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Numerical Analysis on the Plume Effect on the Interstage Separation of a Launch Vehicle

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ABSTRACT

An interstage of several launch vehicles is separated as the launch sequence after the stage separation to fulfill the design requirements even though both the upper and the lower stages are already separated. In this numerical study, the engine plume effects on this interstage separation are predicted using CFD approaches. The engine plume affects the separation motion of an interstage as soon as an interstage moving by the initial spring force meets the plume from the engine nozzle exit. And the engine plume helps the safe separation without the collision between an interstage and a main stage since an interstage moves through the engine plume and the engine plume plays a role as a damper to avoid a collision.

1. INTRODUCTION

An interstage of several launch vehicles is sometimes divided additionally to match the design requirements like the weight limit even though both the upper and the lower stage are already separated. The engine plume effects on this interstage separation are presented with CFD approaches in this paper.

2. Numerical Results

The commercial CFD solver STAR-CCM+ is used to calculate the engine plume effects on the separation between an interstage and a main stage. Standard air is assumed as a working fluid in this rocket engine neglecting the chemical reactions. And Air pressure of 100 Pa and air temperature of 300K around both a main stage and an interstage are used for the atmosphere conditions. Relative motion between both bodies is only considered neglecting the flight velocity. Spring force to set up this

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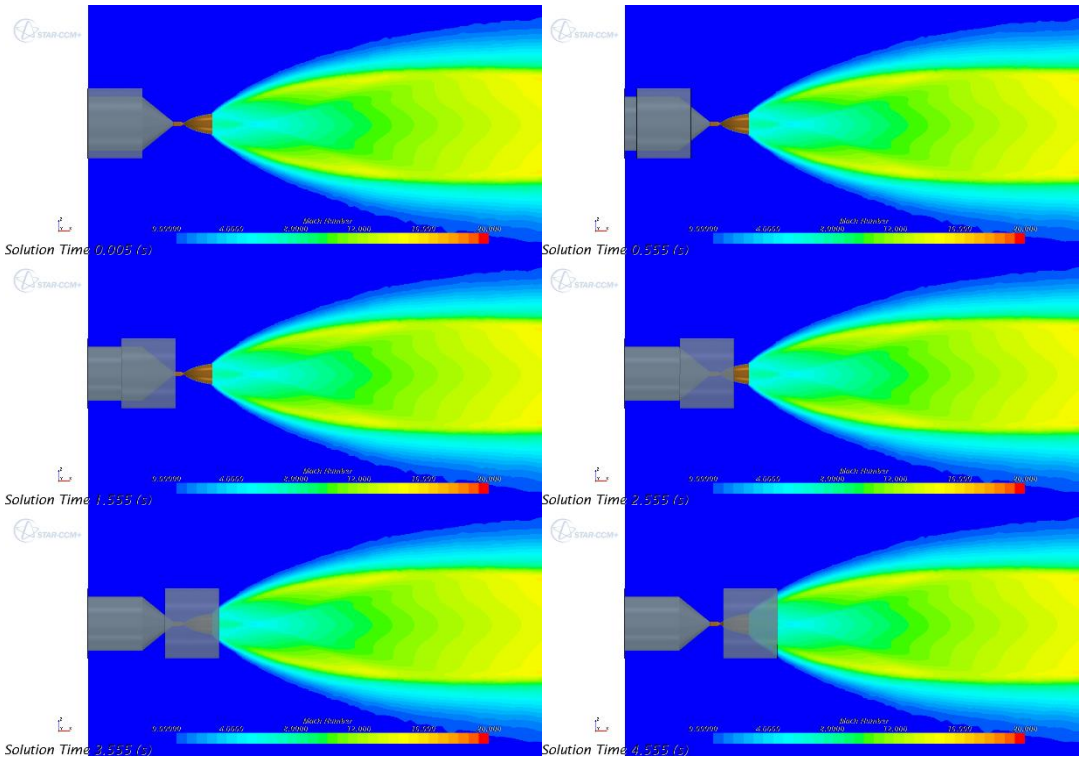
interstage separation and additional initial angular velocity to simulate severe separation conditions are also applied in this study.

