NOx reduction mechanism in an acoustically driven dump combustor

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Abstract

NOx reduction mechanism in an acoustically driven dump combustor was investigated experimentally and numerically. In a non-premixed type dump combustor, detailed measurements on the turbulence characteristics, temperature distribution and NOx emission were carried out with and without Acoustic Excitation (AE, hereafter) (Fig. 1).

The flame is confined within the shear layer that is formed by the velocity difference between the recirculation zone and potential core of the oxidizer. A hole exists in the center of the flame and the flame has no direct contact with the wall. Thus, the flame has the shape of a hollow tube (Fig. 2).

The applied AE increases the turbulence intensity and decreases the centerline velocity, which enhance the mixing and the consumption of fuel. As the results, the flame moves upstream and the

volume of high temperature region shrinks. With the AE NOx starts to form more quickly however the exhaust level has been lowered, which accords with the modified temperature field by the AE (Fig. 3).

From the experimental results such as, for example, the flame structure, we judged that a one-dimensional simulation along the shear layer axis (r = 7.5 mm) is appropriate rather than multi-dimensional ones. The simulation code was based upon Linear Eddy Model (LEM) and sub-models like Eddy Break Up (EBU) model, Zeldovich mechanism, and etc. Input variables for the simulation were extracted from the experimental data. The numerical predictions of NOx emission and temperature are in good agreement with those obtained in the experiment (Fig. 4).

In order to reveal NOx reduction mechanism with the AE, a series of numerical simulations was conducted. The methodology is the following; Set any given conditions as the basis. Change one parameter and its closely related parameters while keeping the others constant. In doing so, parameters concerned with the turbulence were decoupled in the numerical simulations and their effects could be investigated independently.

The increased turbulent intensity that affects the turbulent reaction rate elevates the temperature, especially after the temperature reaches the maximum. The decreased shear layer length that implies the shrinkage of flame volume has similar effects to those of the increased turbulent intensity. On the contrary, the increased cold fluid entrainment lowers the temperature significantly (Fig. 5).

Therefore, the NOx reduction mechanism with the AE can be understood like the following: The cold fluid entrainment suppresses excessive temperature rise while the increased turbulent reaction rate and shortened shear layer enhances the consumption of fuel more rapidly and reduces the volume of reaction zone. We concluded that NOx reduction mechanism in an acoustically driven dump combustor is the decrease of residence time at high temperature region. Also we would like to emphasize the importance of cold fluid entrainment that has the key concern on temperature control and thus NOx emission control.

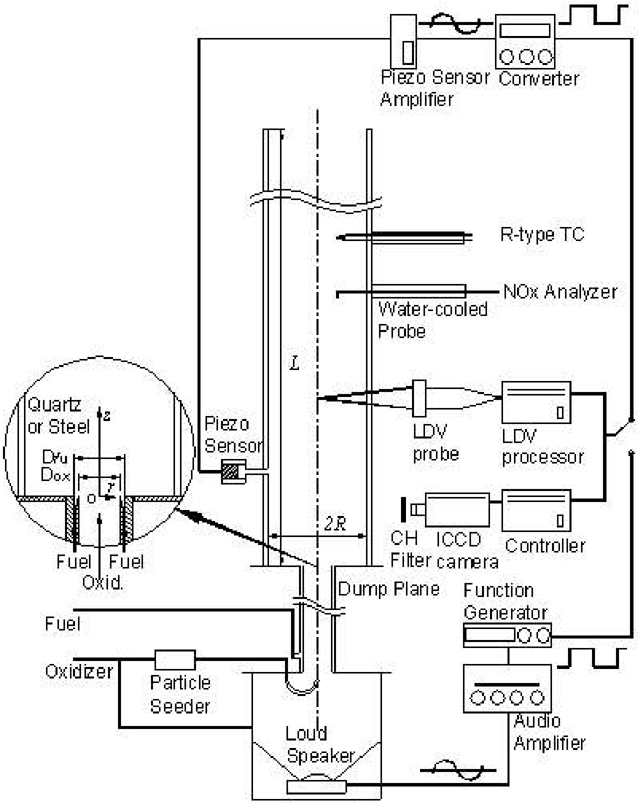
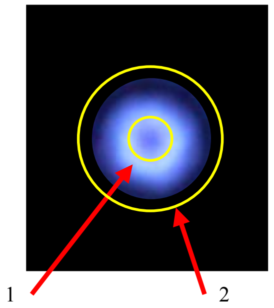


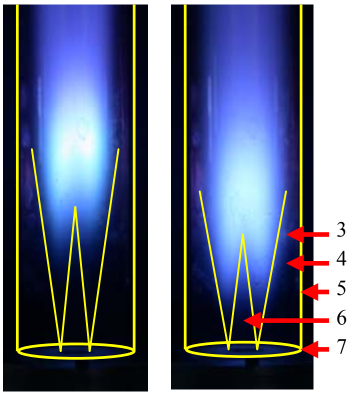
Fig. 1 Schematic diagram of the experimental apparatus

