Detonation dampers for ducts transporting gaseous fuels

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Abstract. The research, reported in the present paper, was aimed at optimization of devices extinguishing detonation, which may occur in pipelines transporting gaseous fuels. Such device, "detonation damper", is a matrix of narrow channels placed across the pipe. Detonation is extinguished by heat exchange between the flame and cold walls of the channels. Improvement of efficiency of the damper was achieved by modification of the channel shape, so that rarefaction waves, cooling additionally the burning gas, appear in the flow.

Keywords*:* Flow Control and Optimisation, Micro- and Nano- flows, Detonation

1. Introduction

Detonation in pipelines transporting gaseous fuels is a very important practical problem. It may occur under nonstationary flow conditions, when decrease of the flow rate produces rarefaction waves, lowering the pressure in the pipe below atmospheric. If the pipe is not perfectly leak proof some air may get inside, the mixture air – fuel may start burning and, finally detonation wave may appear. Detonation is very dangerous for all devices (compressors etc.) connected to the pipeline, therefore suitable "detonation dampers" must be used for their protection. Design of the most efficient "detonation dampers" is the objective of the present research.

2. Details of simulation

The commonly used detonation damper it is a matrix of narrow channels, which is placed across the pipe transporting flammable gas. Detonation wave, travelling along channels of the damper, is weakened because part of energy released in the flame front behind the shock wave is removed by heat exchange with cold walls of the channels.

In the present research project the phenomena inside the channels of the detonation damper are simulated with the Direct Simulation Monte Carlo technique [1].

The flowing medium is simulated as gas of hard sphere molecules. Part of these molecules carry some "internal" energy (of unspecified character) which may be released in the process of collision with other molecules, not carrying such energy. After such collision the relative velocity of colliding molecules is increased suitably.

Subtraction of energy from the burning gas is achieved through interactions of the gas molecules with channel walls. These interactions are described with the Maxwell's model [2]: molecules are reflected from the walls either specularly (no change of kinetic energy and tangential momentum) or diffusely (molecules are adsorbed by the wall and re-emitted in directions selected at random, with energies corresponding to temperature of the wall – maximum exchange of energy and tangential momentum). Ratio of the number of molecules reflected diffusely to total number of reflected molecules is called “accommodation coefficient”, α.

Efficiency of cooling the flowing gas by channel walls depends on the ratio of the number of molecules interacting with walls to total number of molecules in the flow – this ratio and efficiency of cooling decrease with increase of the channel cross-section. Artificial decrease of the accommodation coefficient in simulation of flows in narrow channels leads to similar effect. We utilised it in our work, because otherwise for wider channels – of dimensions acceptable technologically – the simulations would take too much computing time.

3. Results

Figure 1 [3] presents the simulation results for the standard channel of constant cross-section (upper left) and the channel of variable cross-section, as shown in the figure (upper right). At the entrance and at the exit the cross-sections of both channels are the same – square of dimension 5µm (70 mean free paths of molecules in undisturbed gas). At the assumed accommodation coefficient α = 0.05 the described channels behave like channels of dimension 0.1mm.

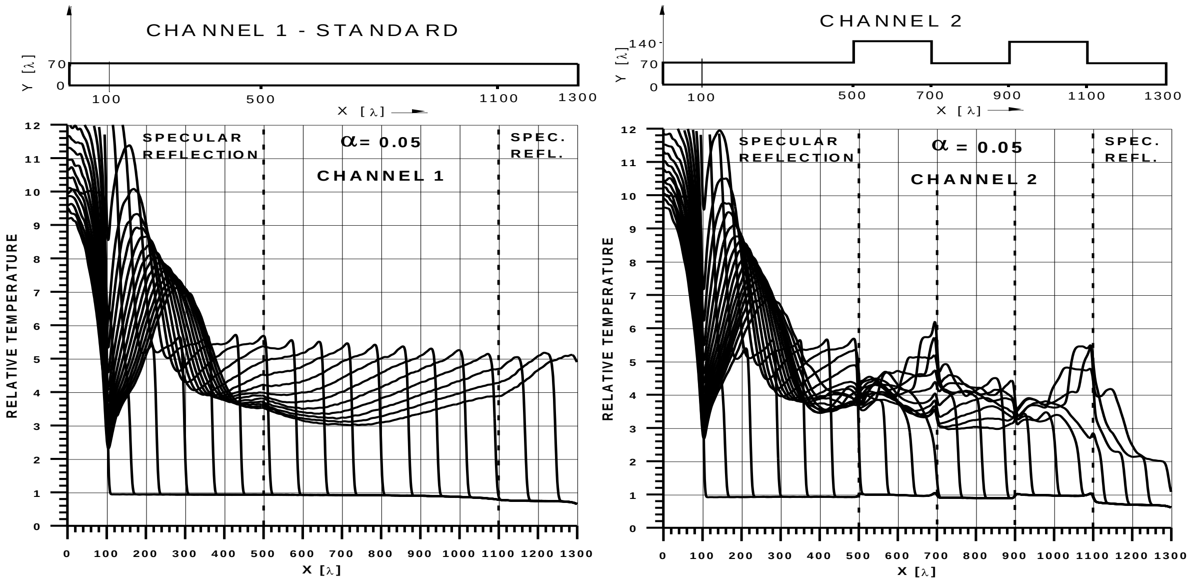

Figure 1. Temperature distributions along channels 1 and 2 in evenly spaced time instants.

Intensity of detonation wave at the beginning of both channels (for x<500λ) is the same. In the straight channel (left) it later decreases very slowly – perhaps detonation would not be damped completely, no matter how long the channel would be. In channel 2 (right) the detonation wave moves slower than in the straight one and, at the end of it, changes into a relatively weak shock wave, followed at some distance by a front of hot gas. It is evident, that channel 2 is more efficient, as far as detonation damping is concerned.

In the full paper more information will be presented on damping efficiency of wider channels – what is the limiting width of the efficient channel.

References

[1] Bird G A 1994 *Molecular Gas Dynamics and the Direct Simulation of Gas Flows* (Oxford: Clarendon Press)

[2] Maxwell J C 1952. In Niven W D (Ed) *The Scientific Papers of James Clerk Maxwell* (New York,, Dover: 2) p 706

[3] Walenta Z A and Słowicka A M 2019 *Optimization of Detonation Dampers for Ducts Transporting Gaseous Fuels* in *Proc. of the 32nd International Symposium on Shock Waves* p 547 doi:10.3850/978-981-11-2730-4_0390-cd