Numerical Simulation of Rotating Detonation in Cylindrical Channel

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In the paper results of two-dimensional numerical simulation of detonation propagation in cylindrical cannel are presented. Calculations were carried out for oxy-acetylene mixtures of a different composition, different location of ignition source, different channel dimensions and different initial velocity of the mixture in the channel. This work is connected with possibility of application of the continuously rotating detonation to jet engine, or so called Rotating Detonation Engine (RDE) descriptions of which could be find in [1].

For calculations a modified program developed by Michel Lefebvr and Toshi Fujiwara from Nagoya University and modified at Warsaw University of Technology was used [2].

Two different combustion models were used. The first simplified model based on data available in [3],[4] an model developed by Williams and described in the paper „The Combustion and Oxidation of Acetylene" [5]. Both models were verified on base of available literature data described in [6]. Most of the calculations were based on the second approach.

The following reactions were taken into account:

	A [cm^3/mol/s]	n	E [cal/mol]	
a) 2 C2H2 + 5 02 → 4CO2 + 2 H2O	4.6E15	-0.54	45000.0	[1]
b) CO + O2 → CO2 + O	2.53E+12	0.0	47688.0	[2]
c) CO + O → CO2 + M	6.17E+14	0.0	3000.0	[2]
d) H+ OH + M → H2O + M	2.21E+22	-2.0	0.0	[2]

The calculations were performed for the mixtures with concentration of acetylene ranging from 3-29%, however most of calculations were done for concentration 14,5% and 29% and initial pressure of 0,2 bar and initial temperature of 300K. A dimension of the cylindrical channel was varied from inner radius of 65 mm to 140 mm and outer radius from 75 mm to 150 mm. Also, calculations were performed for different channel width ranging from 10 mm to 40 mm (with outer channel radius of 75 mm). To shown the effect of centrifugal force on detonation structure some calculations were performed for initially induced flow of the mixture.

It was shown that for small initiation energy, ignition location has significant effect on flame acceleration to detonation. Fastest transition to detonation is obtained for initiation on inner wall of the channel while slowest acceleration is for the initiation on the external side of the channel. In all cases, for initial quiescent mixture, detonation propagates fastest close to inner wall of the channel.

Typical examples of performed calculations are shown on the Fig. 1 – 5. On Fig. 1 pressure distribution in the channel is shown. On Fig. 2-4 the density distribution in the channel of different dimensions and different initial conditions are shown. In all cases the leading front propagates faster on the inner wall of the channel. Also in all cases maximum pressure is located in the outer radius of the cylindrical channel. For the case with induced rotation of the fresh mixture, the pressure gradient in the cylindrical channel is largest.

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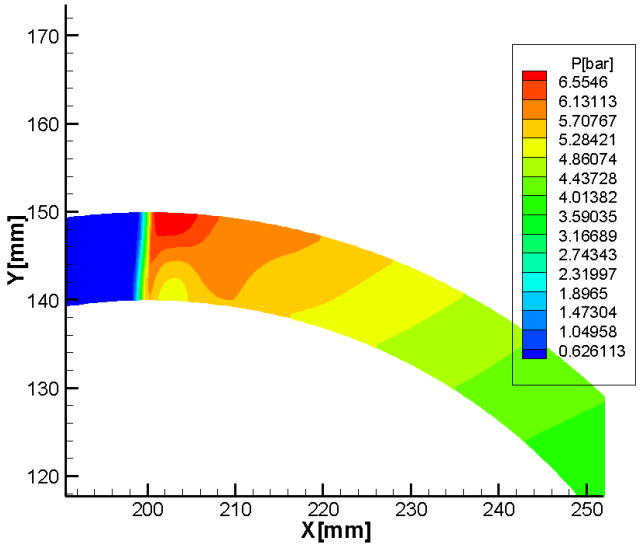

Fig. 1 Pressure distribution behind detonation wave for mixture: 29% C2H2 i 71% O2**.**

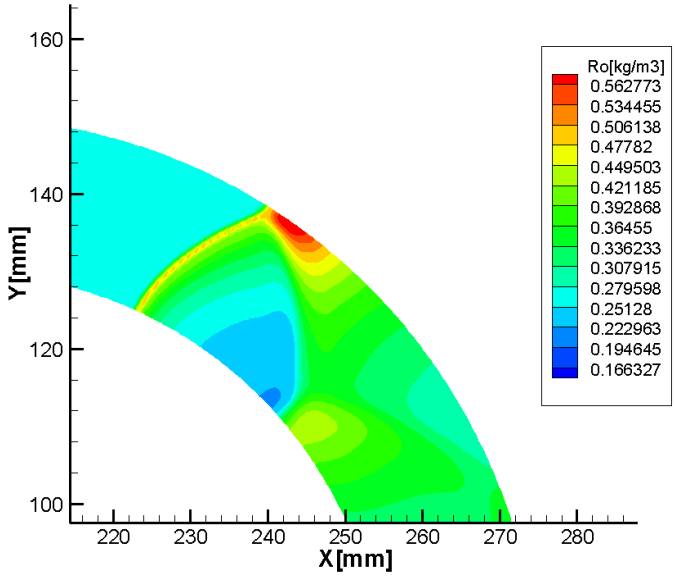

Fig. 2 Density distribution in the channel (channel thickness - 20mm), for mixture: 14,5% C2H2, 85,5% O2.

