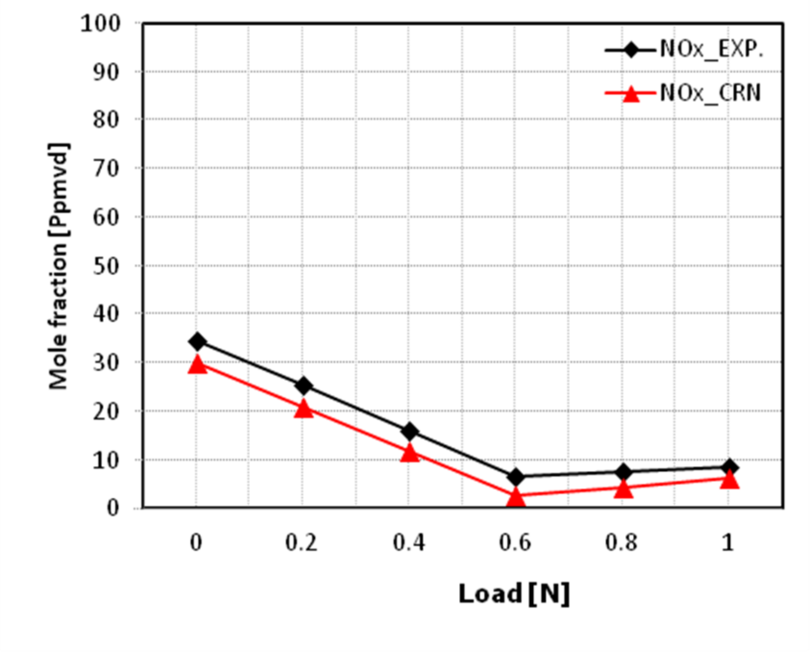

Figure 9. Non-uniformity Mole Fraction of NOx in Hot Condition

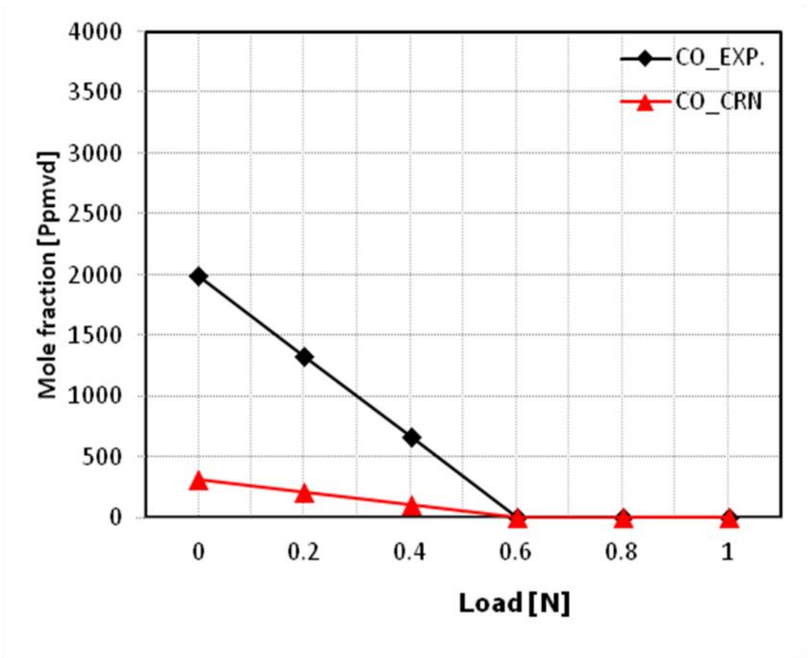

Figure 10. Non-uniformity Mole Fraction of CO in Normal Condition

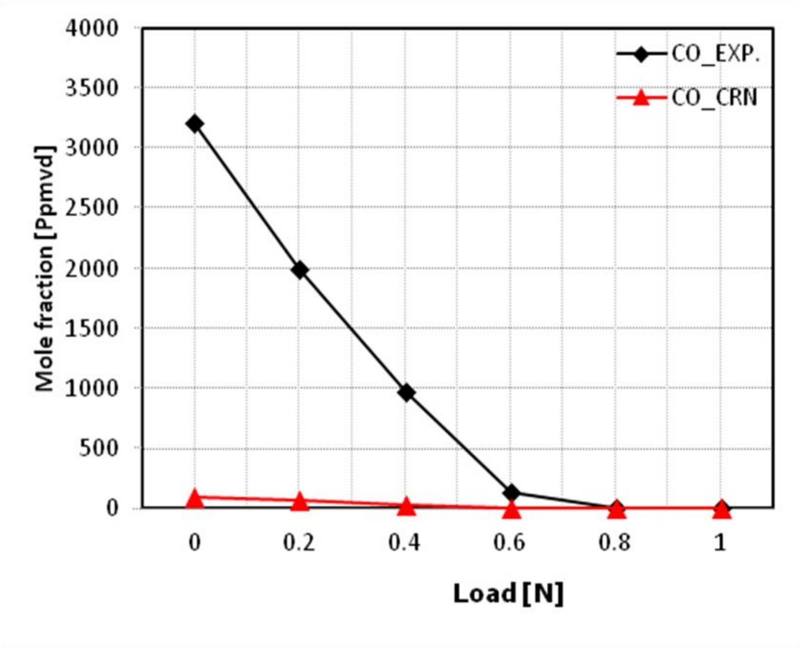

Figure 11. Non-uniformity Mole Fraction of CO in Cold Condition

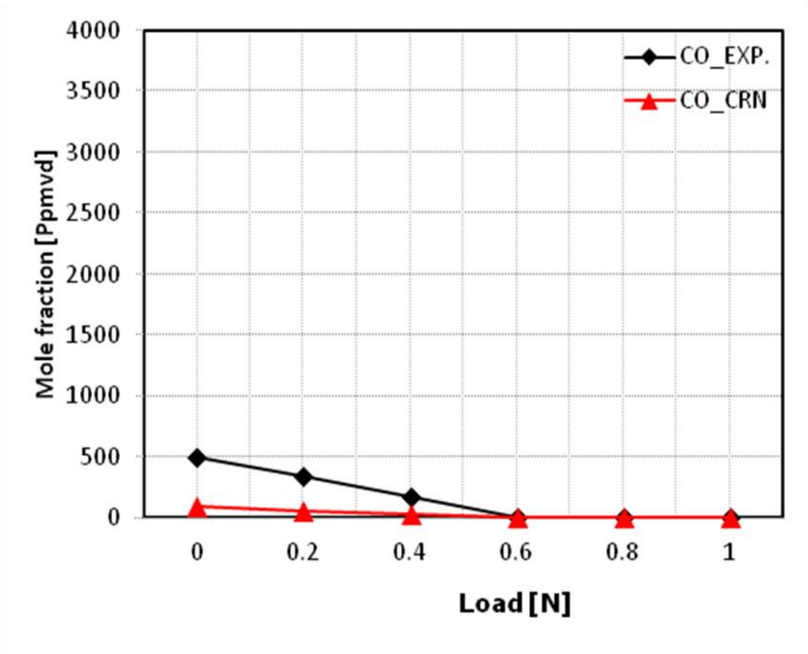

Figure 12. Non-uniformity Mole Fraction of CO in Hot Condition

The mole fraction of NOx in the normal condition is shown in Figure 7. The figure also shows the differences of each mole fraction of the NOx formation mechanism. The largest mole fraction of the NOx formation is at the idle load. The mole fraction of the NOx formation at the 0.6N load is lower than the idle load. Finally, the mole fraction of the NOx formation at the 0.8N load and the 1.0N load is equal to zero. At the 0.8N load and the 1.0N load cases, the temperature in the flame is high enough to trigger the thermal NOx production (Figure 4), so the mole fraction of NOx is low. However, the mole fraction of NOx that is exposed to this temperature is relatively small. Thus, the lowest mole fraction of the NOx formation is at the 0.8N load.

