WEAK SHOCK WAVES ATTENUATION THROUGH GRANULAR FILTERS

G. Ben-Dor, A. Britan, O. Igra, H. Shapiro
Department of Mechanical Engineering, Pearlstone Center for Aeronautical Engineering Studies
Ben-Gurion University of the Negev, Beer-Sheva, Israel.

It is well known that direct exposure to shock or blast wave is harmful and therefore protective measures are needed. As a typical example of such a situation let us view the case when a blast wave, generated by high explosive weapon, hits the ground in the vicinity to a shelter as shown in Fig. 1. The unavoidable ventilation duct offers a way for the blast wave penetration into the shelter. It is a common practice to use a granular filter inside the air intake system to prevent such penetration and to protect expensive chemical filters placed downstream the ventilation duct. While granular filters are widely used as protectors against shock and blast waves, very little information is available about their performance. Among the few available papers in this subject, the most relevant results are related to attenuation of shock waves with a decaying pressure profile through the perforated partitions and grids[1-4]
. Note that the destructive nature of shock/blast waves depends upon pressure signature of the incident shock as well as on the distance between the various obstacles. This makes the problem rather complex[3] . Extensive measurements of the post shock wave overpressure upstream and downstream of various granular flters for shock waves with step-like pressure profiles were performed by Medvedev et al.[5] The experimental results were compared with calculations and good agreement was found between experimental and theoretical findings. Engebretsen et al. [6] also investigated experimentally a similar problem in a shock tube. Typical examples of their pressure profiles, as measured and calculated using Random Choice Method (RCM) are shown in Fig. 2. In these experiments Kistler pressure transducers were placed upstream and downstream of a 220-mm long filter composed of 15-mm diameter glass beads. Note that the first abrupt pressure jump with an overpressure of ΔP2 =0.7 bar (marked by an arrow) corresponds to the arrival of the incident shock wave to the pressure transducer placed upstream of the filter. Thereafter this pressure rises due to the shock wave arrival that was reflected from the filter entrance. While the overpressure ΔP2 serves as an input parameter, the overpressure downstream of the filter is the output parameter for estimating the attenuation performance of the filter. In fact, the pressure profiles show that while the wave prior to the filter is a shock wave, downstream of the filter it is a pressure wave. Here the front is not abrupt and the pressure profile is unsteady. The uncertainties in the interpretation of such signals should be the reason for poor correlation of the experimental and simulated pressure profiles shown in this figure.
Summary of the physical properties of the granular filters used in the experiments of Medvedev et al.[5] and Engebretsen et al.[6] are listed in Table 1. It is apparent from Table 1 that both studies used granular filters in which the length ratio L/d_p and the porosity ε, were varied within similar ranges. Furthermore, both used similar incident shock wave Machnumber M_S. As could be expected the experimental results obtained by these authors, shown in Fig. 3, demonstrate a similar tendency in variations of the exit relative pressure behind the transmitted shock wave $\Delta P_{exit} / P_0$ as function of the filter length (here P_0 is the initial gas pressure inside the shock tube). However, while the results obtained by Medvedev et al.[5] demonstrated strong dependency of the exit relative overpressure on the shock wave Machnumber M_S, those of Engebretsen et al. [6], presented in Fig. 3 by a single dashed line, did not indicate a dependency of $\Delta P_{exit} / P_0$ on M_S . In addition, Engebretsen et al.[6] stated that the effect of changing the material density and the size of the granules on the attenuation phenomenon is negligibly small. Such conclusion casts doubt because the particle size is responsible for the granular filter permeability, which is known to have a direct effect on the shock wave attenuation.

Another feature, which most probably will affect the wave attenuation, is the duct geometry and the particle diameter. For cases were the factor $H/d_p < 20$ (here H is a cross section width of the channel), the side wall friction may strongly effects the flow[7]. As a result one-dimensional presentation of the flow pattern inside a granular filter is questionable. The air gap length downstream of the filter Δ, may also effect the filter performance depending on how the filter is installed inside the duct, close to or far upstream from the protected surface[3]. Since the air gap length used by these authors was sufficiently large, (Δ = 1÷2.8 m) one cannot infer any practical information from their results regarding the role of this air gap in real ventilation systems. Bearing all these in mind, the main goal of the present study is to investigate the dependence of the granular filter performance on the following parameters:

- the filter length - L.
- the length of the air gap downstream of the filter - Δ
- the diameter of the beads composing the filter - d_p
- the density of the beads composing the filter - p_p

During the present study we looked first at the dynamics of the pressure signature upstream, inside and downstream of the filter for different filter lengths and composition. Thereafter, we checked the influence of the air gap length on the obtained pressure signature. Finally, experiments are repeated for the filters that are placed close to the protected surface (no air gap). The knowledge to be obtained from the present study should provide a basis for protection design not only for shelters and other high-priority military and urban assets, but also for combustion suppressors, protective shields for munitions storage facilities [4].