Extinguishing detonation in pipelines transporting gaseous fuels

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Keywords: Detonation, Detonation damping, Flow control

ABSTRACT Very serious problem connected with transport of gaseous fuels is due to the fact, that the pipelines used for this purpose may not be perfectly tight and under certain conditions some air may leak inside. The mixture of fuel and air may start burning and eventually a detonation wave may be generated. Detonation wave is very dangerous particularly for the equipment controlling the flow of fuel. To prevent damage of this equipment the special "detonation dampers" are used.

The standard detonation damper is a matrix of narrow channels placed across the channel transporting fuel. Detonation is actually a shock wave followed by a flame, which is the source of energy for the shock. Extinguishing this flame by means of cooling it by heat transfer to cold channel walls is supposed to "kill" the detonation.

To understand better these processes the simulations with the Direct Simulation Monte Carlo (DSMC) technique [1] were performed. The obtained results [3, 4, 5] indicate, that detonation may be extinguished in the way described above, provided that the damper channel is sufficiently narrow (hydraulic diameter of the channel cross-section should be of the order of 70 mean free paths of molecules in the flowing gas, which is equal to about 5 micrometers). Unfortunately, manufacturing a matrix of such narrow channels is technologically impossible.

In a real damper the hydraulic diameter of the channels is equal to about 0.5 mm, constant along the whole length of the channels. Our simulations suggest, that such damper may be rather inefficient. However, its efficiency would be improved if cross-section of its channels was not uniform [6, 7]. Figure 1 presents the shape of the channel which, according to our simulations, is perhaps the most efficient. The increase of damping efficiency of such channel is connected with the fact, that apart from cooling by heat transfer to the walls, the burning gas is additionally cooled by rarefaction waves generated in places, where channel cross section increases.

To understand the situation better some simulations for wider channels seem to be necessary. Unfortunately they would require taking into account very large number of molecules, which would make them extremely time consuming.

However, under assumption of the Maxwell's model of molecular interactions with solid sufaces [2], only diffuse reflections of molecules influence the flow. Decreasing artificially in simulation the number of molecules reflected diffusely (i.e. decreasing the assumed accommodation coefficient) it is possible to obtain, in the narrow channel, the flow picture similar to that in the channel of larger cross-section.

According to our recent simulations, which will be presented in more detail in the full paper, to maintain the efficiency of detonation damping the damper channel of larger cross - section should be geometrically similar to that, shown in Figure 1. We found, that one rarefaction wave is not sufficient to extinguish detonation. If this geometrical similarity is not preserved, particularly if the lengths of some parts of the channel have been increased too moch, then detonation after being cooled in one rarefaction wave would have enough time to recover before entering the next one.

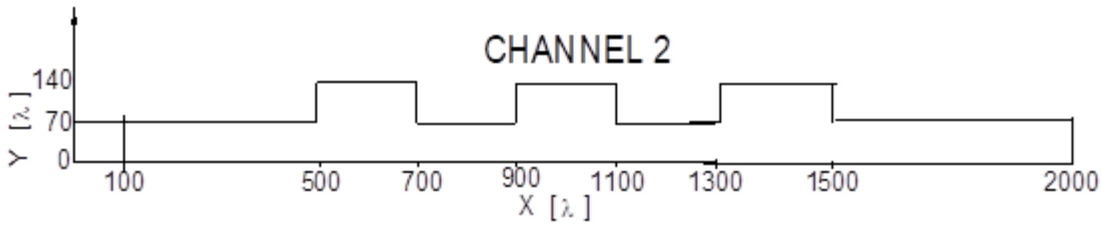

Figure 1. Optimum shape of the damper channel.

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