Supersonic Turbulent Flow Analysis for the Base Flow over Multistep Afterbodies of Axisymmetyric Body

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Abstract

Drag is one of the most important factors to consider in the configuration design of launchers, missiles, and other vehicles. The total drag of the vehicle is composed of pressure and friction drag. Friction drag is closely related to the surface area of the vehicle, so unless the system requirements are changed, it is hard to reduce friction drag. If the geometries of main body and pins are changed to reduce the total drag, it can greatly affect the basic functions of each component and the characteristics of flight stability. On the other hand, pressure drag is closely related to the shapes of the leading edge and trailing edge, it does not affect the overall characteristics of the configuration of vehicle.

At high speeds, the base drag of afterbody comprises over 50% of the total drag. To reduce the base drag, we need to predict the base pressure accurately. Numerical analysis was performed to characterize the turbulent flow including base region, and the results were used to analyze the geometries of afterbodies that could reduce the base drag. The base drag produced by afterbodies can be reduced by the following methods: boat tail, base bleed, ventilated cavity, blunt base, mass injection, and multistep afterbody. Herrin & Dutton performed experiments for the base flow of a vehicle. Based on their experimental results, numerical analyses were carried out by Sahu, Chuang & Chieng, J. S. Kim & N. E. Park, and Kim & Park . P. R. Viswanath carried out experiments on multistep afterbody.

Supersonic simple base flow of a launch vehicle is characterized primarily by the formation of expansion waves at the corner of the base and formation of recompression waves at the wake. The turbulent boundary layer that develops on the wall splits at the corner of base into a recirculating flow and free shear layer. Then, the flow develops a rear wake at the reattachment point on the axisymmetric axes. For the case of the flow over a multistep afterbody, such simple base flow becomes complex, consisting of expansion waves, toroidal vortices, recompression waves, free shear layers and so on, at each step of a multistep afterbody, as shown in Fig. 1.

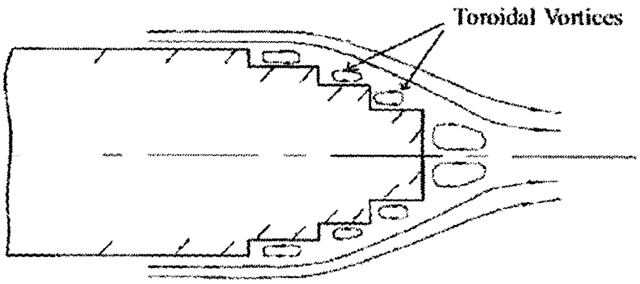

Fig. 1. Flow over a multistep afterbody

In this study, the supersonic turbulent base flow over multistep afterbody, including expansion waves, recirculating flow, recompression waves, shear layer and so on, were investigated. The turbulence model is the Jones-Launder $\kappa - \varepsilon$ model equation with Sarkar correction term. HLLE technique of a second order accurate upwind scheme and a two-step second order accurate scheme is used to discritize space and time derivatives on rectangular unstructured adaptive meshes, respectively. The flow characteristics according to multistep shape, in terms of height and width, were analyzed to compare pressure drag reduction. Numerical results for the flow characteristics of afterbodies including an oblique shock wave, the shear layer, the recirculating flow, and the reattachment point, were compared with experimental results.