Engineering Universe for scientific Research and management
ISSN (Online): 2319-3069 Vol. XIV Issue VI
June 2022

NUMERICAL ANALYSIS OF MICRO-PARTICLE INTERACTION OF GAS FLOW IN A MICRO SHOCK TUBE: A TWO PHASE FLOW

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Abstract

A particle velocity contour, pressure and wall shear stress on the centre line and two distinct point on the surface of wall boundaries within the micro-shock tube has been obtained to describes the different phenomenoninside driver and driven section of the tube. Therefore, it is highly required to improve the performance of micro-shock tube in engineering and medical fields,it is significantly important to investigate shock waves and particle-gas flows induced by micro-shock tubes. Even though shockwaves and multiphase flows discharged from micro-shock tubes have been studied for several decades, the characteristics of unsteady particle- gas flows are not well known to date. In the present studies, 2D micro-shock tube models were used fornumerical simulations. Discrete phase method (DPM) was used to simulate unsteady particle-gas flows and the discrete random walk model was chosen to record the unsteady particle tracking. The results obtained from numerical simulation has been compared with the test data obtained from reference paper and having good agreements. The propagation of shock waves was observed to agreed well with the experimental results from numerical simulations. The particle velocity which has been calculated was smaller than the gas velocity, therefore it is required a injected particles with higher drag.

Keywords: Shock wave propagation of gas particle, Needle-free medicine delivery device, Particle tracking velocity, Pressure Fluctuations.

1. Introduction

Shock wave comes from both nature and man-made objects. In nature, a shock wave occurs in the explosion of a supernova and solar wind (when in contact with the earth's magnet). A common example of a wave shock wave in everyday life is the sonic boom produced by an airplane (e.g., Concorde or any fighter jet planes) that breaks the sound barrier. Shock wave is a fringe science related to many areas of research. In the field of supersonic aerodynamics, especially in the most recent developments in scramjet, shock waves help compress gas flow inside its combustion engine, when moving parts such as the turbine are no longer needed. Reducing wave eruptions has also been an important topic for decades. More recently in electro-hydrodynamics, shock waves are generated by the plasma actuator, and are used to control the flow of aircraft

1.2 Shockwave tube

If not, it should be pierced through the needle by hand. A wave of shock caused by a small earthquake The tube is always a normal shock wave, while it becomes oblique wave shock after displaying the last wall in the geometrical part of a closed micro-shock tube. Supersonic flow they are seduced and accelerated after a shock wave, frequently used in experimental tests such as micro-combustion and explosion. High pressure and temperature the flow is produced at the bottom of the indicated river shock wave. With the development of micro-shock tubes as well innovation in medical practice, delivery of drugs without needles devices designed to inject drug powders into a person the body in an intangible way. the main components of the needle-free drug delivery device is also a micro-shock tube expanded nozzle [26]. Flow of gas and drug powders are present created and accelerated by the shock wave generated in a micro-shock tube and accelerated to extended nozzle and medicine powders are injected into the skin tissue with to get enough momentum. To confirm delivery without harm, the pressure of drug powders it should be strictly controlled.

1.2.1 Research Motivation

This is a recent challenging topic in the field of the CFD and requires advanced and complicated simulation strategy on gas particle movements in discrete phase flow. The effect of the fluid particle in shock tube has been simulated and the particle tracking along with pressure fluctuations has been investigated. These effects require a reliable simulation that captures the flow features of combustion or a mixture of two gas inside the combustion chamber and links such behaviours to the fluctuations in the pressure curves. At the time of the developing this report, there are a limited number of studies about the Particle-Gas Two-Phase Flow through micro-shock Tubes. The following sections will discuss more about the research motivation, a chosen aim, and objectives areas and finally the area of novelty.

2. Literature review

[1]Brouillette et al. (2021) investigated the effects of the scale on shockwave experimental and theoretical distribution with minimal shocktube. Pressure ratings were performed to calculate shock click March number. Shock wave Mach number was low ontest studies compared with those in experimental analysis. In addition, the shock wave gradually decreased as it was transferred to a small shocking tube.

[2] Arun et al.(2020) do the calculations a study on the process of rupture of the diaphragm up and down diaphragm pressure ratios respectively. At high pressure rating, the diaphragm rupture was considered rapid and complete, while the diaphragm is slightly broken at low performance pressure gauge or thick diaphragm used. Part break was detected to start the flow and the shock wave in complexity.

