Shock wave passage over porous particle beds.

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Whilst there have been a number of studies in the past of the interaction of a shock wave with multiphase systems, these have largely concentrated on flow through porous media and dusty gases. The studies have predominantly been one-dimensional and have shown some very interesting effects, such as pressure amplification when a compressible porous layer is positioned on a surface. There have been some studies of wave interactions with shallow particle beds and dust layers on a surface, and on the dynamic behavior at the bed interface. The current paper not only examines the surface behavior of the bed using a range of particles, but also the internal bed movement, and how it contributes to the particle lift-off and development of surface waves on the post-shock surface profile.

Most previous studies have been conducted in relatively short shock tube facilities with limited testing times (less than 10ms). The return of the reflected shock and expansion waves from the ends of the tube thus influences the experimentation, since the response times of particle beds are frequently much longer than this. A special shock tube facility has been built for this study. It is over 50 m long thereby enabling test durations of 0.1s, and incorporates a 1m long bed cavity with a movable floor so that different bed depths could be set. Pressure transducers are positioned along the length of the tube and in the floor of the cavity. Particle motion was evaluated using a 1000 frame/s digital camera, and video clips were constructed. Seven different types of particles were studied. Additional studies with a shorter shock tube were also conducted.

The first figure above shows particle trajectories in a small shock tube test. The small spheres (6 mm diameter) used were initially neatly packed. It is noted that particles originally at 20mm depth and near the front of the bed start moving towards the left, whereas particles further down and higher up move in the wind direction. A swirling motion develops at the front of the bed, which is clearly indicated on the video clips. Tests with much larger spheres (20mm diameter) show remarkably uniform lift off along the length of the bed for uniform packing but significantly more particle/particle collisions leading to very irregular flow for more random packing. Particle velocities can reach tens of m/s in the test section but are still accelerating as they move out of the field of view. Some tests were conducted with particles marked so that rotation could be established. Particle collisions are found to be the main factor in determining rotation and thus Magnus forces are in random directions and appear to be of little relevance. However, gas percolation into and out of the bed is important in causing bed fluidisation. This would be particularly relevant for blast propagation from explosions over soil due the change in pressure gradient as the negative phase of blast pressure propagates over a bed initially pressurized by the positive phase.

The second figure above demonstrates the wave that develops at the leading edge of the bed. The dynamics of this behavior show many interesting features and after transit of the wave leave the bed with an undulating surface. An increase in particle density steepens the trajectory of the wave that forms. Also randomly layered particles result in a flatter trajectory than for neatly ordered beds.