2.1 Case 1 : Initial Angular Velocity 0.0 degree/s

Fig. 1 shows that an interstage moves in a straight line until an interstage meets the engine plume since initial angular velocity 0.0 degree/s. But an interstage shakes a little bit as soon as an interstage encounters the engine plume. Meanwhile, the engine plume is not symmetry in x-y plane since an engine nozzle deflection angle by z-axis is not zero degree. An interstage is, therefore, in pitch motion while an interstage is in the region of the engine plume. But the pitch angle decreases and an interstage moves stably downstream following the thrust axis.



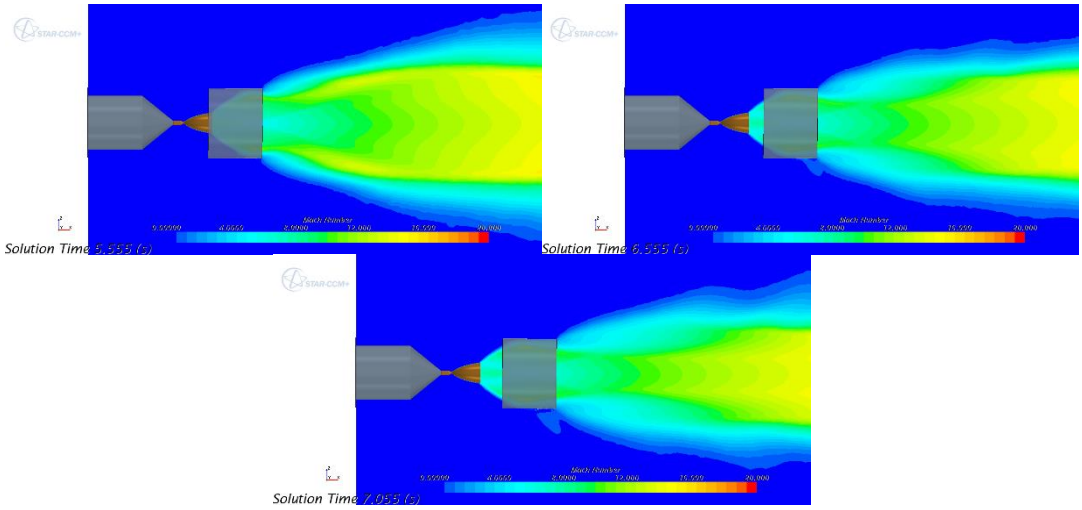


Fig. 1 Interstage separation for the initial angular velocity 0.0 degree/s

2.2 Case 2 : Initial Angular Velocity 1.0 degree/s

Fig. 2 shows that the pitch angle of an interstage for this case is bigger than one for the initial angular velocity 0.0 degree/s before an interstage meets the engine plume. And at the beginning of the intersection between an interstage and the engine plume, the amplitude of the pitch motion for an interstage is not low. But the amplitude of the pitch motion decreases and an interstage moves through the thrust line as time passes. The distance between an intersage and a main stage diminishes if the engine plume does not exist and the collision between an interstage and a main stage can occur unfortunately. But the engine plume makes the proper distance between an interstage and a main stage maintain and prevents an interstage from running into a main stage. Fig. 3 indicates the variations of the aerodynamic loads and moments on an interstage as time passes. The aerodynamic loads and moments are approximately zero before an interstage meets the engine plume and increase after an interstage intersects the engine plume.

