모형 연소실에서 분사기 연소 안정성 평가에 관한 실험적 연구

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A Experimental Study on Combustion-Stability Rating in a Subscale Chamber

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ABSTRACT

To predict combustion instability in actual full-scale combustion chamber of rocket engines, air-injection test is proposed with scaling techniques. From the data, damping factors have been obtained as a function of hydraulic parameter and the data give us instability map. Two instability regions are presented and it is found that they coincide reasonably with them from hot-fire test with full-scale flow rates. Accordingly, the proposed approach can be applied cost-effectively to stability rating of jet injectors when mixing of fuel and oxidizer jets is the dominant process in instability triggering..

Key Words : Combustion Instability, Air-Injection, Instability Map

In various combustion chambers, high-frequency combustion instability is the phenomenon that pressure oscillations are amplified through in-phase heat addition/extraction from combustion. Unfavorably, it may lead to an intense pressure fluctuation as well as excessive heat transfer to combustor wall in combustion systems such as solid and liquid propellant rocket engines, ramjets, turbojet thrust augmentors, utility boilers, and furnaces [1-3].

Accordingly, combustion stability is one of design factors which should be checked by engine designers. In this regard, the impact of candidate injectors on stabilities is to be examined for injectors screening at the initial stage of combustor development, and thereby, the suitable injector specification will be selected. For this purpose, it is the best and most reliable method to conduct experimental test using actual (full-scale) combustion chambers to which candidate injectors are mounted. But, it is rather exhaustive method in both viewpoints of cost and time. Especially, considering the recent economic constraint applied even to space-technology program, it is required to find the cost-effective ways to validate each hardware but without losing the essential part of its characteristics. One of them is to use model (sub-scale) chamber instead of actual chamber [2]. For this, the previous works [4-6] proposed the method for hot-fire modelling of high-frequency combustion instability using model chamber and realized the method experimentally. And, the previous numerical work [7] proposed air-injection technique for stability rating.

In the present study, the possibility of stability rating using this scaling technique is examined and stability boundaries are compared with those from the previous works [5, 7].

There is no doubt about the fact that full-scale test is needed to predict combustion instability in an actual combustion chamber. But it is very difficult and expensive way to conduct hot-fire test for actual operation condition in a full-scale combustion chamber. Accordingly, in the present study, a subscale combustion chamber is adopted instead of an actual liquid-propellant rocket combustor and

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air is injected instead of actual propellants. Based on the scaling method [2, 4, 5], the geometric dimensions of the model chamber should be chosen to provide the same natural frequencies in a subscale or model chamber as those in an actual chamber.

The experimental setup for air injection is manufactured. A five-injector unit is mounted on the plate, so that the injector exit is flush with the plate surface. The chamber operates at atmospheric pressure and can move freely on the injector-faceplate simulator. Both the oxidizer and the fuel are simulated by air in this test. For hydrodynamic similarity, the velocity ratio of fuel to oxidizer is maintained as discussed in the previous work [7]. Air is supplied through both oxidizer and fuel feed lines at room temperature.

Acoustic-pressure responses at the monitoring point are measured and calculated as a function of time and its FFT spectrum is obtained. This study is focused on the first tangential (1T) mode.

Damping factors are obtained for the various conditions. Local minimum points in damping factor correspond to the points on the stability boundary. They are transformed on to several coordinate planes. Two unstable regions can be identified. Both regions are outside the operating window, but the stability margins are not so large.

The experimental and numerical data are in a good agreement with each other with respect to stability boundary. The present unstable regions can scale up to the actual value. The data scaled up are in a good agreement with hot-fire test data. Therefore, these points verify that it is useful to predict combustion stability boundaries using scaling techniques.

To predict combustion instability in actual full-scale combustion chamber of rocket engines, air-injection test is proposed with scaling techniques. Damping factors have been obtained as a function of hydraulic parameter and the data give us instability map. Two instability regions are presented and it is found that they coincide reasonably with them from hot-fire test with full-scale flow rates. Accordingly, the proposed approach can be applied cost-effectively to stability rating of jet injectors when mixing of fuel and oxidizer jets is the dominant process in instability triggering.

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