Mathematical modeling of shock waves passing through mesh barriers

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Abstract. Considered the passage of shock waves with drop pressure from 1.513 to 29.0 on obstacles with different coefficients of permeability $K_c = 0.76, 0.3$. A noticeable attenuation of the pressure drop on the shock wave in the range from 1.1 to 1.9 times was obtained.

1. Introduction
The interaction of shock waves (SW) with various technical devices can cause them to break or to exit the operating state. Therefore, the possibility of reducing the pressure drop on the shock wave is of great practical importance. Moving shock waves attenuate in different ways, for example, the creation of the jets on their movements. Another way to reduce the intensity of the shock wave is to create a mesh partition in the way of its movement. When passing through it, the shock wave should weaken. In this paper, using mathematical modeling, we consider such a method of attenuation of the shock wave intensity.

2. Computational model
The propagation of a shock wave through a rectangular channel blocked by a mesh partition is considered. The channel can be schematically accepted as shown in figure 1. Here: $dd$ - through hole, through which the gas has the possibility of free passage, $dc$ - solid impermeable mesh partition surface. The calculated grid is given in the form of identical cells. Considering the gas flow has symmetry about any two lines $OO_1$ and $O_2O_3$. Here: $Cdd_1C_1$ – fragment impermeable to gas mesh partitions; $OO_1O_3C_1d_1dCO_2$ – region in which there is movement of gas, $dd$ – through hole through which gas is free to pass, $dc$ – a solid impervious surface of the partition grid.

Setting the initial conditions in this case is reduced to setting the parameters on the left behind the plane shock wave (ASSB region) and before it the parameters of the undisturbed resting gas.

Boundary conditions consist of:
- fulfillment of the symmetry condition on the lines $OO_1$, $O_3O_2$;
- the conditions of equality to zero flows of all quantities on the boundaries of mesh partitions $(Cdd_1C_1)$ and on the right end of the channel $O1O_2$; - maintain parameters behind the shock wave on the $AB$ line.

During the calculation, weak and strong SW were considered in the range of pressure drop on SW from $1.513/29$ when passing the mesh partition with $K_c = 76\%, 30\%$. The initial shock wave propagates from left to right and is characterized by a dimensionless pressure drop $\Delta P_+=P_s/P_0-1$, and the shock wave that has passed the grid is $P_-= P_{ss1}/P_0-1$. On the walls of the
channel and on the solid boundaries of the grid, the conditions for the absence of flows are set. The grid is characterized by the coefficient of permeability $K_c = S_d / S_c$, where $S_d$, $S_c$ – respectively, the total area of the grid holes and the channel area. The calculations used a system of equations of gas dynamics in the form of Euler, written in a conservative form in the form of conservation laws using traditional designations.

The calculations are based on the difference scheme of the Mac-Cormak [1] and the program used for the calculation of various problems [2, 4].

The characteristic parameters of the problem, which include all dimensional quantities: undisturbed pressure $P_0$, density $\rho_0$, characteristic linear scale $L = 1$ m.

3. Results obtained
On the figure 2-the results of calculations at different times in the form of tonal pressure patterns (color background displays the pressure levels, black lines-lines of constant pressure) and the pressure distribution along the length along the upper boundary of the computational grid (along the line, flow symmetry).

Figure 2 presents the calculation results for the weak SW during its passage through the high permeability grid.

The shock wave that has passed through the grid is clearly visible, having less intensity in relation to the initial shock wave and reflected from the grid, which departs from it by a considerable distance in the opposite direction.
As the initial shock wave amplifies, secondary shock waves are observed in the calculation (they are poorly distinguishable at weak waves), moving in the opposite direction to the flow and carried by it after the last shock wave, that is illustrated in figure 3.

The main difference of the low permeability grid for weak shock waves is the formation of a compression wave of a noticeable length – the result of the interaction of Prandtl-Mayer waves reflected from the upper boundary of the calculated grid with the past shock wave, which is illustrated by figure 4.

![Figure 3](image3.png)

**Figure 3.** A shock wave with pressure of 29.0 when passing the mesh partition with $K_e = 0.76$.

![Figure 4](image4.png)

**Figure 4.** A shock wave with pressure of 1.513 when passing a mesh partition with $K_e = 0.3$.

In the case of amplification of the shock wave, there is a noticeable drop in its intensity behind the mesh partition, which is illustrated by figure 5.
Figure 5. A shock wave with pressure of 29.0, while passing the mesh partition with $K_c = 0.3$.

The presence of one perforated partition on the shock wave path may not lead to the desired result of the shock wave attenuation due to the large integral force loads acting on the grid, leading to its rupture. Therefore, the use of two perforated partitions is of great interest.

Figure 6 shows the results of the calculation of the shock wave propagation with a pressure drop of 29 two grids with permeability coefficients of 30% + 76%. The following symbols are used in the figure:

- the shock wave (SW) that has passed the mesh partition and reflected from it (SR);
- secondary weak shock wave RP;
- extension wave FW.

Figure 6. The passage of the shock wave of two mesh partitions.
Calculations show that the basic laws of the gas-dynamic flow, manifested during the passage of one perforated partition are preserved in the presence of several; the presence before the shock wave 2 partitions of different permeability leads to a greater weakening of the shock wave in the case of a combination of 76% + 30%, than in the case of a combination of 30% ÷ 76%.

Conclusion
The cases of strong and weak shock waves passing through channel blocked by grids with different transparency coefficients are considered.

It was found that the passage of the shock wave of the mesh partition is a noticeable weakening:

• for a shock wave with a mesh permeability Kc =76% and with the pressure equal to 29, decreases by 1.9 times;
• for a shock wave with a mesh permeability Kc =30% and with the pressure equal to 1.513, decreases by 1.1 times.

References
[1] Mac–Cormak R W 1969 The effect of viscosity in hypervelocity impact cratering AIAA Paper 1969-354 pp 69–354
[2] Kirillov I A, Osinina E V, Panasenko A V and Strelkova M V 2005 Modeling of formation of a detonation with use detailed chemical kinetics Mathematical Models and Computer Simulations 17 (11)
[3] Ganiev Y C, Gordeev V P, Krasilnikov A V, Lagutin V I and Panasenko A V 2000 Aerodynamic Drag Reduction by Plasma and Hot-Gas Injection J. of Thermophysics and Heat Transfer 14 (1) pp 10 – 17
[4] Kotov M.A., Kryukov I.A., Ruleva L.B., Solodovnikov S.I., Surzhikov S.T. Multiple Flow Regimes in a Single Hypersonic Shock Tube Experiment AIAA 2014-265 pp 1-22