Propagation Mode of Detonation Waves in A Narrow Gap

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1. Introduction

A study on propagation ability of detonation waves in a narrow gap is important for safety reasons in terms of detonability limits(1). In the present work, propagation behavior of detonation waves in a narrow gap was studied to clarify its propagation ability for various types of mixtures.

2. Experimental apparatus

The detonation tube used in the present work is a stainless tube of 5330 mm in length and of 50 mm in inner diameter. To form a narrow gap, a pair of stainless plates 47 mm wide and 1500 mm long are inserted in the test section. Two metal spacers are interposed at both side edges of the plates so that a gap width is 2.0 mm. The plates are supported by 15 combination probes(2) which are composed of pressure and ion probes and with which it is possible to detect a shock and a reaction front individually at one measurement point.

An initial pressure was constant of 39 kPa and an equivalence ratio of hydrogen-oxygen mixtures and its dilution rate were varied in order to study effects of cell width on propagation behavior in the narrow gap.

3. Results

Figure 2 shows typical velocity profiles of five propagation modes: (a) stable; (b) quasi-stable; (c) galloping; (d) single spin; (e) failure mode. As for the stable mode, propagation velocity is constant and cell width in the gap has a little variation, although the mean cell width is slightly larger than at the gap entrance. This mode was obtained for hydrogen-oxygen mixtures with f = 0.3 ~ 1.5 and stoichiometric hydrogen-oxygen mixtures diluted with 50 ~70 % argon and with 15~25 % nitrogen, where f denotes equivalence ratio. In the quasi-stable mode, the propagation velocity is almost constant, while cell width shows larger variation. This mode was typical for mixtures of f = 0.2, 1.7, 2.0 and cases of dilution with 40 % nitrogen. For the galloping mode, a large velocity fluctuation of more than ± 500 m/s was usually observed as shown in Fig. 2 (c) and little repeatability was obtained in the velocity profile. Decoupling and Re-coupling of the leading shock and the reaction front correspond to deceleration and acceleration of the waves. This propagation mode was observed for mixtures of f = 2.0 ~ 2.5. For less detonable mixtures, trace of the single spin was obtained on smoked foil records. In this case, the wave propagates almost steadily in the gap and its average velocity is about 60% of the Chapman-Jouguet one.

Figure 3 shows relationship between velocity deficit and gap width normalized by cell width. In the present work, the velocity deficit ΔV was defined by the following equation:

$$\Delta V = (V_0 - \overline{V}) / V_0 \times 100 \,, \qquad (1)$$

where, V_0 and $\overline{V}$ denote propagation velocity at the gap entrance and average propagation velocity in the gap, respectively. Most of mixtures show the same behavior that the velocity

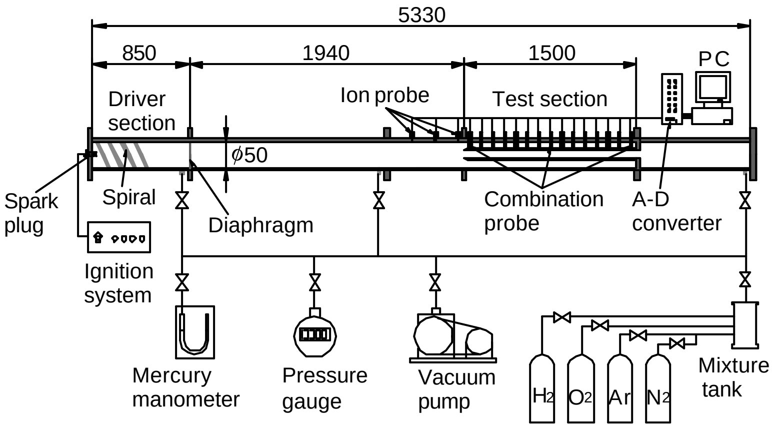

Fig. 1. Schematic of experimental apparatus. Dimensions in mm.