[3] Mcbride and Raghunath (2019) used Pitot tubes to investigate flowing through supersonic tubes. Pitot tubes come in a variety of sizes are designed to study their effects on pressure measurements. Pressure coming from Pitot tubes with large diameters was near actual flow pressure and limit of Pitot tubes with-the larger the size shown the smaller. Schlieren eye method was used to visualize the shock waves generated [59]. Shocking waves caused by supersonic the flow in wedge-shaped models was clearly seen.Tungsten particles with a diameter of 1 mm and 5 mm were present accelerated to about 300 m / s by using compressed nitrogen internally a shock-driven device [60]. This speed is caused by the shock of the wave stested to be sufficient to allow the particles to reach the setepidermal layers.

[4] Kendall et al.(2018) perform pressure measurements, Schlieren look and image particles velocimetry (PIV) to monitor the flow of gas particles in a congested area shock tube (CST). Speed and the shock of the incident waves were found. In addition, the speed of the particles was measured again.

[5] Rasel et al.(2017) conducted numerical studies atto fine-tune the design of the shock- absorbing tube so that it does not have a needle drug delivery device. Different shock length tube and diaphragm pressure gauges were investigated. Particle speed and movement observed and compared in different working contexts .Particle movements in supersonic flows were investigated with a laser Doppler velocimetry [65]. Different coefficients of drag discussed and new exposure sphere draw coefficient is proposed. Particle speed was obtained from calculate drag coefficients and compare theoretical results. the test method used to test the response time of particles across the stagnant shock wave were tested in the form of PIV measured[66]. Different response time particles across the oblique shock wave of Mach 2.0 were also present investigated.

[6]Fincher et al. (2016) provided details on the scope of Drug powders are used to inject into the human body medical fields. Scope of particles used in current experiments studies were transferred to an average range of drug powders given in the index .In this paper, a micro shock tube and various nozzles which assembled into different contoured shock tubes (CST) were designed and investigated experimentally. For investigation effects of diaphragms varying in generation and distribution of shock waves of incident, pressure gauges and Schlieren visualization done. Particle-gas is two phases the flow caused by sonic and supersonic pipes respectively was and was studied using Pitot tube measurements and particles velocimetry tracking (PTV). Particle speed indicating flow features obtained from the outlet of the nozzle by inserting a sonic or supersonic tubes at the outlet of the micro shock tube. In addition, distribution of particle numbers was also detected.

A brief review diagram is shown in Fig. 1.1. Shock wave research part of the fluid mechanics family. At this stage, we focus on the shock wave, not a total fluid mechanic. But just out of curiosity, I want to say it soon that major historical role players in liquid mechanics include Zhang Heng, Newton, Euler, Bernoulli etc. It is known that Newton gave his second book of the Principia to fluid mechanics. In my literature research, I also read about Zhang Heng which may be less well known in the west. He is, in fact, the founder of the universe the first water-efficient armillary sphere to aid astronomy. In addition, Zhang Heng developed an inland water clock and developed the world's first seismoscope.

We are now reviewing the study of the shock waves, dating from the Stokes era in (the same Stokes known by the famous Navier-Stokes figures). He did it perhaps he made the first assumption that pressure exacerbation may spread to a stressful environment medium to high speed than audio speed. This pressure escapes today they are called shock waves. Early attempts at mathematical interpretation produced by Airy and Eam shaw. Mathematician Bernhard Riemann (best known for his numerical theory) was also involved in a panic attack research. He described the transformation of the pressure wave into a shocking wave first. Riemann's counselor in doctoral thesis was a great mathematician. Carl Friedrich Gauss University of Göttingen. However, Gauss' direct involvement the study of the shock waves is unclear due to the lack of literature.

[7] WJ Macquorn Rankine etal.(2015) made theoretical calculations related to the transformation of the state of gas in the shock zone in. In, Pierre Henry Hugoniot discovered increased entropy in wave shock. Today, their names represent celebrities a set of statistics describing the transformation of the gas state beyond the shock zone, i.e. Rankine-Hugoniot relationship. The suitability of this relationship will also be discussed at and thesis. Because panic waves are obvious and fast-moving, special techniques they are necessary in order to be visible and measurable.

