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NUMERICAL ANALYSIS OF SHOCK WAVES BEHAVIOR AROUND AERODYNAMIC DECELERATOR FOR MARS PLANETARY PROBE

Mirai SUEKI*, Toshiharu MIZUKAKI**
***MC Student, Graduate School of Engineering, Tokai University,**
****School of Engineering, Tokai University**

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Abstract

The present paper describes results of numerical analyses on supersonic flow field, at around a supersonic parachute as deceleration device for planetary probes. In this report, the analyses were focused on the flow field around supersonic parachute. A commercially available hydro-code, AUTODYN (ANSYS) was employed for the analyses. 2D axial symmetry simulations and 3D simulation around rigid body like a parachute were carried out. The results clearly show the flow field including shock waves and confirmed pressure changes in the hemisphere. We will extend the procedure described in the present report to simulate the flow field around the DGB-type parachute consisting of flexible material in near future.

1 Introduction

In pioneering research, unstable shock wave oscillation has been observed around a hemisphere model. Stable shock wave mode was changed into unstable mode. The phenomenon was observed at over Mach 3.0.[1] Similar phenomena have been observed around a supersonic parachute.[2] When shock wave oscillation occurs at supersonic parachute, stable and safety flight are difficult to obtain. At worst, shock wave oscillation leads to structural damages of supersonic parachutes and out of control. In order to contribute to safety flight, it is necessary to investigate into flow field around supersonic parachute. Accordingly, analyses of flow around rigid body were carried out. It is necessary to primary analysis for fluid structure interaction simulation. This present paper describes results of numerical analysis around supersonic flow field, using rigid models.

2 Numerical analysis

2.1 Numerical analysis method

A commercially available hydro-code, AUTO-DYN (ANSYS) was employed for the analysis. In this analysis compressible non viscous unsteady flow was solved. In this analysis, we consider that the body shape was not deformed (rigid body). The first analysis was 2-dimensional axial symmetry simulation. The body shape was a hemisphere shell like a cup that simulates a canopy.[3] Second analysis was 3-dimensional simulation. The body shape was entire Disk-Gap-Band (DGB) type parachute.[3]

2.2 Pressure changes in hemisphere

2.2.1 Calculation condition

In this analysis 2-dimensional axial symmetry simulation was solved. The flow gas Mach number were 2.0 and 3.0, ideal gas was used in this calculation respectively. Figure1 shows model arrangement of this analysis. Pressure time history was measured at gauge point. The calculation cases were shown table 1. Where D_h is a diameter of hemisphere, L is hemisphere's distance from forward object.

2.2.2 Result and discussion

In order to clarify forward object acts on the hemisphere, the simulations were carried out.

Figure 2 and figure 3 show analysis results of case 1 and case 2. In these analyses, stable shock waves in front of hemisphere were observed respectively. Also, figure 4 shows that pressure time history in the hemisphere was kept stable state.

Figure 5 shows pressure time history of case 3 and case 4. The pressure was observed that have cyclical pulse. From figure 5, we can see that interval of the cyclical pulse in case 4 were approximately 1.3 times compared with case 3. Figure 6 shows pressure distribution of case 4. In figure 6, high pressure area was moving. The high pressure area was moving from forward object to hemisphere alternately. It was conceivable that pressure fluctuation in hemisphere depends on a distance of between forward object and hemisphere.

Figure 7 shows pressure distribution of case 5 and figure 8 shows pressure time history. Figure 8(a) indicates during the small fluctuation of pressure in hemisphere. In figure 8(b), the value of pressure in hemisphere was increased abruptly at 0.71 [s]. In this calculation, the periodicity of pressure fluctuation was not observed.

2.3 Around entire supersonic parachute

2.3.1 Calculation condition

In this analysis 3-dimensional simulation was solved. The flow gas Mach number was 2.0, ideal gas was used in this calculation. The body shape (Figure 9) was a Disk Gap Band parachute model that simulates the parachute just after finishing the inflation. The model configuration was simplified like Viking model.[4,5]

2.3.2 Result and discussion

Figure 10 shows density distribution around entire parachute. The calculation was steady state at 0.166 [s] later. A result clearly shows flow field including shock waves in front of capsule and canopy. The distance of shock wave in front of canopy was 1.29D_c from disk section. Where D_c is a diameter of canopy. In this calculation, unsteady shock wave was not shown. We made a comparison between numerical result and experimental result. The experiment was carried out in supersonic wind tunnel at JAXA.[2] The flow Mach number was 2.0, the parachute model was used flexible materials. Figure 11 shows result of numerical analysis and experiment respectively. Both figures show shock wave in front of canopy. It was conceivable that the result of numerical analysis agreed with one of experiment qualitatively.

3 Conclusions

Numerical analyses have been carried out about the flow field around some rigid simulation parachute model in supersonic flow for primary simulation of fluid structure interaction analysis. Results are summarized as follows.

- 2D simulations of pressure changes in hemisphere.

