Turbine System Driven by Direct Combustion of Rich Ammonia (Vol. 2)

Ammonia, which does not emit CO_2 as flue gas, is attracting attention as a fuel for large gas turbines for power generation. To evaluate output and efficiency of turbines, more accurate improved evaluation method was developed based on chemical equilibrium calculations to minimize the total free energy of the working fluid, instead of conventional simple method assuming working fluid as air. Applying the newly developed method, an ammonia-fueled turbine system was evaluated in terms of combustion efficiency and reduction of NO emission under excess ammonia condition. The performance of the turbine system was also compared with a hydrogen-fueled turbine system.

- An ammonia-only combined cycle under excess fuel condition is shown feasible even by the newly developed more accurate evaluation method. The estimated output was higher than that by the previous estimation [1].
- At an inlet temperature of 2,000K and a pressure ratio of 25, under normal lean NH_3 fuel condition, the thermal efficiency of the turbine was 0.63 and the NO concentration of the exhaust was 4,300ppm, whereas under excess NH_3 fuel condition, the thermal efficiency dropped to 0.63 but NO concentration showed double-digit improvement to 13ppm.
- The new method also showed that excess H_2 fueled combined cycle is feasible for the first time. The thermal efficiency of the cycle was 0.50 and NO concentration was 49 ppm.
- Not only with lower thermal efficiency and higher NO concentration, but also with the need for a larger amount of exhaust gas recirculation (larger EGR rate) than the NH_3 fueled combined cycle, H_2 fueled combined cycle has no advantage over NH_3 fueled cycle.

Table 1: Power and thermal efficiency with turbine inlet at 2,000 K

Fuel	Pressure Ratio	Equivalent Ratio	EGR Rate	Output[b] (MW)	Thermal Efficiency	NO (ppm)
NH_3	25	0.61	0	318	0.63	4,324
NH_3	25	1.52	0.2	504	0.53	41
NH_3	25	1.31	0.4	417	0.56	9.6
NH_3	25	1.08	0.6	340	0.60	13
NH_3	20	0.641	0	324	0.61	4,135
NH_3	20	1.67	0	581	0.50	109
NH_3	20	1.45	0.2	482	0.53	38
NH_3	20	1.22	0.4	395	0.56	7.6
H_2	25	0.47	0	296	0.61	5,314
H_2	25	1.74	0.8[a]	506	0.50	48.8
H_2	25	1.46	0.9[a]	434	0.53	52.4
H_2	20	0.49	0	303	0.60	5,189
H_2	20	1.79	0.7[a]	530	0.49	80
H_2	20	1.51	0.8[a]	457	0.51	29.1

a) EGR gas composition: N_2/H_2=0.75/0.25, b) Upper cycle flow rate 300 kg/s

Proposals for Policy Development

The ammonia rich combined turbine system could be a major breakthrough as a CO_2-free high-powered power generation system. To realize the system, a new combustor design is necessary, which will require large amounts of time and money.

1) A design and feasibility study of the turbine combustor need to be conducted by a team of experts. This would take around one year.
2) A national project needs to be implemented involving multiple companies with a proven track record with turbine systems.

[1] LCS Proposal Paper for Innovation Policy Development "Turbine System Driven by Direct Combustion of Rich Ammonia" Dec. 2018.