# Study of Small Blockage Effects on the Detonation Transmission from a Confined Tube into Open Space

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## 1 Introduction

The study of detonation diffraction or the critical tube diameter - above which a self-sustained detonation propagating in the confined tube can transmit into an open space without failure - is a basic research topic of detonation dynamics [1]. It also applies to Pulsed Detonation Engine (PDE) research especially for tube initiator geometries, e.g., when a detonation transmits from the small pre-detonator to the main thrust tube of the pulse detonation engine [2].

The criterion for successful transmission of a self-sustained detonation from a confined tube to an open area is often understood from the description of the failure mechanisms during detonation diffraction. For common hydrocarbon mixtures in which detonations are unstable with highly irregular cellular structures, successful transmission is often found to originate from localized region in the failure wave, which eventually amplified to sustain the detonation propagation front in the open area. Hence, failure is invariably linked to the suppression of instabilities at which localized explosion centers are unable to form in the failure wave when it has penetrated to the charge axis [3].

To illustrate the importance of instability for the detonation transmission, our recent research investigates the effect of finite perturbation generated by placing a minute obstacle with a small blockage ratio (*BR* ~ 0.08) at the tube exit diameter just before the detonation diffraction and study how the phenomenon responds. Results show that the small perturbation can have an effect in undiluted hydrocarbon mixtures resulting in the decrease of the critical pressure for successful detonation transmission. In other words, the disturbance caused by the small obstacle promotes transmission and this result seems to support that local hydrodynamic instabilities are significant for the detonation diffraction in undiluted unstable mixtures [4, 5].

In this study, we continue our effort to understand the effect of perturbation generated by thin obstacle on the critical tube diameter problem in undiluted stoichiometric acetylene-oxygen and acetylene-nitrous oxide mixtures. The aim of this study is to systematically study the effect of different blockage ratios with *BR* varied from 0.05 – 0.25. It is anticipated that large *BR* will have an adverse effect due to excess momentum losses caused by the blockage and decrease of the effective cross-section area of the tube. Therefore, this work attempts to determine the optimal value of which detonation transmission is favorably promoted. In addition, a different perturbation arrangement is designed in an attempt to further promote the detonation transmission for possible application in PDE.

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## 2 Experimental Setup

The experiments were carried out in a spherical explosion chamber of 20.3 cm in diameter and 5.1 cm in wall thickness. The chamber's body is connected at the top to a 41.8 cm long vertical circular steel tube, of $D$ = 12.7 mm. Figure 1 shows the schematic of the experimental setup. Stoichiometric mixtures of acetylene-oxygen or acetylene-nitrous oxide prepared beforehand by the common method of partial pressure in separate gas bottles were tested in this experimental study. For each experiment, the setup was initially evacuated to approximately 100 Pa and then filled through the valve with mixtures at various initial test pressures $p_o$ by which the mixture sensitivity is varied. A high-voltage spark ignition source initiated a planar Chapman-Jouguet (CJ) detonation that propagated through the vertical steel tube and from its end emerged into the large spherical chamber. A piezoelectric pin (CA-1136, Dynasen Inc.) was located at the bottom wall of the chamber and it measured the time-of-arrival of the wave, which was used to determine whether the emergent detonation was successfully transmitted into the open space or not, see [6]. The critical condition for each mixture is characterized by the critical pressure below which the detonation fails to emerge into the large spherical chamber. To investigate both the effect of small perturbations, flow disturbance was generated by the insertion of slender needle(s) at the exit diameter of the vertical tube (see Fig. 1). Different sizes of needle were inserted to vary the blockage ratio *BR* from 0.05 - 0.25.

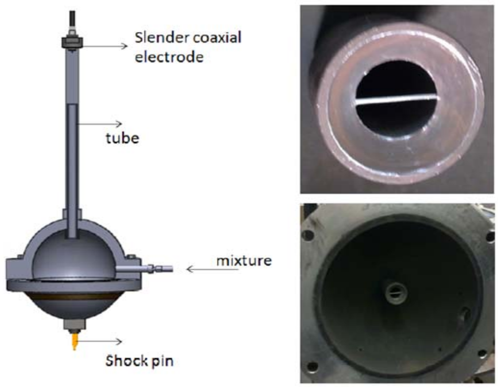


Figure 1. Experimental setup.

Taking into account the manufacturing challenge and durability of the obstacles, a novel perturbation configuration is designed as shown in Fig. 2 instead of using needles as obstacles. The "injector" is made out of a stainless steel cylindrical block. This design retain the symmetry and three blockage ratios of this configuration were studied with *BR* = 0.095, 0.13 and 0.25.