  In flow Mach number 2.0, the pressure fluctuation in hemisphere have cyclical pulse. In Mach number 3.0, the value of pressure in hemisphere was increase abruptly at approximately 0.71 [s].

- 3D simulation around entire supersonic parachute .

  A result clearly shows flow including shock waves in front of capsule and canopy. The shock wave positon in front of canopy was 1.29 D_c from canopy. The shock waves were kept a steady state.

References

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[3] T W Knacke., “Parachute Recovery Systems Design Manual,” Para Publishing, 1992.

[4] D. Dickinson et al., “BALLOON LAUNDHED DECELERATOR TEST PROGRAM:POST-FLIGHT TEST REPORT,” NASA Paper, September 1973.

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Table 1 Calculation cases.

Case	Mach	Forward object : L
1	2.0	-
2	3.0	-
3	2.0	$2D_h$
4	2.0	$3D_h$
5	3.0	$3D_h$

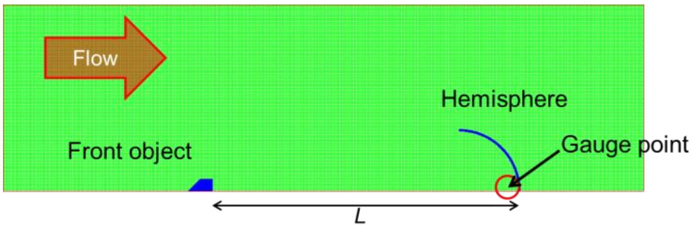


Figure 1 Model arrangement of 2D axial symmetry simulation.

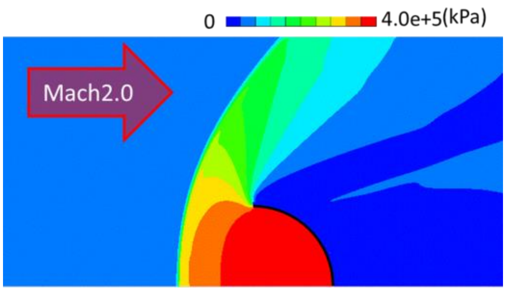


Figure 2 Pressure distribution of case 1.

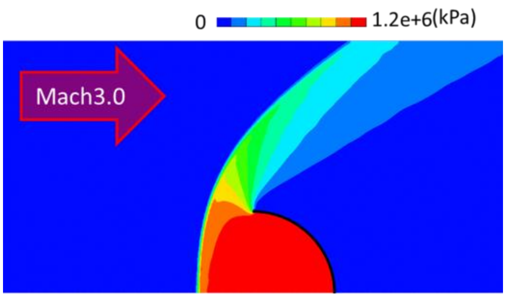


Figure 3 Pressure distribution of case 2.

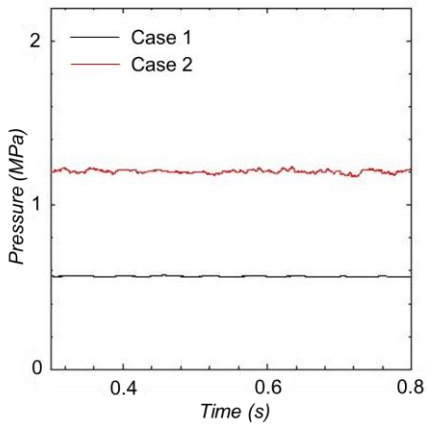


Figure 4 Pressure time history of case 1 and case2.

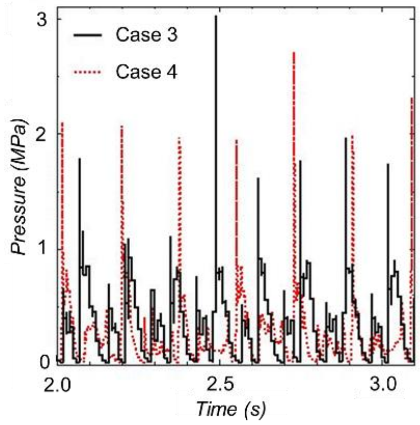
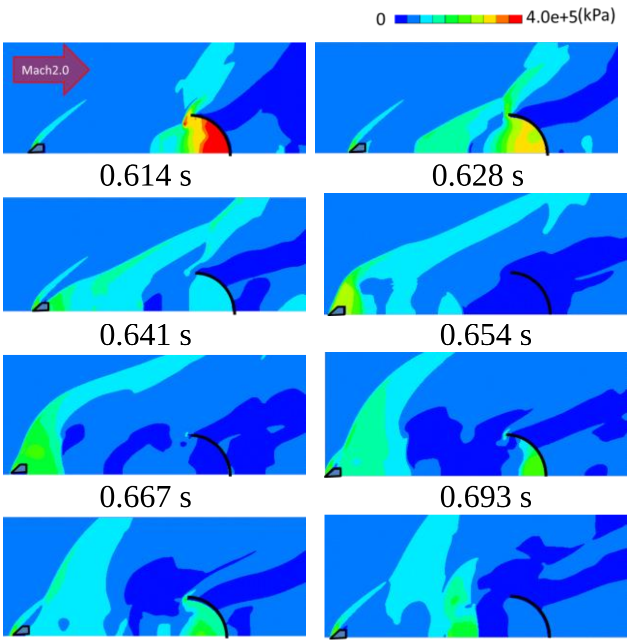


Figure 5 Pressure time history of case3 and case4.