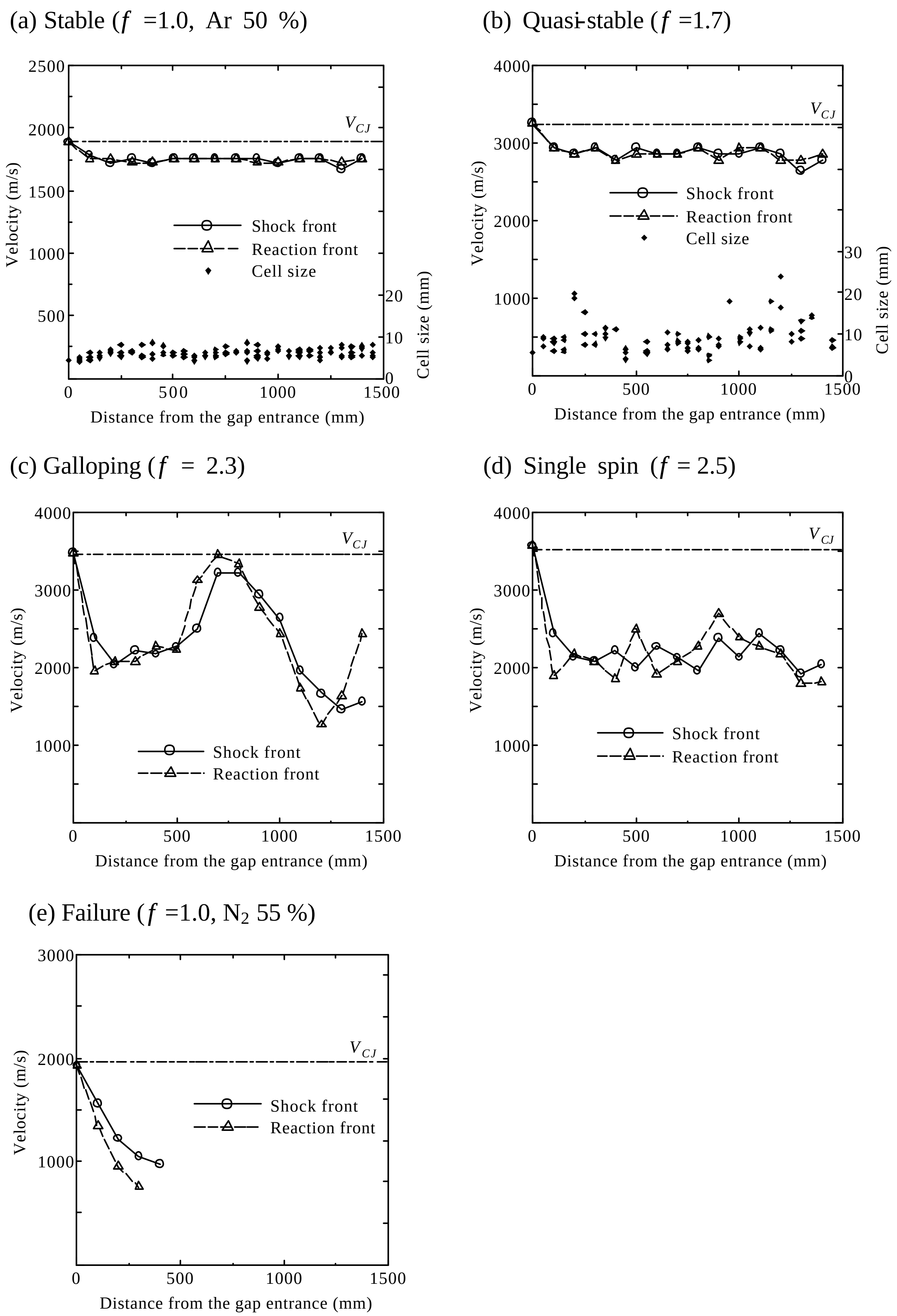

Fig. 2. Velocity profiles of five propagation modes of detonation waves propagating in a narrow gap.

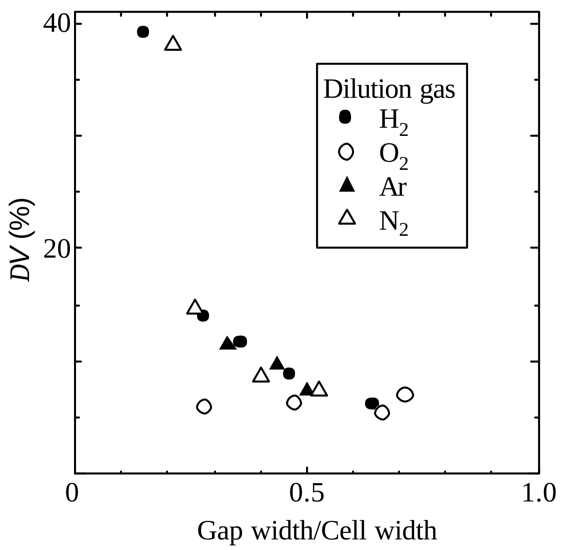

Fig. 3. Relationship between velocity deficit and normalized gap width.

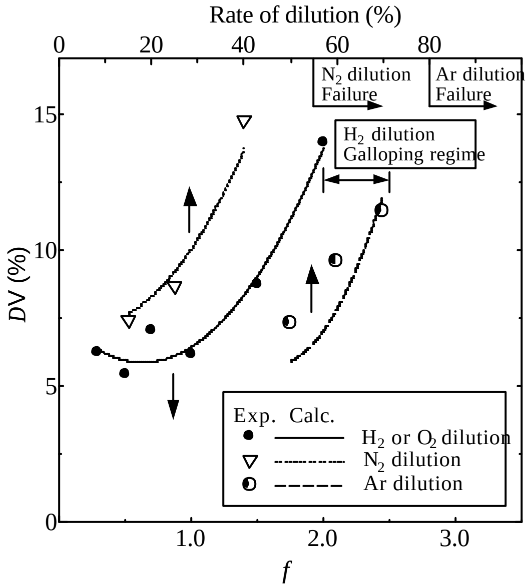

Fig. 4. Velocity deficit for various types of mixtures.

deficit increases with decrease in the normalized gap width, although the velocity deficit has little dependency on dilution rate of oxygen. In Fig. 4, lower velocity deficit is obtained for mixtures diluted with argon as compared to with nitrogen. This corresponds to a difference between nitrogen and argon in the critical dilution rate for which a detonation fails to propagate in the gap.

4. Conclusion

From the velocity profiles and smoked foil records it is found that five propagation modes exist for detonation propagating in a narrow gap, namely stable, quasi-stable, galloping, single spin, failure mode. The velocity deficit is dependent on the gap width normalized by the cell width except mixtures diluted with oxygen.

References

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