# Minefield Clearing by Explosion of Fuel-Air Cloud Created in Exhaust Stream of Armoured Vehicle

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## 1 Introduction

Different local wars appear in the world regularly. As a rule, they are accompanied by wide application of anti-tank and anti-personnel mines. Due to the relative cheapness of the mines, the scale of their application increases. The civil population becomes the main victim of mine weapon. A majority of them consists of women and children. According to UNO statistics, 110 million mines are set on the territory of 65 countries. Up to 10 thousand men perish on the abandoned minefields annually and twice more of the people get heavy injury. Considerable losses are done because of the vast plots of land do not use in agricultural production also.

The active use of mines during the battle actions is explained via few reasons. The main one is simplicity of the device and their application allowing to use it by a low-qualified personnel, cheapness of production making possible to acquire large parties of mines by price which is accessible even to terrorist organizations. Some types of anti-personnel mines cost three USA dollars presently and the anti-tank ones cost 75 US$. The cost of destroying of a mine is more than 300 US$. According to UNO data, expense on the demining of 1 $m^2$ exceed 0.6 US$ by productivity of the field engineer equalled from 10 to 20 $m^2$ per a day. It is an explanation of the low rate of the demining works in world. Therefore, the amount of the deposited mines exceeds the number of annihilated ones. 2÷5 million mines are annually set and a 100 thousand ones are extracted only. As a result, the common amount of the non-destroyed mines grew up to 130 million in world, and 33 billion dollars are required to neutralize it.

The simple, high-productivity and relatively safe clearing method of the pressure-sensitive minefield by volume explosive is presented in the work. The feature of the offered method is an application of exhaust gas stream of heavy armoured vehicle for forming of fuel-air mixture and its spreading over minefield. Research results concern with Former Soviet Union armoured vehicles.

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## 2 Explosive minefield clearing with use of heavy armoured vehicle

It is offered to equip the armoured vehicle by the system of minefield clearing that uses the effect of volume explosion. Essence of the system application is in the following. A vehicle 1 moves across a minefield 2 spraying a detonable liquid in opposite direction of the vehicle motion (fig. 1). Thus, an extensive fuel-air mixture 3 forms behind the vehicle. Fuel injection is carried out in the exhausted gas stream 4 of the one. Due to the preliminary-heated and turbulent gas stream, it improves the fuel evaporation and the fuel-air mixing. As a result, the mixture gets more detonable and the distribution of fuel concentration becomes comparatively equal in the formed cloud. When the mixture is distributed over the area of the minefield, the detonation 5 is initiated. It results in the onset of pressure impulse on this area and, accordingly, explosive mine clearing. The vehicle equips with plows 6 in case of an antitank minefield clearance. The plow knifes extract mines outside of vehicle track only.

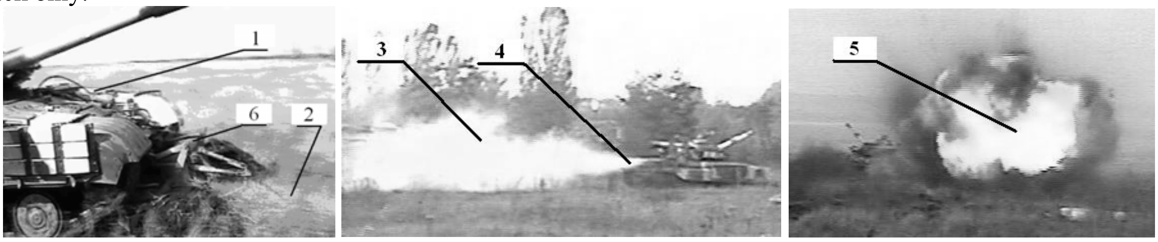


Fig. 1. The method of the minefield clearing.

## 3 Advantages of the heavy armored technique application to clean the minefield by explosion

Fighting purpose of armored vehicles causes presence in its functional constituent of a powerful collective protection system. One of these protection elements is counteraction from shock wave injuring of the vehicles crew, units and assembly’s which are placed in it. This protection is provided by armoring and vehicles hermetic protection. As the result, weakest constructive elements of the some types of heavy armored vehicles can protect from pressure impulse up to 0.5 MPa. There is the second advantage due to the engineering equipment which is intended for overcoming antitank mine fields by armored vehicles, for example, mine trawl KMT-8. Powerful tank’s engines need in intensive cooling which is provided finally due to heat exchange with atmospheric air. Only insignificant air share which passed through a power-plant of the vehicle is used into combustion process. It is necessary to consider, that the diesel working process is realized with air surplus approximately in two times. Therefore, the exhaust gases jet depending from the engine loading contain no less than 80% of unreacted air. Thirdly, there is an opportunity to create a detonation-ability mixture into hot exhaust gases jet of the heavy armored vehicles. Tank’s engines are multifuel, as a rule. It is known, that gasoline’s vapors have high detonation ability [1]. Thus, fourthly, the part of vehicles fuel system could be used in the design of the mine-clearing system.

