light flux is bigger, it means that the greater amount of energy it consumes turns into light, if it is smaller, then in another kind of energy, heating for example . In this graph, the difference between the various representatives is clearly marked, this behavior is due to different designs of the SPF.

We group them by behavior.

Representatives of Eurolamp, Jazzway and Estares have similar characteristics, since the launch it slows down, starting at 77 lk / w and completing its slump in operating voltage in the range of 45-47 p / w. Videx has shown a similar behavior, but in the other range - from the start of 96 lk / w and up to a working voltage of 65.9 psi / w.

The next comparison is the dependence of lighting on voltage, Figure 3.

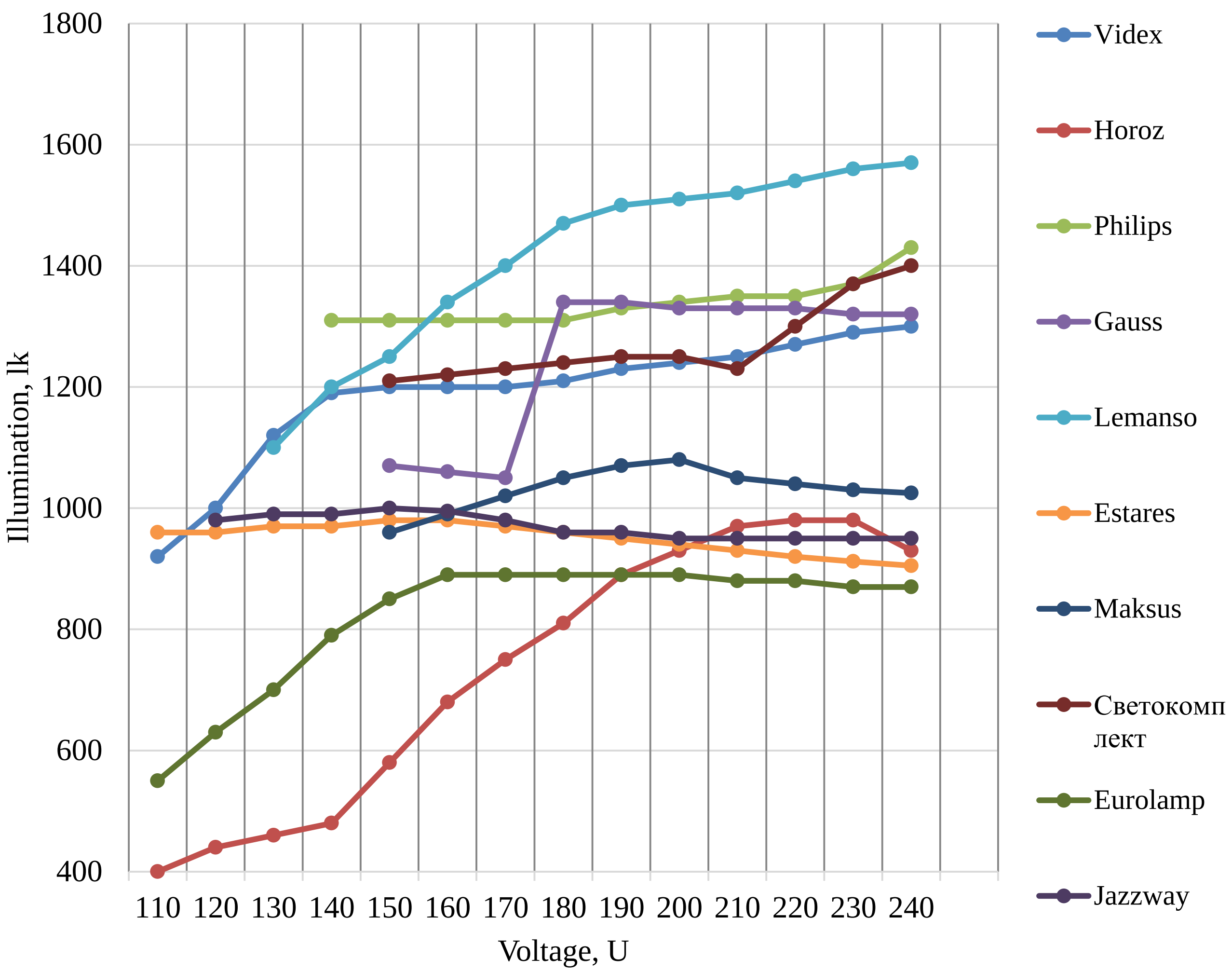

Figure 3. Dependence of the illumination on voltage

In the working range of 210-230 B practically all showed a stable level of illumination. Only representative Svetkomplekt demonstrated a jump of illumination in 170 ps in the range of 110-130 V, at 220V-1300 pp. Because of this behavior, the fatigue of the eyes during work will increase, there will be discomfort. Lemanso has the largest illumination of 1540 pages, Philips 1350 lk has a fairly good light and stable operation at Gauss's low voltage of 1330 lk at working voltage, but with the output of stable illumination of 180V, not from the moment of ignition. Videx 1270 lk, has a smooth rise in illumination from the moment of launch and in a small range. Maxus in the range of 1040 lk, stable.