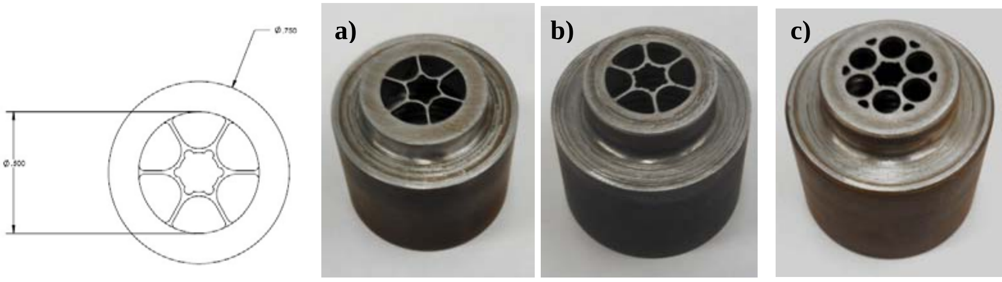


Figure 2. A new perturbation configuration with a) *BR* = 0.095; b) 0.13; and c) 0.25.

## 3 Results and Discussions

Figures 3 first show critical tube diameter results for the stoichiometric $C_2H_2/O_2$ and $C_2H_2/N_2O$ mixtures respectively with needle perturbation of different blockage ratios. These plots summarize the critical pressure limits below which the detonation wave cannot successfully transmit from the confined circular tube to the open area in the spherical chamber. Blockage ratio of zero refers to the unperturbed case. From the results shown in Fig. 3, it is observed that for sufficiently small blockage ratios, the needle obstacles can have a noticeable influence on the critical tube diameter phenomenon by lowering the critical pressure values for the successful transmission. For very high *BR* > 0.18, excess blockage leads to a negative effect of which too much of a momentum loss of the emerging detonation front will not promote the detonation transmission in the open space and actually increases the critical pressure. Furthermore, geometrically increasing the blockage ratio leads to a decrease of the effective tube diameter, thereby causing the increase of critical pressure. It is found for both tested mixtures that the optimal blockage ratio is around 0.10.

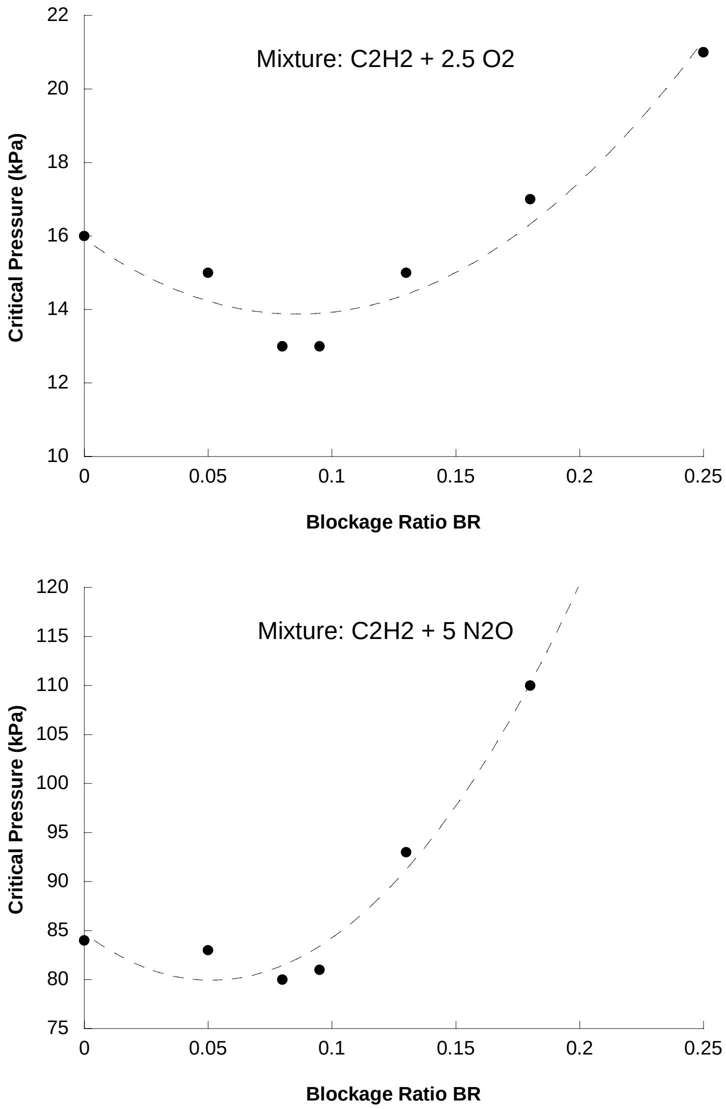


Figure 3. The effect of blockage ratio on the critical pressure for successful transmission. (The dashed line approximates the trend of the experimental results).

Similarly, Figs. 4 present the results for the new "injector" configuration with various *BR* = 0.095, 0.13 and 0.25 showing go/no go data and the critical pressure limits. For each experimental condition (i.e., mixture composition, initial pressure $p_o$ and blockage ratio *BR*), experiment was performed 8 times to ensure repeatability of the results. It is found that these results are in good agreement with those previously obtained with needles, for example, as shown in Fig. 3. In other words, while maintaining a constant blockage ratio, the effect observed using these injectors with symmetrical obstacle arrangements is found similar to those with different needle(s) perturbations, i.e., both showing similar decrease in critical pressure for successful transmission.

