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Experiments and Numerical Simulation of Deflagration-to-Detonation Transition and Detonations in Gaseous and Two-Phase Systems

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In existing power plants and burning devices chemical energy of fuel is converted into heat and mechanical work by slow burning – deflagration. In addition to deflagration, there is another known combustion mode – detonation. Fuel oxidation in a detonation wave occurs in the mode of self-ignition at high pressure behind a strong shock wave. Deflagration of air mixtures of hydrocarbon fuels are accompanied with about 1 MW/m2 heat release per unit area of the reaction front, whereas the heat release in the detonation front is about 4 orders of magnitude higher (~ 10000 MW/m2). Furthermore, in contrast to the products of slow burning, detonation products have tremendous kinetic energy: the speed of the detonation products is 20–25 times the speed of slow-burning products. If, for example, instead of the existing chambers with continuous combustion one applies chambers with continuously rotating detonations or with pulse detonations, these could provide great benefits when used in the energy and propulsion sector due to the energy release with a considerable gain in total pressure and the combined shock wave (mechanical) and thermal effects on the target objects. In view of it, there is a growing interest to the studies of controlled detonations worldwide. In this paper the physical principles and problems of controlling deflagration-to-detonation transition and detonation propagation in gaseous and two-phase systems, as well as recent accomplishments of the author's group at Semenov Institute in relevant experimental and numerical studies will be outlined. Several examples of detonation devices will be discussed, namely (1) the pulse detonation burner operating on natural gas–air mixture – a prototype of novel industrial burners for rapid heating and fragmentation/gasification of various materials, (2) the pulse detonation rocket engine for orbit correction providing calibrated bits of thrust, (3) the air-breathing pulse detonation engine integrated in subsonic and supersonic ramjets, and (4) the pressure gain continuous-detonation combustor designed to replace a conventional combustor in a gas-turbine engine.