Horoz is a dim light bulb that meets the declared lightness and smoothly raises it from start to nominal voltage, with a stable working range of 980lk, Jazzway and Estares have similar behavior since the launch of 960-980 pages and at working voltage 913-94 0lk, which is also a very good result. The Eurolamp is the worst of these representatives, with a total of 870 pages in the operating range, has a smooth start-up illumination of 630 pages.

It is very important that the light does not overheat, since, as it is warmer, the more energy will go to its heating.

Their behavior is depicted in Figure 4.

The next paraname for comparison is cosμ, the greater its value, the greater the efficiency of its operation.

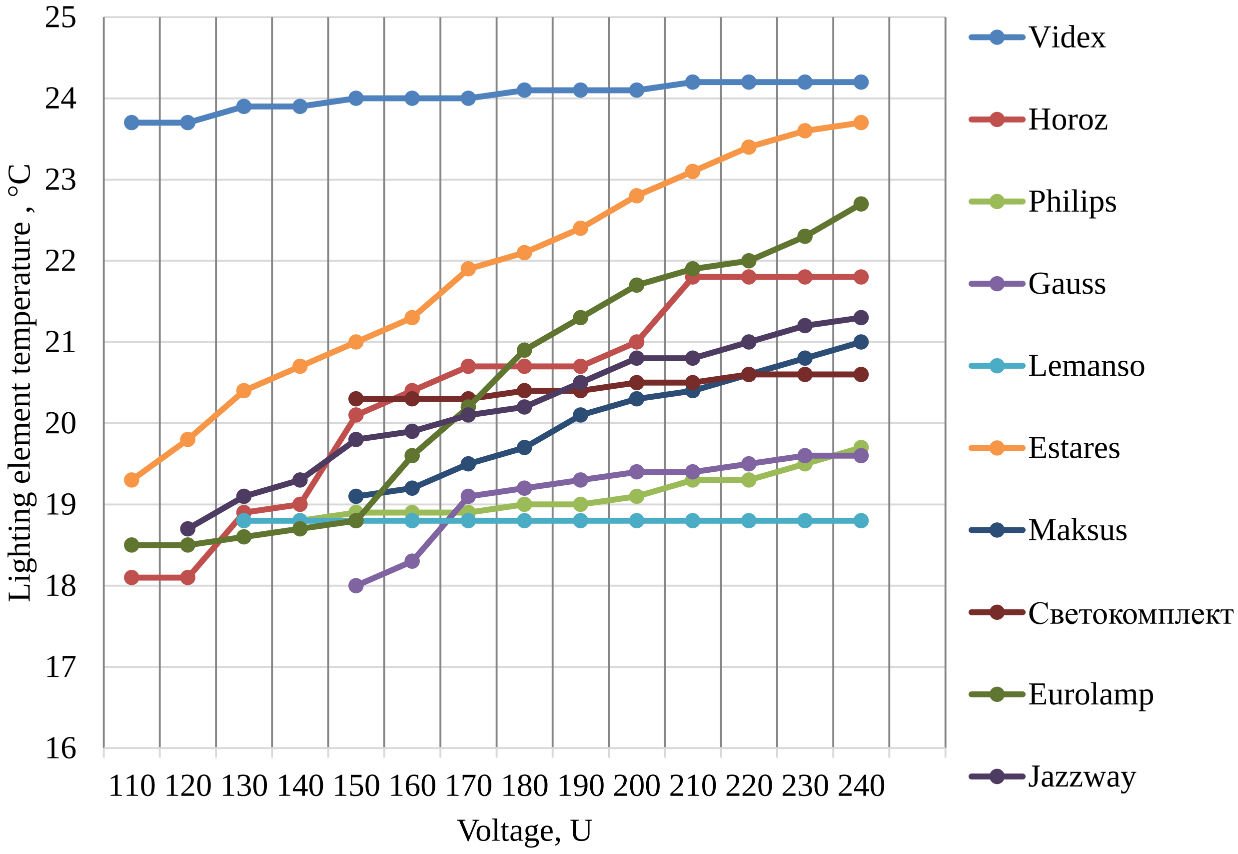

Figure 4. Dependence of the temperature on voltage

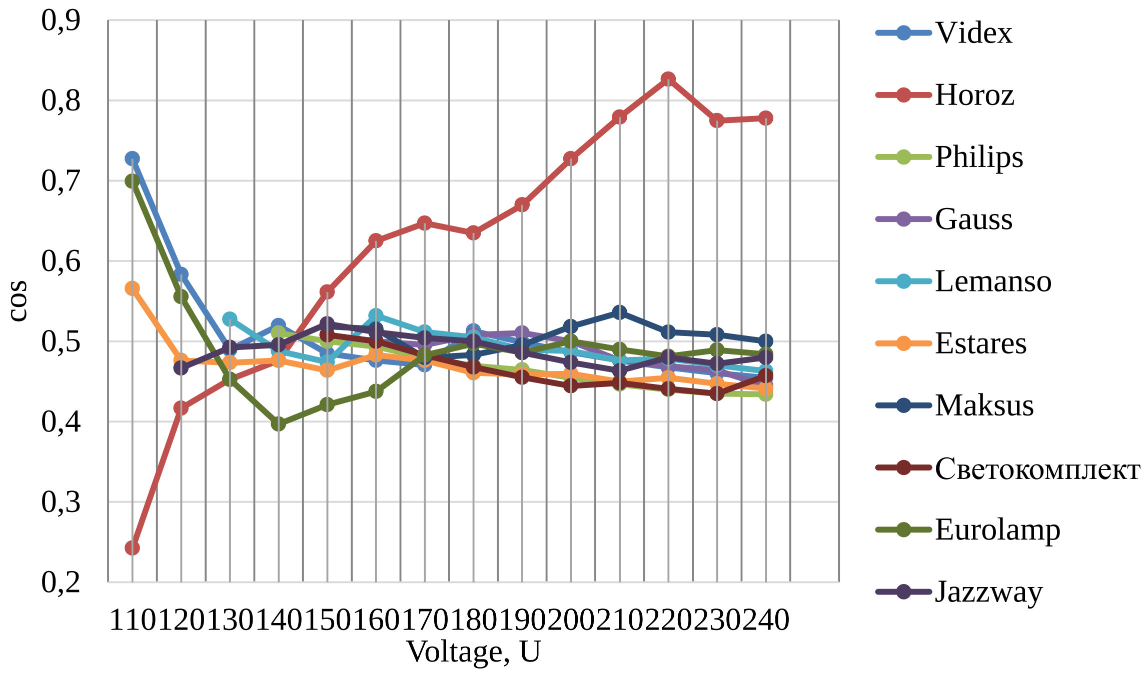

Figure 5. The dependence of $\cos_{\varphi}$ on voltage

The cosine φ was determined to understand the impact on the network, if more than 1 is near, the reactive component gets less effect, and vice versa. Horoz was the best reported with the highest data of 0.82, the following are much worse, Maxus - 0.5, Lemanso, Jazzway, Eurolamp - 0.47, Gauss, Videx - 0.47, Estares - 0.44, Svetkomplekt and Philips complete with the worst performance in 0.43

CONCLUSIONS

1. The larger and more stable the light flux, the more efficient and stable is the level of illumination and the more energy-efficient light bulb, that is, if the light flux is bigger, it means that the greater amount of energy it consumes turns into light, if less, then into another kind of energy, heating for example. Representatives of Eurolamp, Jazzway and Estares have similar characteristics, since the launch, it smoothly decreases, starting at 77 l / w and completing its decline in operating voltage in the range of 45-47 lm / W. Videx has shown a similar behavior, but in another range - starting at 96 lm / W and up to operating voltage of 65.9 l / w.

