Experimental study on turbulent combustion of hydrogenair mixtures and possible DDT in a confined channels

Andrzej Teodorczyk, Andrzej Dabkowski

Warsaw University of Technology, Institute of Heat Engineering Nowowiejska 21/25, 00-665 Warszawa, Poland

1 Experimental

A study of flame propagation, acceleration and transition to detonation in hydrogen-air mixture in 2 m long rectangular cross section channel filled with obstacles located at the bottom wall was performed. The initial conditions of the hydrogen-air mixture were 0.1 MPa and 293 K and stoichiometric composition (29.6% H₂ in air). Four different cases of channel geometry and obstacle density were studied with the channel height equal to 0.01 m (Case A), 0.02 m (Case B), 0.04 m (Case C) and 0.08 m (Case D). The height of the obstacles was equal to one half of the channel height. The channel width was 0.11 m in all experiments. The blockage ratio was 50% in all cases.

The propagation of flame and pressure waves were monitored by four pressure transducers and four in house ion probes. The pairs of transducers and probes were placed at various locations along the channel in order to get information about the progress of the phenomena along the channel.

Additional experiments were performed in the channel with the height 0.01 m (Case A) to examine the influence of mixture composition on flame propagation. Two additional compositions tested were 20% and 25% of H_2 in air by volume.

Figure 1 shows the schematic of experimental facility and fig.2 presents the view of obstacles in Case D.





Fig.1. Schematic of the experimental facility

Fig.2. Case D

Correspondence to : ateod@itc.pw.edu.pl

2 Case A

Figure 3 presents the diagram of average velocity of pressure wave (black) and flame (red) vs. distance along the channel estimated from the pressure and ion probe signals.



Fig.3. Velocity vs. distance diagram for Case A, $29.6\% H_2$ (H = 10 mm)

It is visible that deflagration wave, after initial acceleration, reaches terminal steady velocity of the order of 1000 m/s, which is close but below the sound speed in combustion products (Table 1).

It may be concluded that in Case A the flame propagates in fast deflagration regime.

Table 1. Detonation parameters in 29.6%, 25% and 20% hydrogen in air mixture at 0.1 MPa and 293 K, calculated from the CJ model using SUPERSTATE code

Parameter	29.6% H ₂	25% H ₂	20% H ₂
Detonation velocity, [m/s]		1870	1704
Sound speed of products, [m/s]	1093	1048	971
Pressure, [MPa]	15.91	14.97	12.77
Temperature, [K]	2951	2781	2419

The velocity vs distance plot shows that deflagration wave at the distance of 0.45 m from ignition point reaches terminal steady velocity of the order of 800 m/s, which is below the sound speed in combustion products (Table 1). In this case flame propagates in fast deflagration regime.

The velocity vs distance plot shows that deflagration wave at the distance of 0.45 m from ignition point reaches terminal steady velocity of the order of 700 m/s, which is below the sound speed in combustion products (Table 1). In this case flame propagates in fast deflagration regime without transition to detonation.

3 Case B

Figure 4 presents the diagram of average velocity of pressure wave (black) and flame (red) vs. distance along the channel estimated from the pressure and ion probe signals.



Fig.4. Velocity vs. distance diagram for Case B (H = 20 mm)

It is visible that deflagration wave, after initial acceleration, reaches terminal steady velocity of the order of 1000-1100 m/s, which is very close to the sound speed in combustion products (Table 1). However, at the distance of 600-800 mm from the ignition, the velocity in some experiments is larger, up to 1700 m/s, which may indicate the local DDT event leading to the formation of detonation that is quickly attenuated by the obstacles.

It may be concluded that in Case B the fast deflagration at the distance of 600-800 mm from the ignition point transforms into quasi-detonation and that soon becomes steady CJ deflagration, propagating with the velocity equal to the sound speed of the combustion products.

4 Case C

Figure 5 presents the diagram of average velocity of pressure wave (black) and flame (red) vs. distance along the channel estimated from the pressure and ion probe signals.

Fast deflagration regime of flame propagation transits to detonation regime at the distance of 800-1000 mm from the ignition point. Detonation wave propagates for the short time and is attenuated by the obstacles. This is quasi-detonation regime.



Fig.5. Velocity vs. distance diagram for Case C (H = 40 mm)

5 Case D

Figure 6 presents the diagram of average velocity of pressure wave (black) and flame (red) vs. distance along the channel estimated from the pressure and ion probe signals.

Fast deflagration regime of flame propagation transits to detonation regime at the distance of 1700-1800 mm from the ignition point.



Fig.6. Velocity vs. distance diagram for Case D (H = 80 mm)

Acknowledgement

This research was carried out under SHIMIZU Corp. Contract entrusted by NEDO as part of an International Joint Research Project.

21st ICDERS - July 23-27, 2007 - Poitiers