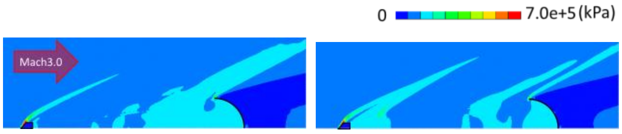
0.614 s 0.628 s

0.641 s 0.654 s

0.667 s 0.693 s

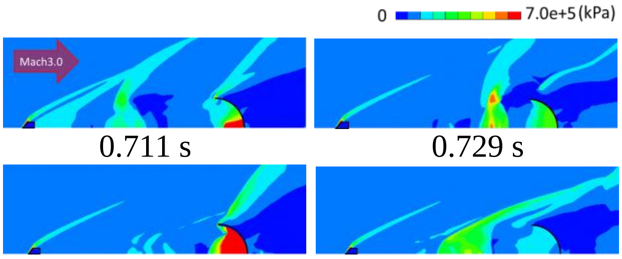
0.701 s 0.715 s

Figure 6 Moving high pressure area of case 4.



0.164 s 0.209 s

(a) During the small fluctuation of pressure in hemisphere.



0.711 s 0.729 s

0.753 s 0.772 s

(b) Increasing pressure in hemisphere.

Figure 7 Pressure distribution of case 5.

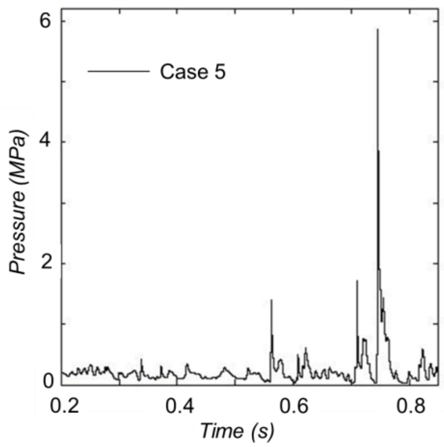


Figure 8 Pressure time history of case5.

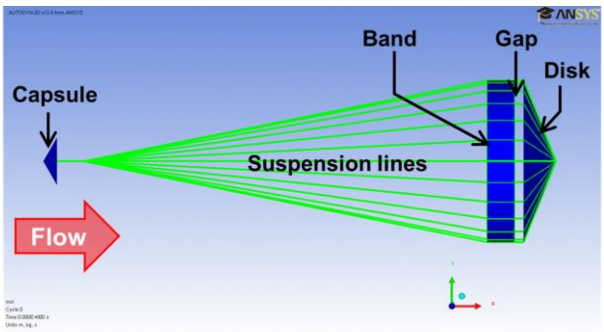
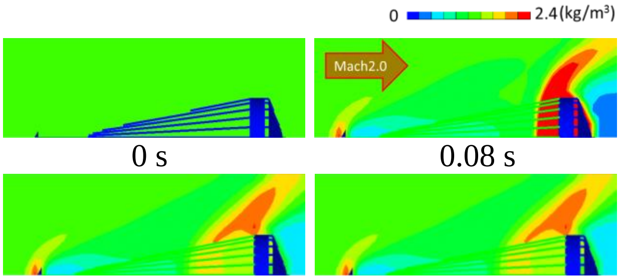


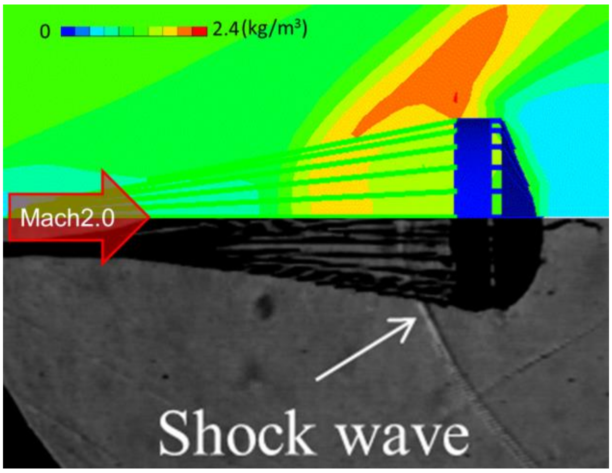
Figure 9 Entire model of Disk Gap Band parachute.



0 s 0.08 s

0.160 s 0.240 s

Figure 10 Density distribution around Disk Gap Band parachute.



Upside : CFD, downside : EFD (Schlieren)

Figure 11 Comparison between numerical result and experimental result.

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