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TECHNOLOGICZNE, TECHNICZNE I STRATEGICZNE INNOWACJE W RATOWNICTWIE

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USE OF THE CAVITATION EFFECT IN RESCUE OPERATIONS

Introduction

Technological development of the production process often combines the use of the latest samples of chemical or radioactive substances. Consequently, the probability of crimes related to the use of these compounds has been increasing over the past years. At the same time, since the beginning of the full-scale aggression of Russia, the risk of using chemical weapons by the terrorist country keeps increasing every day. Understanding this and having international experience, we cannot ignore this problem.

Decontamination of victims, especially in mass casualties, is an essential and complicated problem, as it has been shown by the example of the use of sarin nerve gas by terrorists in the Tokyo subway in 1995. Due to a large number of injured people and the lack of equipment for immediate decontamination and protective devices, secondary contamination of medical aid workers was only possible as a result.

Another well-known incident occurred in 2000 in the hospital of Frankston, Australia, when, due to the hospitalization of a victim contaminated with chemical substances, the staff of the emergency department was re-infected and the work of the emergency department was suspended for more than 20 hours. The main reason for this was the failure to decontaminate the victim on time.

The threat to radiation and chemical safety of our country may occur not only as a result of the use of chemical or radioactive weapons. The main factors of chemical hazard in Ukraine include the existence of more than 1.4 thousand facilities where high-risk chemicals are kept or used in industrial activities.

These include facilities for the production of explosives and the disposal of unserviceable ammunition, large-scale production of inorganic materials, oil and gas refineries, facilities for the production of organic synthesis products, facilities that use or preserve chlorine and ammonia, storages with large stocks of agrochemicals, ammonia and ethylene pipelines, etc. Most of these objects are now located in the occupied territories.

Special purification is a complex of organizational and technical measures, which consists of activities strictly regulated in place and time. The main types of special treatment include degassing, neutralization, disinfection, decontamination and sanitary treatment. On the other hand, the treatment process at pre-hospital stage is carried out by units of the emergency rescue service of SES, in accordance with internal legislative documents. For the elimination of emergency situations related to the radiation and chemical hazard, units of the Operational and Rescue Service of Civil Protection are equipped with special treatment machines. This group of special equipment includes disinfection-shower units and automobile filling stations.

Figure 1. SES vehicles provided for sanitary work

Source: M. Sychevskyi, A. Renkas, *Engineering and rescue equipment*, Lviv State University of Life Safety, Lviv 2011.

Full hygiene consists of washing the body with warm water and soap with a mandatory change of underwear and clothing. This should be done directly after leaving the contaminated area. In the case of a massive arrival of contaminated victims, additionally deployed are decontamination systems. However, it should be noted that the escalation and full implementation of the sanitation process with special vehicles requires time, which, as practice shows, is not enough on a large scale. In addition, the decision to use the appropriate kind of decontamination system depends on territorial accessibility, cost, number of contaminated victims and mobility needs of this system.

The simplest method is to wash the surface with a weak stream of water simultaneously using a surgical sponge. The water should be warm, since hot water opens the pores of the skin, which promotes the absorption of radioactive substances through the skin, while cold water closes the pores where hazardous substances may remain.

Therefore, summarizing everything noted above, the issue of immediate sanitation or decontamination of victims and rescuers deserves special attention when introducing the latest tactical methods of rescue operations and creating modern fire trucks.

Exploring the use of cavitation for decontamination

Rescuers on fire engines are the first to arrive to handle emergencies. The firefighting equipment, with its tactical and technical capabilities, is not able to prepare water for the sanitary treatment of the victims. Therefore, the improvement of fire-fighting equipment by furnishing it with a water heating system needed for special disinfection of the population at an accident place seems to be an urgent priority that would further expand the capabilities of this type of equipment.

Utilising the heat effect from the cavitation phenomenon that occurs during the operation of the fire pump will allow pre-heated water to be obtained for sanitary washing of people at the emergency site.

Cavitation is the process of breaking the continuity of fluid flow. This phenomenon occurs when the local pressure is reduced to a certain critical point, which is less than the saturated vapour pressure of the fluid being pumped (Psv) at a given temperature.

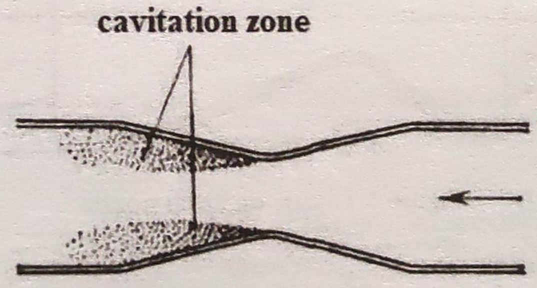

Figure 2. Illustration of the cavitation zone in the nozzle

Source: B. Levytskyi, N. Leshchii., *Hydraulics*, Svit, Lviv 1992.