## 4 Efficiency index of formation of a detonable cloud into gas jet

The principle of minefield-clearing by volumetric explosion is used in the American military mine-clearing systems XM134 SLU-FAE. In the given systems a detonation-ability cloud formation is realized by explosive atomization of the liquid fuel in the environment air. At such way of the mixture formation the main share of the fuel mass concentrates on a thin peripheral layer. As the result, non-uniform distribution of concentration formed in the air-fuel mixture cloud leads to significant pressure impulse decreasing.

The $\eta_f$ index has been entered for an efficiency estimation of detonation-ability cloud formation. It shows a ratio of a fuel weight $m_d$ concentrated in a volume of detonable mixture to a full fuel weight $m_{cl}$ expended on air-fuel cloud formation:

$$\eta_f = (m_d/m_{cl})\cdot 100\%.$$

The given index was calculated for circular nozzle with diameter of 1.4 m. The speed of the air-fuel mixture's outflow was 9.2 m/s from the nozzle. The mathematical model was used to calculate the convection axisymmetric weakly-vortex turbulence jet. The efficiency index was more than 80 % for cloud formation time up to 5 sec. A cloud distribution achieves about 15 m in length over the ground area.

# 5 The numerical simulation's results

It is enough to use the truncated Navier-Stocks equations by means of neglecting of viscous terms (the Eulerian approximation with source terms) for description of two-component gas mixing process [2]. The turbulent diffusion coefficient in the equation for admixture concentration changing was defined in accordance with algebraic model proposed by M.E.Berlyand.

The boundary conditions on the income zone have been assigned on the surface planes of simulation cells, that are in contact with boundaries of simulation regions and through which the atmospheric air is coming. The approach stream on the inlet has been determined by the following values: total enthalpy, entropy function, the direction of stream velocity vector, relative specific mass density of admixture Q ($Q \leq 1$ if the gas admixture is incoming). The law of admixture outcome consumption changes was assigned on the permeable boundaries. In outcome regions the atmospheric pressure was assigned as well. The environment parameters were assigned in all "gaseous" cells of simulation region in the initial moment.

The impermeable boundaries modeled a form of armored vehicle cross-section was set in simulation region. The nozzle was inserted into the impermeable boundaries. The fuel-air mixture outflows from the nozzle. The nozzle had the rectangular form with the sizes 250×1500 $mm^2$. Fuel mass concentration was equaled 10 % in the outputting mixture in the nozzle edge. The concentration did not change during the calculation period. The gases mass consumption was 5.7 kg/sec. A speed of wind was equaled 3 m/s. The simulation's results of mass concentration fields received in vertical and horizontal cross-sections of the jet axis direction are presented for the time moment equaled 15 sec (fig. 2, 3).

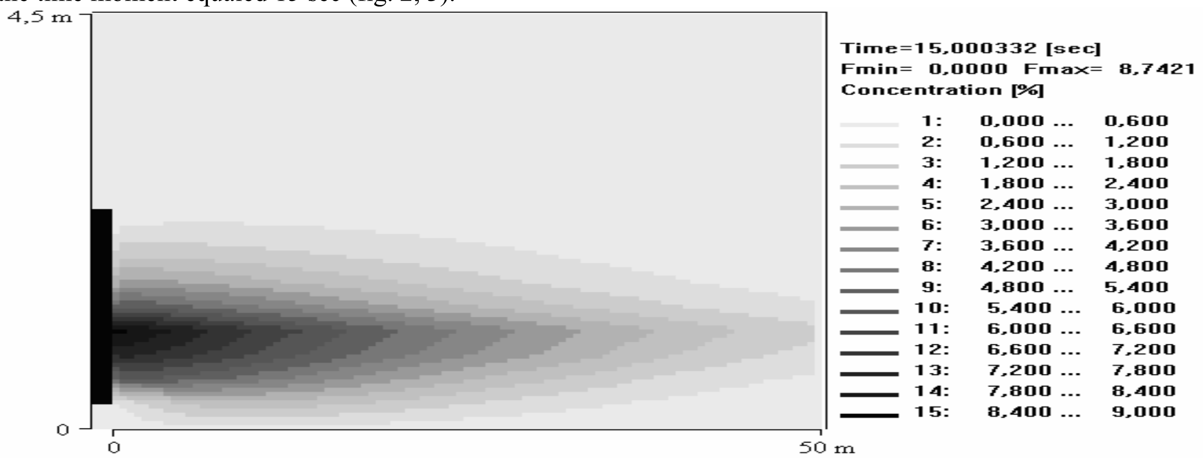


Fig. 2. The mass concentration fields received in vertical cross-sections of the jet axis direction

The calculations and experimental results are satisfactory coincidental. Length of cloud which is able to detonate achieves up to 25 m, if the fuel injection is done on a top limit of detonable concentration into the exhausted jet.