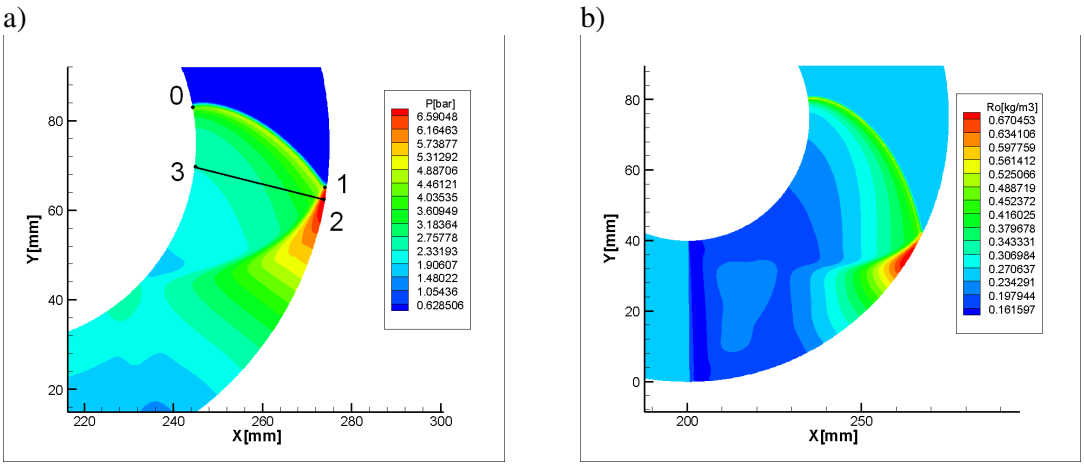

Fig. 3 Density distribution in the channel, for mixture 14,5% C_2H_2, 85,5% O_2, for different channel thickness : a) 30mm; b) 40mm

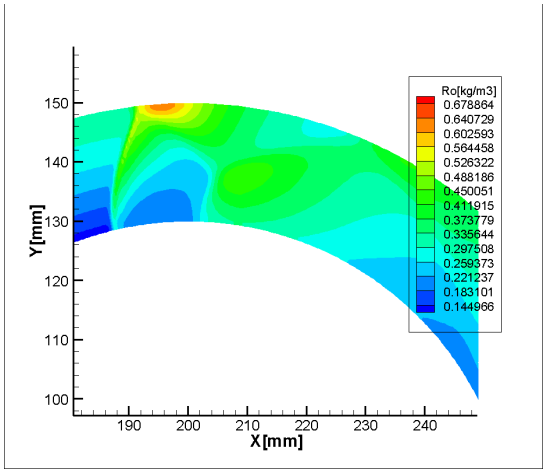

Fig. 4 Density distribution in the channel, outer radius – 75mm, thickness – 20mm. Fresh mixture in the channel rotating with initial velocity – 500m/s.

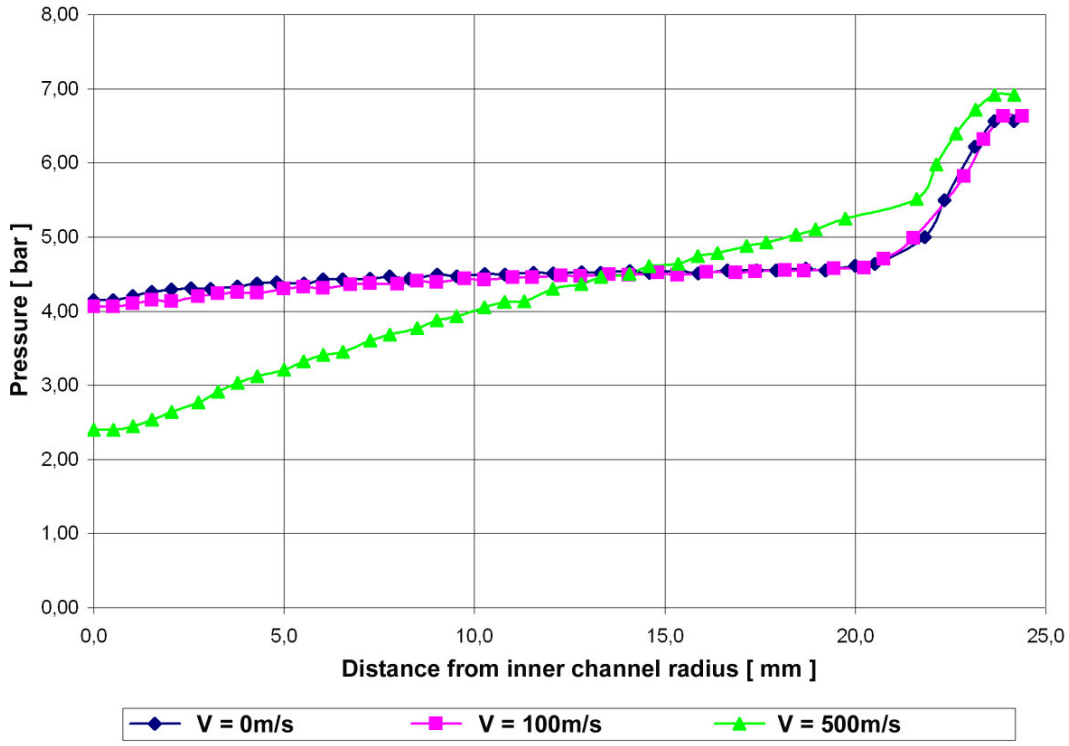

Fig. 5. Pressure along detonation wave for three initial velocity of fresh mixture.

It was show that induced flow of a fresh mixture produce the pressure and density gradient which results in a significant pressure gradient behind detonation front in a cylindrical channel. Such pressure gradients might be essential in establishing detonation engine based on continuously rotating detonation.

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