2. In the operating range of 210-230 V practically all showed a stable level of illumination. Only representative Svetkomplekt demonstrated a jump of illumination in 170 ps in the range of 110-130 V, at 220V-1300 pp. Because of this behavior, the fatigue of the eyes during work will increase, there will be discomfort. Lemanso has the largest illumination of 1540 pages, Philips 1350 lk has a fairly good light and stable operation at Gauss's low voltage of 1330 lk at working voltage, but with the output of stable illumination of 180V, not from the moment of ignition. Videx 1270 lk, has a smooth rise in illumination from the moment of launch and in a small range. Maxus in the range of 1040 lk, stable.

3. Horoz is a dimerlamp that corresponds to the declared light and smoothly raises it from the moment it starts and to the nominal voltage, in the working range is stable - 980lk, Jazzway and Estares have similar behavior since the start of 960-980 pages and at working voltage 913-94 0lk, which is also a very good result. The Eurolamp is the worst of these representatives, with a total of 870 pages in the operating range, has a smooth start-up illumination of 630 pages.

4. A cosine φ was determined to understand the effect on the network, if more than 1 is closer, the reactive component gets less effect, and vice versa. Horoz was the best reported with the highest data of 0.82, the following are much worse, Maxus - 0.5, Lemanso, Jazzway, Eurolamp - 0.47, Gauss, Videx - 0.47, Estares - 0.44, Svetkomplekt and Philips complete with the worst performance in 0.43

5. In the above experiments, it is clearly demonstrated how manufacturers establish low-quality FDIs or light-colored elements, which, in their turn, give away the characteristics that are presented by manufacturers. Only 1 in 10 lamps chosen by us, is approximately equivalent to the given parameters.

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