[8] Ernst Mach et al. (2014) made the first (and perhaps the first) Schlieren's portrait a panic wave, produced by a flying bullet from a gun. The first shock-absorbing tube (modern diaphragm / membrane technique) is being developed. by Paul Vieille. That is why at ISSW (International Symposium on Shock Waves) there is always a talk called Paul Vieille. After that established, the shock tube is often used as a tool to study shock waves in labs. A common shock tube uses a diaphragm process with hydraulic inches in diameter, where collision and heat play a small role in it shock distribution, because the volume and location ratio is large enough. Old- fashioned opinions (such as the Rankine- Hugoniot relationship) about panic waves so do not ignore the conflict time in the energy saving equation and time to heat up in energy saving equation. The study of classical shock wave is well described by textbooks

3. Shock Waves in a Viscous Non-Ideal Gas

3.1 Shockwave

Isentropic flow is a flow with a fixed entropy. It has no irreversible loss and no additional heat. Isentropic flow is mathematically easy, but by reading it one can begin to discover interesting contradictory things that occur in the flow of a high Mach number. For example, when the flow requires acceleration, we automatically adjust the nozzle. However, it requires a nozzle to accelerate the supersonic flow from the magnetic valve. The reason for this lies in the conversion of energy. The shock wave is not an isentropic flow, described at the beginning of this chapter. But isentropic flow theory can be used to study the pressure of standing before and after a shock wave. With a change in stop pressure, one can calculate the entropy conversion in the shock wave [90]. At this stage, we take an isentropic flow that exceeds the control volume .

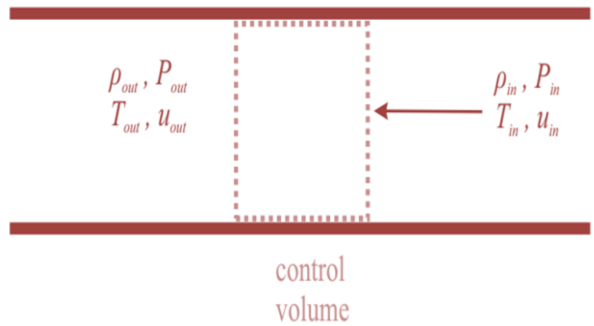

Figure 3.1: The variation of flow parameter ρ, P, T, u

3.1.1 Numerical Model

The purpose of these sections is to consider the flow of a tube with a transport phenom due to wall collision and temperature changes. It has already been said at the beginning of the thesis that with low flow, wall friction and heat conduction is ignored. This leads to a fundamental difference between a micro and a macro shock wave, from Extreme shock waves are considered normal as inviscid and adiabatic. Logically, in a wave of small shocks will be introduced thename of the wall collision in the energy saving equation. The temperature term of the wall will also betaken into account energy saving statistics. This brings us to a very important question section: How to calculate wall collisions and temperature of tube flow? These questions will be answered as follows. First, we begin by considering the volume control 'CV' in the tube shown in Figure 3.2. The impact of the collision is simulated as the shear pressure on the wall acting on the control capacity. The shock wave is not included in the control volume in this thesis section, so that the flow of material changes caused by wall collision and heat conduction can be considered separately.

3.1.2 Rankine-Hugoniot relations

All the question related to shock waves i.e. How do the gas properties changes across the shock waves? And what, If we actually know one of the parameter e.g. Mach number of local flow velocity, then, how do we should actually derive the other parameters of the gas related to the thermodynamic? All these questions can be easily answered from the Rankine-Hugoniot equations. The relation between Rankine-Hugoniot is given in short.

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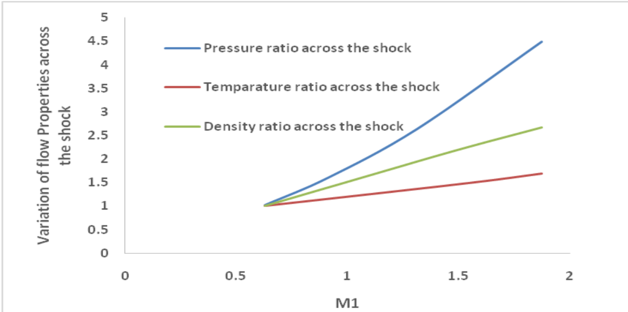