The mole fraction of NOx in the cold condition is shown in Figure 8. The figure also shows the contributions of each mole fraction of the NOx formation mechanism. The largest mole fraction of the NOx formation is at the 0.6N load. The mole fraction of the NOx formation at the 0.8N load is lower than the 0.6N load. Finally, the lowest mole fraction of the NOx formation is at the 1.0N load. The differences of the mole fraction of NOx compared to the normal condition show better results.

The mole fraction of NOx in the hot condition is shown in Figure 9. The largest mole fraction of the NOx formation is at the idle load. The mole fraction of the NOx formation at the 0.6N load and the 0.8N load is lower than the idle load. The differences of mole fraction of NOx in the 0.6N load and the 0.8N load between the experiment and the CRN simulation are zero.

Although the pilot flame has high temperature and species concentration as shown in Figure 7-9, a lot of NOx can be seen. The formation of NOx in the gas turbine combustor non-uniform inlet was applied using new modified CRN to predict the NOx emission, which is closer to the experimental data than the uniform inlet combustor, especially near the idle load.

Figures 10 ÷ 12 are used to show the mole fraction of the CO results in three CRN model conditions. The amount of CO at the low load appears significantly higher than others. Especially the mole fraction of CO in the cold condition is highest. The effect of the temperature on the formation of CO into the turbine combustor plays the role of the great importance.

The CO emission at the exit of the turbine combustor is essentially depended on the overall fuel-air equivalent ratio of the idle load, the 0.6N load, the 0.8N load, and the 1.0N load. The formation of CO in the gas turbine combustor non-uniform inlet was applied using new modified CRN to predict the CO emission, which is closer to the experimental data, especially near the 1.0N load.

Conclusions

The new CRN mechanism has been applied the CFD modeling of the gas turbine combustor in order to obtain the insight on the flow, the temperature, and the species fields. The flow field information from the gas turbine combustor CFD has been analyzed to determine the combustion zones in the combustor. These zones are modeled as the chemical reactor elements in CRN. The methodology of CRN development is determined based on the agreement between CFD and CRN models.

The new CRN model using the 24-idealized reactor scheme modeling has been developed based on the CFD results for the gas turbine combustor with the overall fuel-air equivalent ratio of the idle load, the 0.6N load, the 0.8N load, and the 1.0N load. The formation of the NOx and CO emissions in the turbine combustor non-uniform inlet prediction is closer to the experimental data, especially at the low overall equivalent ratio. This research has shown that:

- The combined CFD and CRN approach shows the ability to accurately predict the NOx and CO emissions for the lean premixed gas turbine combustor.
- The new CRN model by applying the non-uniform inlet is able to predict the NOx and CO emissions more accurate than the uniform inlet.
- The new CRN model can also be applied to the industrial combustors. The resulting CRN incorporates the important flow features and the boundary conditions such as: the fuel-air distribution, the velocity profile, the entrainment of the main recirculation zone and the main flame.

Nomenclature

CRN : Chemical Reactor Network
CFD : Computational Fluid Dynamic
CFM : Coherent Flame Model
EBU : Eddy Break Up
PPDF : Presumed Probability Density Function
CH_4 : Methane
CO : Carbon monoxide
NOx : Nitrogen oxides
K : Kelvin temperature scale
g_i : Gravitational acceleration component in direction x_i
k : Turbulent kinetic energy
P : Production term generation by normal stresses
P_B : Production term generation by buoyancy forces
P_{NL} : Production term generation by nonlinear models
S_{ij} : The mean strain
u_i : Absolute fluid velocity component in direction x_i
u_i' : Fluctuation fluid velocity component in direction x_i
ε : Dissipation rate of the turbulent energy
μ : Gas viscosity
μ_t : Turbulent viscosity
ρ : Gas density
$\sigma_{h,t}$: Turbulent Prandtl number

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