L = 0.8 m, $2R$ = 50 mm

D_{fu} = 17.2 mm, D_{ox} = 14.0 mm



(a) top view



(b) front view, w/o AE (c) front view, w/ AE

Fig. 2 Flame and flow structure by direct photographs (AE : Acoustic Excitation)

1. Oxidizer nozzle 2. Periphery of the dump plane 3. Shear layer boundary 4. Recirculation zone 5. Combustor wall 6. Potential core 7. Dump plane

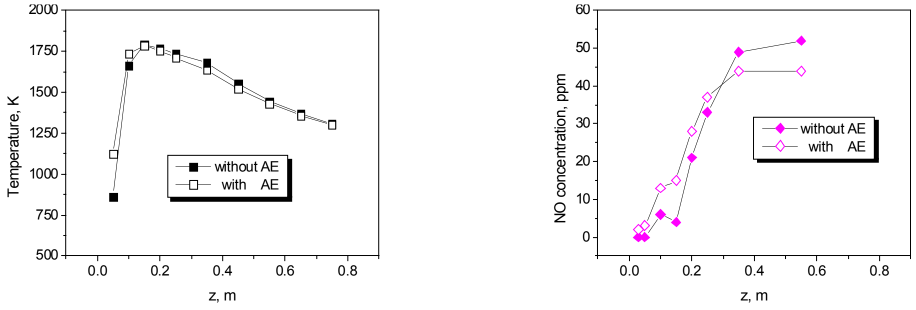


Fig. 3 Measured temperature and NO concentration along the shear layer axis (r = 7.5 mm)

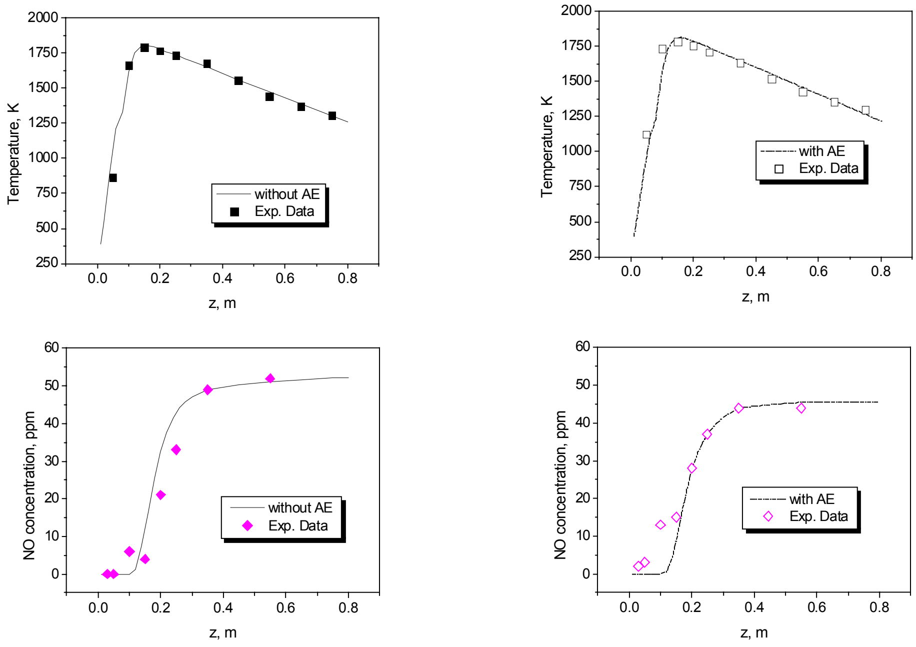
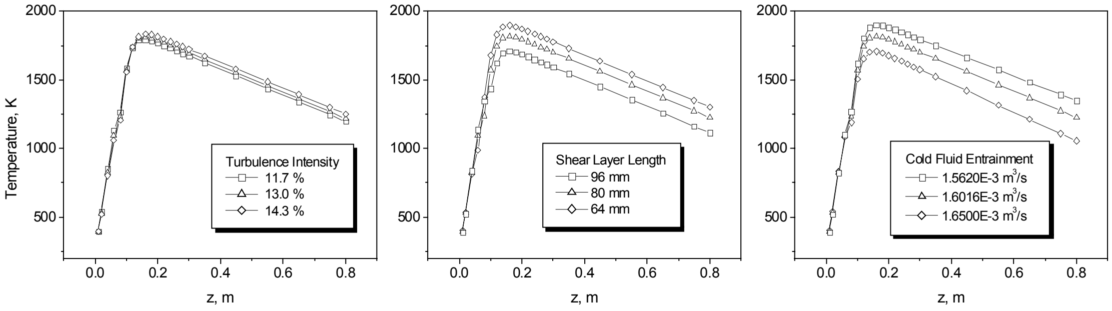


Fig. 4 Numerical prediction of the experimental results



(a) (b) (c)

Fig. 5 Numerical simulations on the changes in (a) turbulent intensity (b) shear layer length (c) cold fluid entrainment