Shock-to-detonation transition in tube coils

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Summary. Experimental and computational studies of reactive shock wave propagation through tube coils with different curvature radii demonstrate that tube coils promote shock-to-detonation transition.

1 Introduction

There are several ways to decrease the predetonation distance in gaseous explosive mixtures. In 1920s, Laffitte [1, 2] experimentally demonstrated that a decrease in the tube diameter and an increase in the initial pressure of an explosive mixture decrease the predetonation distance. Shchelkin and Sokolik [3] detected a decrease in the predetonation distance after preliminary thermal treatment of fuel. Shchelkin [4] revealed that the aerodynamic conditions in the channel play a leading role in the deflagration-to-detonation transition (DDT). He showed that, if an obstacle in the form of a wire spiral (a Shchelkin spiral) is placed in the channel, the predetonation distance decreases considerably. Since then there were many studies of DDT in straight tubes with obstacles (McGill University, Caltech, CNRS, Russian schools, etc.)

Recently the topic of DDT and shock-to-detonation transition (SDT) have attracted much attention in view of possible application of detonation to propulsion. Brophy et al. [5] showed that the predetonation distance in the case of ignition of a mixture by a nanosecond corona discharge in combination with a Shchelkin spiral is smaller than that in the case of ignition of a mixture by an arc discharge. Frolov et al. [6] proved experimentally that the predetonation distance can be significantly decreased by accelerating a weak primary shock wave by a traveling forced ignition pulse. For this purpose, several (up to 7) electric dischargers mounted along the tube were triggered synchronously with the primary shock wave arrival at their position. Frolov et al. [7–11] discovered and studied experimentally a significant effect of tube coils and U-bends on reduction of the predetonation distance at SDT. It was found that the shock waves propagating at velocities above 800–900 m/s in the stoichiometric gaseous propane–air mixture (51-mm U-bent tube) and above 900–1000 m/s in the heterogeneous n-hexane–air and n-heptane–air mixtures (36-mm and 28-mm tubes with coils) were capable of transitioning to detonation after passing 180-degree U-bends or tube coils. For obtaining such shock waves we used a weak electric igniter and a Shchelkin spiral.

The objective of the experimental and computational research outlined in this paper was to better understand the phenomena accompanying SDT in the course of shock propagation through the tube coils represented by circular 360-degree loops of tubes with different curvature radii.