The process of cavitation is characterised by the appearance of many bubbles filled with liquid vapours, gases, in particular air, which become dissolved in the liquid. As a result of cavitation, the liquid seems to boil, and a huge number of air bubbles (cavities) are formed. When the cavities are flattened, huge energy is released, due to which the liquid is heated.

In addition, energy causes the destruction of the impellers of pumps in case of their incorrect usage. To avoid negative effects of cavitation and enhance the efficiency of heating of the liquid, a special technical component called a cavitator is used. For cavitation to occur, it is necessary to provide a high speed of fluid movement into the cavitator. The pump compresses the liquid upstream of the nozzle, it is channelled into the nozzle bore, which has a much smaller cross-section than the feed pipe, and this ensures a high velocity at the nozzle outlet. Due to the violent expansion of the liquid at the nozzle outlet, there are all reasons for the occurrence of cavitation. This is also facilitated by the friction of liquid against the surface of the nozzle channel and by water vortices created when the water jet is drawn quickly out of the nozzle. With the help of a pump water circulates in a closed circuit, repeatedly going through the cavitator, which leads to heating.

There are two possible designs for such devices: rotor and static. In the first case, as the name indicates, a rotor is used to create cavitation, in the second case, the main element of the device is a nozzle. A rotary heat generator is, in fact, a slightly modified centrifugal pump, where a rotor is set in the working chamber, and acts as an impeller. As it is inappropriate and rather costly to make changes to the fire pump design during an investigation, we considered the second type of heat generator. This type of heat generator is called static, which is due to the absence of rotating parts in the cavitator's structure. To the extent known, different types of nozzle can be used to create cavitation processes. Generally, the de Laval nozzle is taken as a basis and then modified.

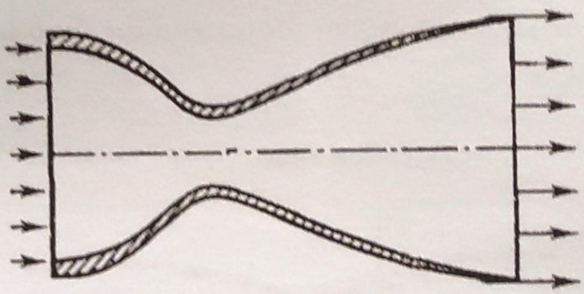

Figure 3. Classic de Laval nozzle

Source: B. Levytskyi, N. Leshchii, op. cit.

One of the key factors is the cross-section of the channel between the diffuser and the confuser. Only when the water leaves the small cross-section hole and enters the expansion chamber, the greatest degree of dilution, and, consequently, more active cavitation can be achieved. Quite often, to provide maximum pressure drop, the diameter of the nozzle is greatly narrowed. In case of a small diameter, the volume of pumped water will be limited. In the next stage, the mixture with cold water will take place, and accordingly, the cavitator will not be able to provide the necessary heat transmission. In addition, the small cross-section of the channel will contribute to the airing of water entering the inlet of the working pump. As a result, the pump will run noisier and cavitation may occur in the pump itself, posing an additional risk to staff.