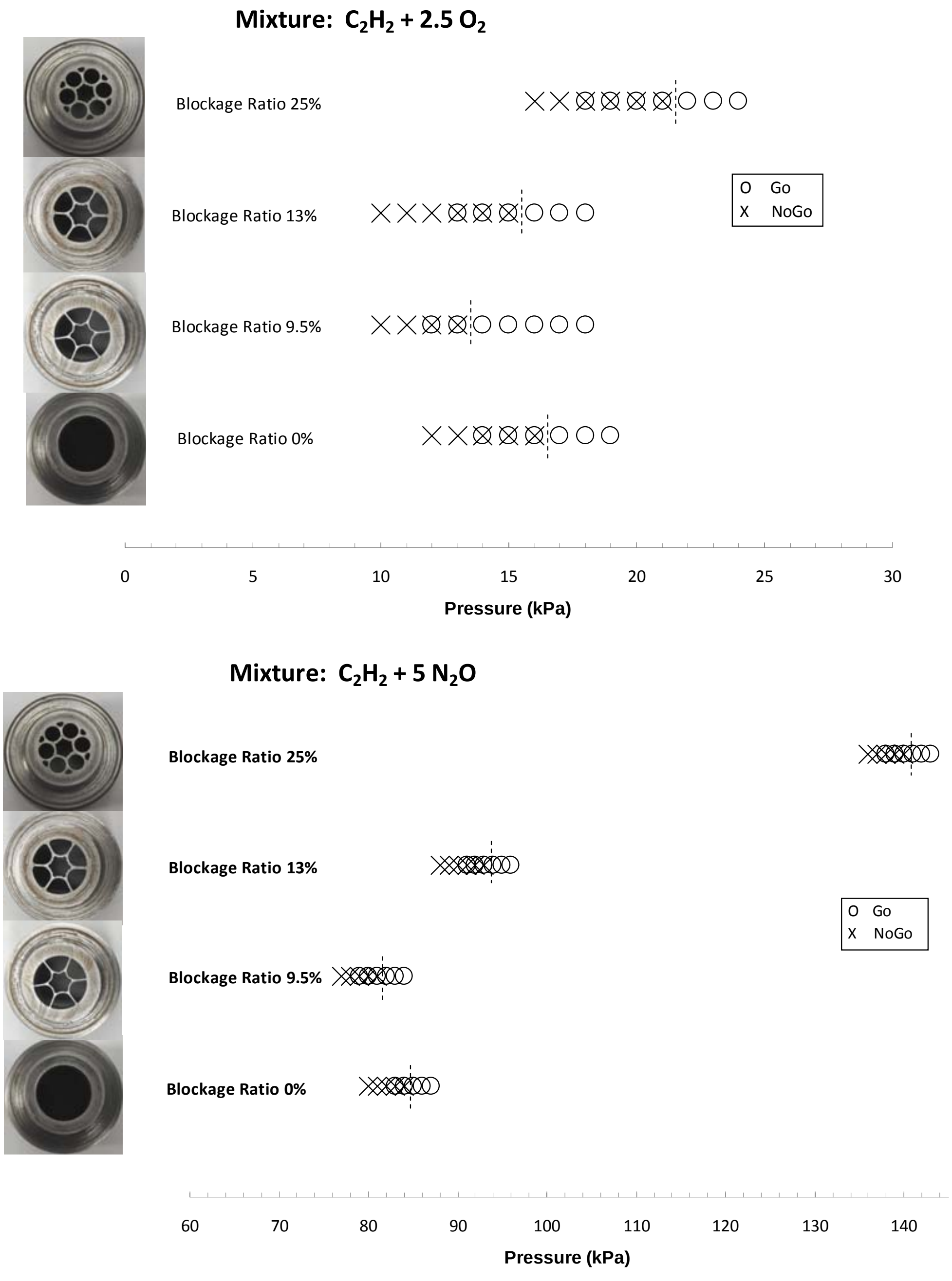


Figure 4. Summary of go/no go results for the two combustible mixtures with different *BR* of the injector.

## 4 Concluding Remarks

In this study, the effect of small perturbation with varying blockage ratio on the critical tube diameter problem is investigated in two unstable mixtures typically with irregular cellular pattern. Perturbation was introduced using both needle(s) insertion at the exit of the tube before the gaseous detonation emerged into the free unconfined space and three “injectors” machined from a stainless steel cylindrical block. In all cases, it is found that the optimal blockage ratio is about 0.10 with largest decrease in critical pressure below which transmission of detonation into free space is unsuccessful. Furthermore, the results indicate that while maintaining a constant blockage ratio, the effect observed with these two different obstacle configurations (i.e., using needles or symmetric injectors) is similar even for the irregular mixtures where all the results show similar decrease (or increase with excess blockage) in critical pressure for successful transmission.

## Acknowledgement

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