varies as the inlet mach. The non-equilibrium effects can be neglected when the inlet mach is 2.5, while the push calculated is nearly 15% higher considered the chemical reaction process than in the frozen flow when the inlet mach is 1.5. As there are more dissociated components with higher temperature at the inlet, more dissociation energy releases during the process because of the higher temperature. The effects are small when the mach is 2.5, because the less of the dissociated components.

TABLE IV. NOZZLE PERFORMANCE AT DIFFERENT INLET MACH

		Frozen Flow	**Non-equilibrium Flow**	**Ratio of Increase**
Inlet Mach 2.5	***Fx (N)***	680.46	681.80	0.20%
	Fy (N)	2381.59	2386.84	0.22%
	M (Nm)	1285.07	1288.70	0.28%
Inlet Mach 2.0	***Fx (N)***	1730.35	1799.93	4.02%
	Fy (N)	4756.56	4939.47	3.85%
	M (Nm)	3723.29	3862.01	3.73%
Inlet Mach 1.5	***Fx (N)***	3475.31	3991.84	14.86%
	Fy (N)	7943.41	8991.94	13.20%
	M (Nm)	8258.40	9196.51	11.36%

C. Influence of Fule Equivalence Ratio to the Chemical Non-equilibrium Effects

According to the calculated results of the up-wall push about the sample problem with varied fuel equivalence ratios from 0.6 to 1.4 shown in Table Ⅴ, the chemical non-equilibrium effects on the nozzle performance and the ratio are related. Compared the increase ratios of the push calculated in different flow models, the non-equilibrium effects are more significant when the fuel equivalence value closer to 1. The components at the inlet vary with the fuel equivalence ratio, thus the quantity of dissociated components what would recombine during the expansion has been changed. The chemical non-equilibrium effects would be greater when the equivalence ratio closer to 1 with more recombination.

TABLE V. NOZZLE PUSH PERFORMANCE COMPARED

Equivalence Ratio	***Fx (N)*** **in Frozen Flow**	***Fx (N)*** **in Non-equilibrium Flow**	**Ratio of Increase**
0.6	1707.43	1752.33	2.63%
0.8	1721.39	1777.13	3.24%
1.0	1730.35	1799.93	4.02%
1.2	1692.78	1747.47	3.23%
1.4	1714.48	1755.91	2.42%

V. SUMMARY

The chemical non-equilibrium has obviously effects on the nozzle performance, because of the radical recombination during the expansion in the hydrocarbon scramjet nozzle. The performance calculated about chemical non-equilibrium is 4% greater than that in frozen model.

The main component in radical recombination is CO_2 and the mass fraction of CO_2 has a visible increase during the expansion, while the recombination of H_2O is tiny.

The chemical non-equilibrium effects relate to the inlet mach and the fuel equivalence ratio. The effects are more obvious when the inlet mach decrease, and the effect would be greater when the equivalence ratio closer to 1.

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