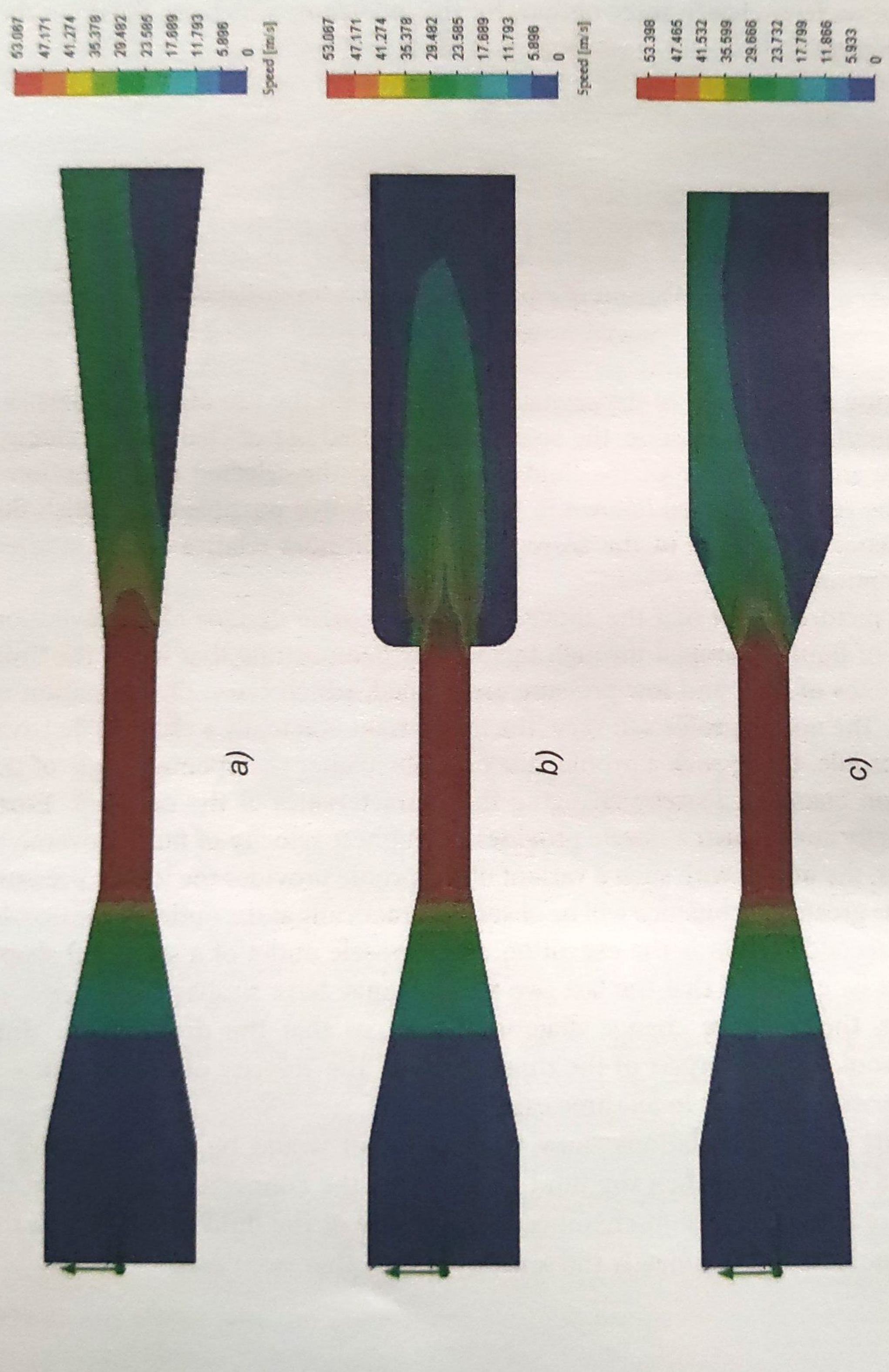

Figure 5. Analysis of the change in fluid flow rate through different nozzle variants

Source: own research.