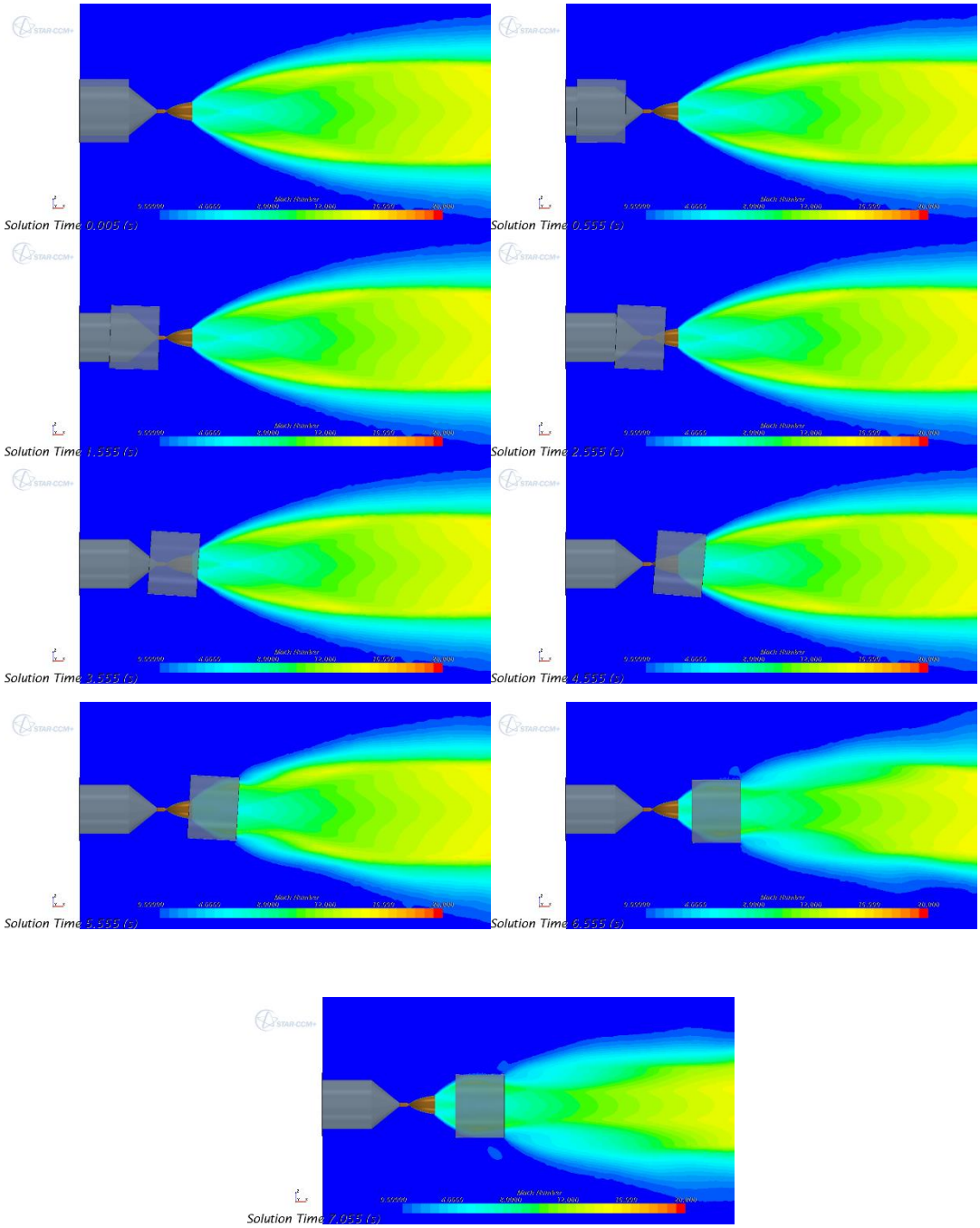


Fig. 2 Interstage separation for the initial angular velocity 1.0 degree/s

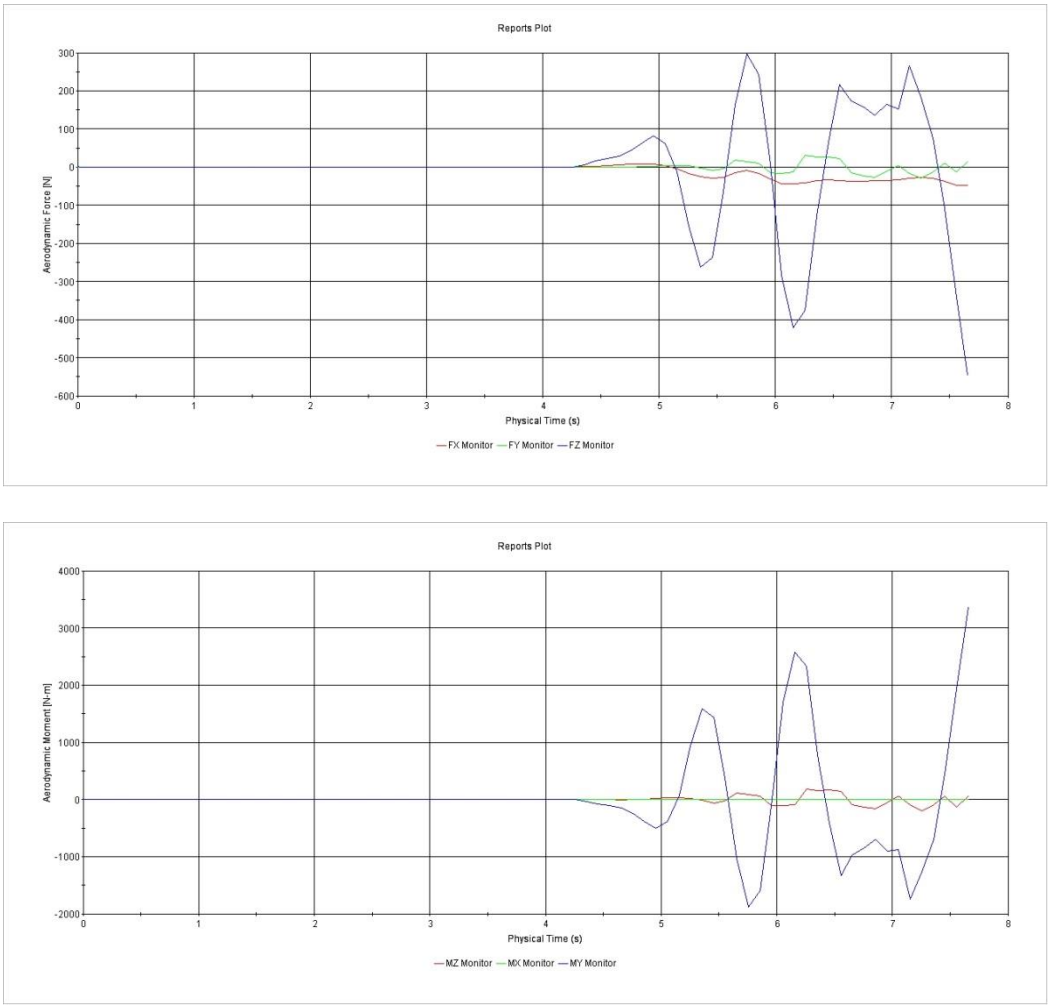


Fig. 3 Aerodynamic forces and moments for the initial angular velocity 1.0 degree/s

3. CONCLUSIONS

The engine plume effects on the separation between an interstage and a main stage are calculated using the numerical approaches. The engine plume affects the separation motion of an interstage as soon as an interstage meets the engine plume near the nozzle exit. Meanwhile, even though the plume expansion angle increases and an interstage meets the engine plume in front of the nozzle exit, there will be probably no collision between an interstage and a main stage since the engine plume plays a role as a damper to avoid a collision.

REFERENCES

CD-adapco (2015), “USER GUIDE STAR-CCM+”.