Quenching of gas detonation in tube by injection of inert gas

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Introduction

There are numerous examples of industrial accidents involving gaseous detonations that have resulted in severe destruction of capital equipment and loss of life. Conditions that lead to detonative combustion are more prevalent today in large modern installations with long pipe runs, large vessels, and high-velocity vapor lines than those in the smaller refineries in the past. Unfortunately, the majority of industrial installations is not designed to withstand detonations, this is simply too expensive and not recommended by risk analysis. So, the only way to prevent serious disasters and losses in human lives and property is to prevent detonation formation or quenching it during its propagation. In the practical situation of a pipe in which fuel-air mixture is created and ignited accidentally, leading to the formation of detonation, preventing an accidental disaster. Some of the safety systems, especially in the oil field production and during the ship to shore off-loading, use similar technique to prevent accidental explosions.

Moen et al. [1] studied the effect of chemical inhibitors and diluents on the detonability of fuel-air and fuel-oxygen mixtures. Gmurczyk and Grosshandler [2] studied the effect of halon-alternative agents on detonations in C_2H_4 -air mixture. The interactions of detonations with inert gas zones were studied by the author [3-5]

More fundamental knowledge on the suppression effectiveness of inert gases and fire fighting agents is required to improve the industrial safety measures.

Experimental

The effectiveness of an inert gas or fire-fighting agent in suppressing detonation can be rated by the extent to which it decelerates the propagating wave and simultaneously attenuates the hazardous shock wave, which is always ahead of the flame in the decoupled quenched detonation. In this study the suppressant was injected into the combustible mixture prior the ignition.

The detonation tube shown in Fig.1 was used in the experiments. It consisted of a 1 m long booster and 8 m long square cross-section channel with internal dimensions 110×110 mm. The booster was filled with the oxy-acetylene stoichiometric mixture, which ignited, by a 1 J electric spark rapidly detonated initiating in turn detonation in the acceptor mixture in the main channel. The acceptor channel was filled with stoichiometric acetylene-oxygen mixture at an initial pressure of 0.01 MPa. The suppressing gas was injected in about 1/3 of the channel length about 1 s prior the ignition by the Servojet solenoid valve. The pressure and time of injection varied the amount of suppressant.



Figure 1. Schematic of experimental apparatus

A number of piezo-electric pressure transducers were fitted into the channel to monitor detonation and shock propagation. An X-band radar Doppler unit was also used for continuous monitoring of the detonation velocity. The Doppler unit was located at the end of the channel. The Doppler unit and the pressure transducers were used to observe the suppressing effect of injected gases on detonation wave. In few experiments smoked-foil measurements were used for qualitative observation of detonation attenuation. This was done by placing a thin steel plate along one of the walls of the channel.

Four inert agents: He, Ar, N_2 and CO_2 , and one fire inhibiting agent: C_4F_{10} (FC3110), were used in the experiments.

The effectiveness of all suppressants under study was evaluated on the basis of performance parameters defined as the ratio of velocity and pressure reduction in comparison with baseline case of non-inhibited detonation.

Results

Figure 2 shows variation of combustion wave velocity along the tube length for base case without disturbance and for different quantities of argon injected shortly before detonation arrival. In all cases presented in Fig. 2 the subsequent reinitiation of detonation occurs outside the zone of argon injection. The amount of argon was too small to cause detonation attenuation.

Figures 3 and 4 present the variation of detonation velocity along the tube calculated from the indications of microwave radar and from pressure transducers (a), as well as time

profiles from four pressure transducers (b), for the case of injection of argon and carbon dioxide. Figure 3 shows the case of detonation reinitiation outside the inert zone and figure 4 shows the case of detonation attenuation by critical inerting of combustible mixture by CO₂.



Fig.2 Combustion wave velocity along the tube length for the base case and for different quantities of argon injected shortly before detonation arrival; $t^2 - time of injection(s)$; $t^3 - delay of ignition$

References

- 1. Moen I.O., Ward S.A., Thibault P.A., Lee J.H., Knystautas R., Dean T., Westbrook C.K.: *The influence of diluents and inhibitors on detonations*, Twentieth Symposium (Int.) on Combustion, pp.1717-1725, 1984
- 2. Gmurczyk G.W., Grosshandler W.L.: Suppression effectiveness studies of halon-alternative agents in a detonation/deflagration tube, Halon Options Technical Working Conference Proceedings, pp.193-204, 1994
- 3. Teodorczyk A., Benoan F.: Interaction of Detonation with Inert Gas Zone, Shock Waves 6, No.4, 1996, pp.211-223
- Teodorczyk A., Thomas G.O., Ward S.M.: *Transmission of a Detonation across an air gap*, Proceedings of the 20th Intenational Symposium on Shock Waves, Word Scientific Publishing Co. 1996, pp.1095-1100
- 5. Teodorczyk A., Thomas G.O.: *Experimental Methods for Controlled Deflagration to Detonation Transition (DDT) in Gaseous Mixtures*, Archivum Combustionis 15 (1995), No.1-2, pp.59-80



Fig.3 Variation of detonation velocity (turbulent flame) along the tube for argon injection (m = 8, 2 g) calculated from microwave radar signal (a), and time profiles of pressure from four transducers(b).



Fig.4 Variation of detonation velocity (turbulent flame) along the tube for injection CO_2 (m = 21,5 g) calculated from microwave radar signal (a), and time profiles of pressure from four transducers(b)