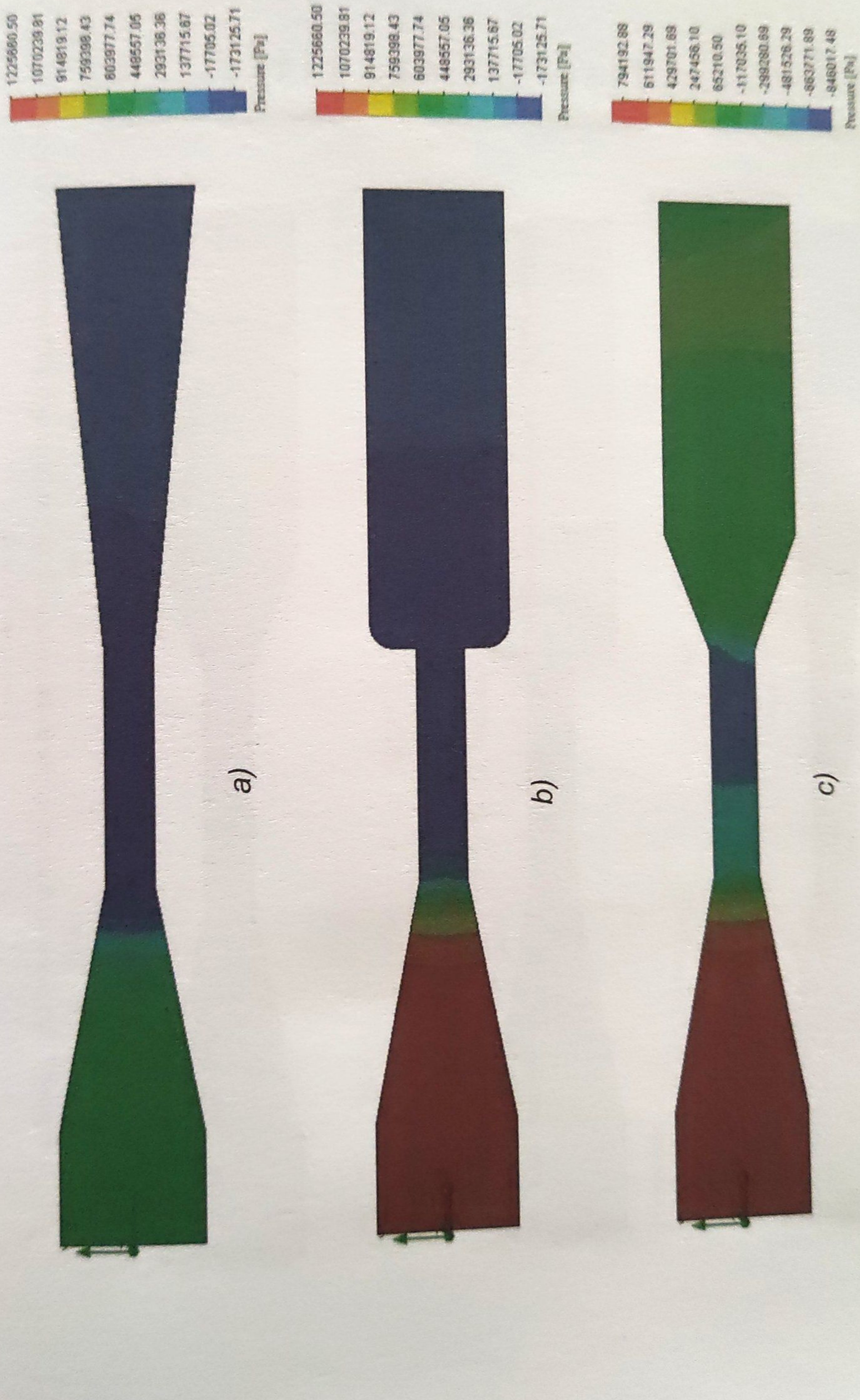

Figure 6. Analysis of fluid flow pressure change through different nozzle variants

Source: own research.

Figure 7. Analysis of changes in the turbulence of fluid flow through different nozzle variants

Source: own research.

Based on the simulation, we have chosen the most effective option of the nozzle, according to which we have calculated the amount of change in water temperature during the passage of one cycle (it is assumed that the water supply pressure is 0.4 MPa, water temperature is 20 °C (293 K), the cavitator model is close to the real size).

Table 1. Results of computer model calculations

Simulation №1 (d=21 mm, T=293,15 K)			
Target name	**Unit of measurement**	**Significance**	**Process execution [%]**
Md Pressure 1	[Pa]	401451,3844	100
Md Temperature 1	[K]	293,2550679	100
Medium Speed 1	[m/s]	12,12703478	100
Minimal Pressure 1	[Pa]	-845575,5646	100
Medium Pressure 2	[Pa]	401451,3844	100
Maximal Pressure 1	[Pa]	1084162,058	100
Minimal Temperature 1	[K]	293,120683	100
Medium Temperature 2	[K]	293,2550679	100
Maximal Temperature 1	[K]	293,4580459	100
Minimal Speed 1	[m/s]	0	100
Medium Speed 2	[m/s]	12,12703478	100
Maximal Speed 1	[m/s]	54,69878132	100

Source: own research.

According to the obtained simulation result, we have measurements of the temperature change of water passing one cycle through a cavitator with a cross-sectional diameter of 21 mm. The change, accordingly, occurs by 0.1 K (at P = 0.4 MPa).

Based on the result obtained, it is theoretically possible to determine the temperature of water heating for a certain time and also to find out the optimal time for getting warm water necessary for the sanitation process.

Conclusions

After analysing the current methods and means of decontamination and sanitisation, it can be concluded that the main problem is that it takes too long for the equipment to reach its destination. At the same time, the operational units that arrive first at the place of emergency do not have special devices for its implementation. Therefore, the urgent task is to equip operational units with special technical facilities for water heating.

Stationary heating appliances are unable to perform the assigned tasks, so during the research, we have focused on expanding the functionality of the existing equipment. One of the ways is the possibility of using such a phenomenon as "cavitation" to heat water.

With the help of a simulation, we have obtained and investigated the main characteristics of the outlet nozzle, which would provide optimal results without causing harm to the pump itself. Besides, the obtained basic parameters allow calculating the rate of water heating or the time required to reach the appropriate temperature. The experimental results allowed establishing the dependence between the amount of water heating on the ambient temperature and the pressure created by the pump.

Based on all the above presented facts, we may presume that the method of heating water we have proposed is an effective way to improve the basic methods of decontamination of victims. This problem is of particular importance at the present time when military actions are taking place on the territory of our country, which creates an additional danger of poisoning of ordinary citizens with hazardous chemicals.

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