Figure 3.2: Changesin gas properties across

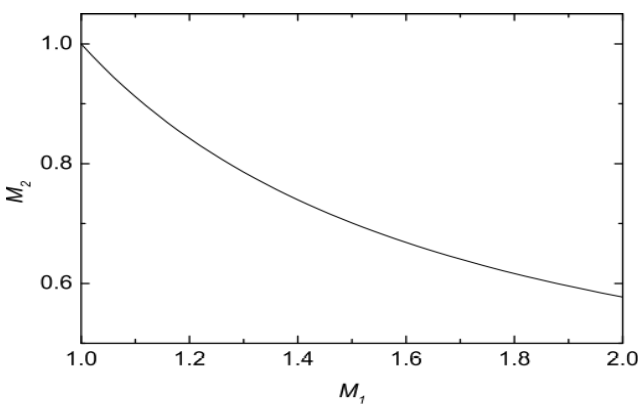

Figure 3.3: Theoretical variation of Mach number

For higher the entropy growth, higher the Mach number M1. Therefore, it is clear that, gas has less energy to do the job, when a strong shock wave has spread through this gas. In low shock waves with a low Mach number, the shock wave reduction is strong, meaning that the total distribution length is small (mm in width shown in the test). Thus, the losses are minimal.

4. Result and Discussion

All numerical simulations were performed in the same conditions as mentioned above in chapter 5. The driven part is maintained at constant atmospheric pressure and the driver part was started with a maximum pressure of 0.9 MPa or we can say that driver section was kept at a pressurised pressure of 0.9MPa, which adjusted the diaphragm pressure to 9 in all the cases. The comparison between history of fluctuating pressure at points p1 and p2 has been shown in Figure 4.1. After the diaphragm rupture, a common wave shock wave was identified and transported to the operating component. As the shock wave reaches the point where the pressure transducers are located, the pressure increases significantly as shown in Figure 4.1. Therefore, as soon as the shock wave meets the two pressure transducers which are almost identical in both Numerical studies by us and by the reference paper. The severity of the shock wave has been shown to be stronger in CFD studies compared to those in experimental tests, which are mainly due to differences in the fracture process. In a diagnostic test, the diaphragm was broken by a manual method and the fracture time did not occur at that time.

4.1 Shock Wave Propagation

In previous experimental studies, Schlieren's observations were used to observe the shock wave in the micro-shock tube as shown in Figure 4.2. The test phase was clearly visible before the normal shock wave was developed. After the diaphragm ruptured, a normal shock wave was seduced and distributed to the retaining wall as shown in Figure 4.2 (b) and 4.2 (c). When the normal shock wave hit the last wall of the drive section, it was shown and the shock wave shown was still a normal shock wave as shown in Figure 4.2 (d). The force of the primary shock wave was stronger than that of the shock wave shown. This is caused by the shock wave shown to rise. As the shock wave shown meets the contact area, the formation of the shock wave reflected as shown in Figure 6.3 (e). The reflected shock wave was no longer a normal shock wave but the direction did not change.

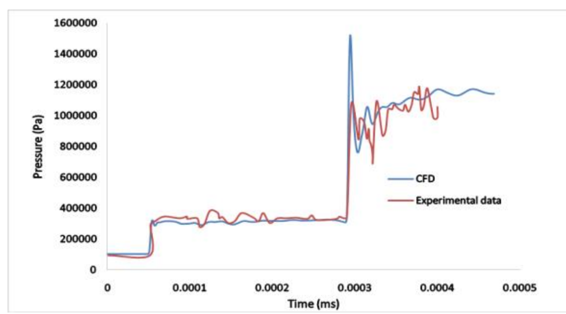

Figure 4.1: Pressure histories of point 1

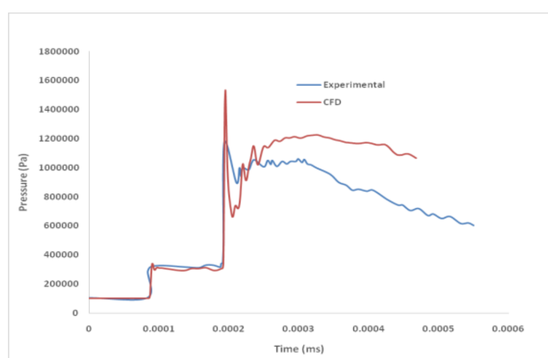

Figure 4.2: Pressure histories for the case

5. Conclusions

- Numerical simulation was performed to study the shock wave diffusion and flow of sonic particle-gas flow as well as the supersonic waves along with the comparisons between the pressure fluctuations and other test results were performed and validated.
- Experimental shock wave and numerical shock wave shown were clearly visible in the CFD studies and there is a good agreement of the test data.
- Particles accelerated in micro-shock tube due to the development of boundary layers after a wave of panic.
- Particles were seen to accelerate in the background from outflow of both sonic and supersonic pipes due to both nozzles ends of the tube were slightly extended.

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