A minimal pressure led to explosion of anti-tank mines can be estimated by a mean maximum pressure of armored vehicle. The means are presented on fig 4. So, a comparison of pressure generated by detonation of hydrocarbon-air with the means shows that the first one is twice over.

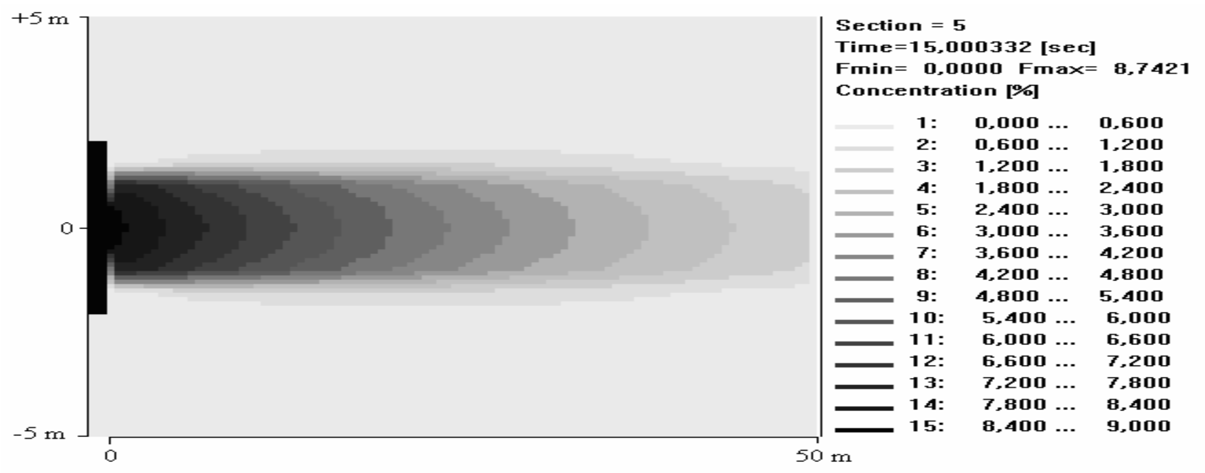


Fig. 3. The mass concentration fields received in horizontal cross-sections of the jet axis direction

Propane-air mixture is able to detonate into unconfined volume by the limits of propane mass concentration from 10.2 to 4.5 %. It is obtained by studying of the concentration field that a detonable cloud forming by propane injection on a top concentration limit extends over 25 m and the cloud diameter equals about 1.5 m. 8.5 kg of propane is spent on the cloud formation in the calculated case. 5.7 kg out of them is concentrated into the cloud. The volume of cloud achieves 44 $m^3$. 267.4 MJ of the chemical energy can be got out of the cloud explosion. This explosion corresponds of an explosion of 63 kg of TNT.

TNT can be used as initiator of the detonation. But the demining method becomes more dangerous in this case. So, a detonation tube supported by electrodynamical accelerator of shock wave is considered as alternative initiator.

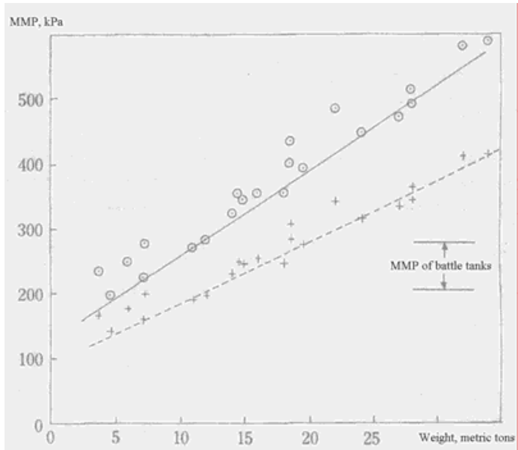


Fig. 4. Mean maximum pressure: solid line corresponds to wheeled vehicles with tires at highway inflection pressure, broken line – at twice highway deflection [3]

## 6 Conclusions

1. Theoretical results confirm possibility to form detonable mixtures in the stream of exhausted gases of armored vehicles.
2. The developed mathematical model allows to take into account influence of weather conditions on the size of detonating cloud.

## References

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