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Unsteady Computational Analysis of Supersonic Underexpanded Jet Impinging on an Inclined Flat Plate

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ABSTRACT

Payload oscillation due to strong acoustics emitted from rocket plume is one of the most significant problems in rocket launch. It is known that the rocket plume produces strong acoustics when it impinges the rocket plume deflector. Therefore, it is important to understand this phenomenon, which can be modelled with a supersonic jet impinging on an included flat plate.

Supersonic jet impinging on an inclined flat plate was experimentally studied by P. J. Lamont and B. L. Hunt[1]. They measured the pressure on the plate surface with pressure taps and visualized the flow fields with shadow graph method. However, the surface pressure data were limited because they are measured on discrete points. Nakai et al.[2] conducted experimental study of the jet impingement on an included flat plate using pressure sensitive paint and Schlieren method. Based on continuous surface pressure data on the plate and the Schlieren images, they classified the flow fields into three types, corresponding to the different shock wave structures (Figure. 1). This classification enables flow type prediction if pressure ratio, the inclined angle of the plate, and the nozzle-plate distance are given. These past researches, however, only steady phenomena are analyzed. Therefore, unsteady phenomena of the supersonic jet impingement, which are key mechanism of acoustics emission, are not well-known.

An objective of the present research is to understand unsteady flow phenomena of the supersonic jet impingement using computational fluid dynamics. So far, steady flow structures have been clarified using RANS simulation, where unsteady flow structure will be analyzed using high resolution scheme. In this abstract, steady analysis of the jet impingement is shown.

In Figure 2, pressure distributions at the pressure ratio PR=7.4 for four different plate angles and four different plate distances are shown as an example. Some cases have a single peak and some cases have a few different types of peaks. In these cases, there observed are four types of pressure peaks; (1) stagnation point of the main stream, (2) strong shock waves in the upstream area, (3) reattachment of the detached flow and (4) interaction between the intermediate tail shock and the boundary layer. Figure 3 shows the flow structure detail about the second type of pressure peaks found through the analysis of the simulation results. Flow structure and the associated pressure peaks are much better understood with analyzing flow field is analyzed using each whole the three-dimensional data of many cases. In addition, flow fields are classified into finer six types with investigating whether these peaks are present or not.

In the final paper, unsteady analysis of the jet impingement will be presented.

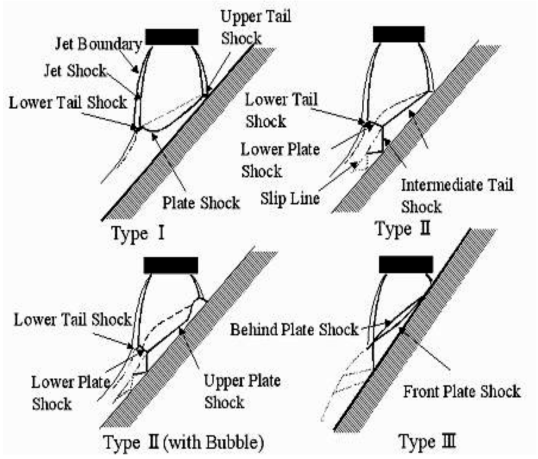

Figure 1. Schematic pictures of typical flow fields for various plate-angle (*PR*>4).

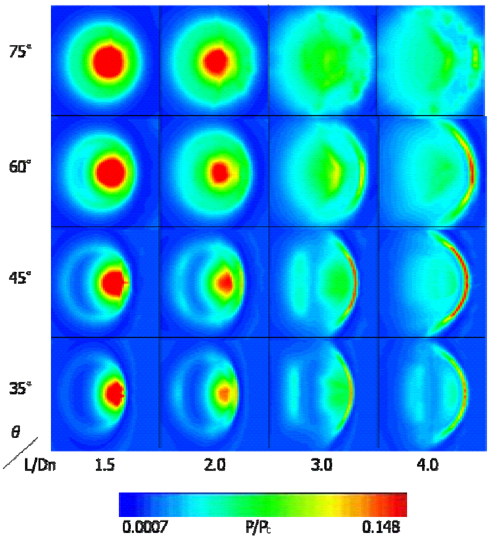

Figure 2. Pressure contours on the plate surface for *PR*=7.4.

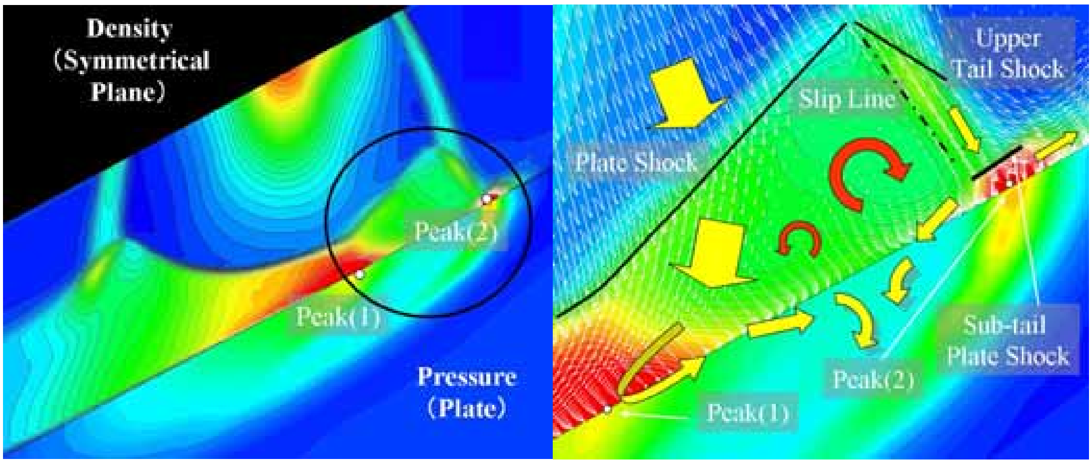

Figure 3. Mechanism of the pressure peak (2) (PR=7.4, L/Dn=3.0, θ=60°)

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