Summary

Shock waves are quite common phenomena during volcanic eruptions and they can be able to damage structures hundreds of km from their source (Hoblitt et al., 1987).
To date they have been poorly investigated and therefore the associated hazard is downplayed in active volcanic areas.
This project aimed to investigate the mechanism(s) responsible for the acceleration of pyroclastic particles in the presence of shock waves.
The idea raised from the evidence of a steel pole impacted by crystals and glass (pyroclasts), 70 to 280 μm in size, at velocities calculated by analytical methods to be between 710 and 980 m/s, found in an active volcanic area in Mexico (Scolamacchia and Schouwenaars, 2009). Such velocities are uncommon for ground-hugging mixtures of gas and fragments (i.e. pyroclastic density currents) generated during explosive eruptions.
Our hypothesis was that particles acceleration would result from a sudden expansion of the gas phase (e.g. water vapor) in which they are immersed, which add momentum to the particles.
For this purpose we used a vertical shock tube consisting of a nimonic steel lower autoclave (HP), pressurized with Ar at pressures between 15 and 18 MPa, separated by a copper diaphragm from an upper tube (LP) of acrylic glass, at atmospheric conditions.
A first series of experiments was devoted to determine the suitability of the set up, using natural pyroclastic samples ranging in size from 177 μm to 8 mm. The experiments that followed were performed using analogue particles consisting of carbon fibers (150 to 210 μm) and glass beads (500 μm in diameter), suspended inside the LP section, at the nozzle exit, or at a distance of 1 nozzle diameter. The use of analogue samples allowed a more easy interpretation of the data/processes, due to their standard dimensions and constant densities, and it resulted more easy to suspend them inside or at the nozzle.
A high-speed camera registered the processes occurred after the diaphragm opening between the first 100 μsec and several milliseconds after shock wave generation, at frame rates between 30,000 and 50,000 fps. Static and dynamic pressure sensors, synchronized with the high-speed camera, recorded the pressure histories of the system before its decompression up to several milliseconds after the diaphragm rupture. Two ambient conditions were used, namely air and air saturated with steam.
With this set up, we were able to measure the velocities of both particles and Argon front exhausting from the nozzle. The condensation front associated with the shock wave was visible when the ambient air was saturated with steam, and attained a maximum velocity of 788 m/s, which is in the range of velocities calculated for the ash impacts on the original steel pole.
Following the condensation front, particles up to 210 μm, exhibited large accelerations, with velocities that vary from few tens of m/s up to 479 (±0.5) m/s, at distances of 1.5 (±0.3) cm, in times of 0.1 ms. This drag did not occur for bigger and denser particles (i.e. 500 μm), which were displaced only later by the Argon gas exhausting from the system.
The results obtained indicated that both grain-size and density are crucial in determining particles acceleration through the expansion of a gas phase associated to a shock wave. In fact, such expansion failed in displacing particles 500 μm in size. Therefore, the use of the pseudogas approximation (i.e. assumption that particles and gas behave as a single fluid), in volcanic modelling should be more critically considered.
Moreover the pressure records in presence of particles differ from those obtained in their absence. A pressure multiplication was registered when the shock wave encountered the particles, with respect to the records obtained with an empty set up, suggesting that a possible different mechanism with respect to gas-particle's coupling can act to accelerate the particles. This mechanism could act to accelerate bigger particles. Further investigations will be carried out in this direction, but a further modification of the set up is necessary.

Investigating different mechanisms responsible for particles acceleration in presence of shock waves will have greater implications for hazard assessment in active volcanic areas, with respect to what originally thought. In fact both greater particles sizes and higher particles velocities could be reached influencing the values of dynamic pressure ($P_{dyn} = \frac{1}{2} \rho v^2$ where ρ= density of the flow and v= velocity of the flow) used to estimate the destructive power of a density current.