8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

Numerical Simulation of the Decelerating Parachute-like Body with Consideration of Virtual Mass

Hiroyuki. Houzu[1], *Norio. Arai[2] and Yoko. Takakura[3]

[1] Dept. of Mechanical Engineering
Tokyo Noko University, 2-24-16 Naka-cho, Koganeishi, Tokyo, Japan
50004833701@st.tutt.ac.jp

[2] Dept. of Mechanical Engineering
Tokyo Noko University, 2-24-16 Naka-cho, Koganeishi, Tokyo, Japan
arai@cc.tuat.ac.jp
http://www.tuat.ac.jp/~arailab/

[3] Dept. of Mechanical engineering
Tokyo Noko University, 2-24-16 Naka-cho, Koganeishi, Tokyo, Japan
takakura@cc.tuat.ac.jp

Key Words: *Parachute, Virtual Mass, Concave Body, ALE.*

ABSTRACT

The parachute is widely used to decelerate the payload to make a soft landing on the ground, in which the ground impact must be avoided perfectly. In the past studies [1, 2], the inflation process is specially focused. However, the stability after inflation is also important in the parachute design. In our past researches, the circular motion around the fixed supporting system is simulated [3, 4] and it is clarified that the pressure within the canopy has large influences on the parachute motion.

In the real descent of the parachute, however, there is the interaction between the payload motion and the canopy motion and, consequently, the descent velocity of parachute system is decided by the balance of both the gravity force and the fluid force. In this article, we propose the physical model taking into consideration of these effects. Furthermore, in our numerical simulation, the virtual mass (also known as added mass, apparent mass) effect is treated very carefully. The numerical simulation has carried out, which has focused on the steady and/or unsteady descent after inflation process with consideration of the interaction between both the payload motion and the canopy motion. The parachute's geometry is a single, round parachute (hemi-sphere). The virtual mass is obtained by a discrete vortex method at every time step. The flow field around the moving parachute body is calculated by the MAC method. The motion around the fixed supporting point is also simulated to compare the results of the payload moving model. In our physical model, the parachute is in the balanced system of both the gravity force and the fluid force acted on the parachute canopy. (See Fig.1)

$$\left(m_p + m_c\right)\frac{d^2x}{dt^2} = F_x - \left(m_p + m_c\right)g - m_x^*\frac{d^2x}{dt^2}.$$

Here, m_p is a mass of payload, m_c is a mass of the canopy, F_x is the fluid force acted on the canopy in x-direction, g is the gravitational acceleration, m_x^* is the virtual mass in x-direction.

The payload is idealized as a concentrated mass point. And also the parachute moves around the gravity point of the parachute system according to the fluid force effect on the body.

$$I\frac{\partial^2\theta}{\partial t^2} = F_T \cdot l_c + m_c g \cdot l_c \sin\theta - m_p g \cdot l_p \sin\theta \, .$$

I is a moment of inertia, F_T means tangential component of the fluid force acted on the canopy.

Following conclusions are obtained. The motion of the payload effects on the motion of the parachute canopy, that is, influences on the whole motion of the parachute system. The effect of the virtual mass force on the whole motion of the system is much larger than the conventional method (virtual mass effect is not included). The correlation between the descent velocity of the parachute system and the attack angle (deflection angle) of the canopy is so strong and the phase difference between them is a quarter-wavelength. (See Fig.2)

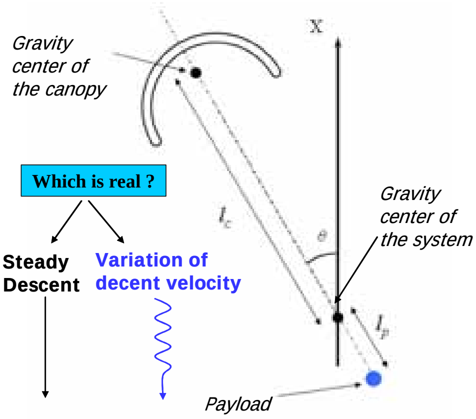

Fig. 1 Physical Model of this Study.

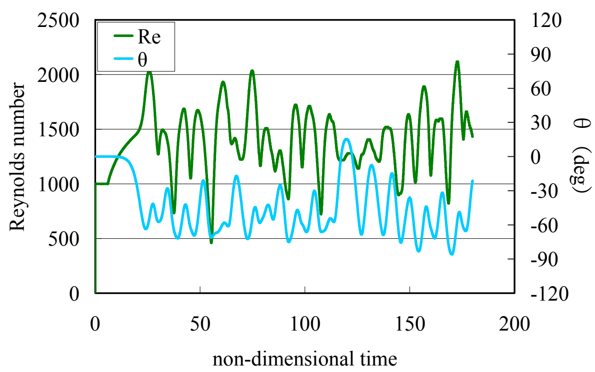

Fig.2 Descent velocity and deflection angle.

REFERENCES

[1] K. Stein, R. Benny, T. Tezduyar and J. Potovin, "Fluid-structure interactions of a cross parachute:numerical simulation", *Comput. Methods Appl. Mech. Engng.*, Vol. **191**, pp. 673–687, (2001).

[2] T. Tezduyar and Y. Osawa, "Fluid-structure interaction of a parachute crossing the far wake of an aircraft", *Comput. Methods Appl. Mech. Engng.*, Vol. **191**, pp. 717-726, (2001)

[3] H. Houzu, N. Arai and Y. Takakura, "Dynamic Characteristics of 2-Dimensional Parachute-like Body with Consideration of Virtual Mass", *Proceeding of 2006 JSASS-KSAS Joint International Symposium on Aerospace Engineering*, pp.255-260, (2006)

[4] H. Houzu, N. Arai and Y. Takakura, "Study on Dynamic Characteristics of the 3-Dimensional Parachute-like Body with Consideration of Virtual Mass", *Proceeding of The 7th International Conference on Fracture and Strength of Solids Collaboration with International Conference on Computational Science and Engineering*, (2007)