Title：Discussion About Supersonic Aviation And Pullout Control In Free-Fall Flying Object From Balloon

Abstract text

The microgravity experimental system that uses the high altitude balloon is now developed in ISAS/JAXA. This experimental method is, 1) the high altitude balloon is raised to 40 km altitude, 2) the experimental system is separated, 3) a free fall for 30-40 seconds is achieved.

In the experiment, the fall body enters a supersonic state when the free fall time exceeds about 30 seconds. Therefore, it can be expected that this fall body will offer a simple supersonic flight experiment besides the microgravity experiment. Actually, it is scheduled to equip the air inhalation type engine developing in the future. In this future experiment, an enough supersonic flight time is necessary to evaluate the performance of the engine. So it is thought that the nose of the body have to be put up since a simple fall from the altitude 40km is insufficient.

This paper evaluates whether a supersonic flight can be achieved in the present experimental system, and whether a supersonic time can be extended by putting the nose up. Some simulation results in several conditions are shown to verify the effectiveness of the putting the nose up of the experimental body.

タイトル：気球から自由落下する飛翔体における超音速飛行と引き起こし制御の検討

概要

現在 ISAS/JAXA では気球を用いた微小重力実験装置の開発を進めている。この実験は、(1)高高度気球で高度 40km まで上昇させる、(2)実験機体を切り離す、(3)30-40 秒間の自由落下を実現するものである。

この実験において、落下機体は 30 秒程度落下したとき超音速になる。したがって、この実験機体は微小重力実験の他に簡易な超音速飛行試験を提供できると考えられる。実際に、空気吸い込み式エンジンを搭載しての実験も予定されている。この将来の実験において、エンジンの性能を測るために、十分な超音速飛行時間が必要です。そのため、高度 40km からの単純な落下では不十分であり、落下中機体を引き起こす必要がある。

今回は、現行の機体で超音速飛行が実現できるかと、引き起こしによって超音速飛行時間を向上できるかを評価した幾つかのシミュレーション結果を示す。

Main Text

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1. Research Background

The microgravity experimental system that uses the high altitude balloon is now developed in ISAS/JAXA. This experimental method is, 1) the high altitude balloon is raised to 40 km altitude, 2) the experimental system is separated, 3) a free fall for 30-40 seconds is achieved.

In the experiment, the fall body enters a supersonic state when the free fall time exceeds about 30 seconds. Therefore, this fall body can offer a simple supersonic flight examination means besides the role as the microgravity experiment system. Actually, it is scheduled to equip the air breathing type engine developing in the future. In this future experiment, an enough supersonic flight time is necessary to evaluate the performance of the engine. So it is thought that the nose of the body have to be put up since a simple fall from the altitude 40km is insufficient.

2. Research Purpose

Whether a supersonic flight can be achieved in a present experiment machine that shows in Fig.1 is evaluated. In addition,whether a supersonic experiment on the length or more time can be achieved by put the nose up. It is a purpose for that to achieve the possibility put the nose up and the put the nose up control by the numerical simulation in consideration of the limiting condition at time of the experiment model.

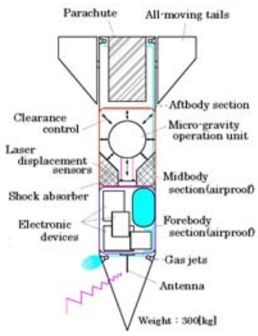

Fig.1 Body structure

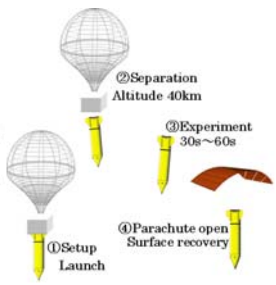

Fig.2 Experimental sequence

3. Outline of microgravity experiment system that uses high altitude balloon

It proposes the microgravity experiment system that uses high altitude balloon by can do the duration of the microgravity of about one minute in the research consortium of ISAS/JAXA, and the achievement of the residual acceleration of 10^{-5}G or less microgravity environment. The experiment sequence is shown in Fig. 2 as an experiment method. The microgravity environment achievement method is Fig. 1, and the center part is a double husk structure with the unit of microgravity environment and the wall outside the airframe. And, the unit is relatively floated compared with the airframe while the airframe is free falling. A free drug has been achieved by controlling the position and the posture of the airframe so that the airframe should not collide with the unit.

4. Application of microgravity experiment model to supersonic flight examination.

4.1 Design of PD control system

The plant characteristic of this airframe is expression (1). Expression (2) is obtained by Laplace transforming expression (1). I : Moment of inertia, α : Attack angle, q : Dynamic pressure, $C_{m\alpha}$: Moment coefficient per unit Attack angle, $C_{m\delta}$: Moment coefficient per unit Steering angle. Moreover, the aerodynamic coefficient such as $C_{m\alpha}$ and $C_{m\delta}$ is presumption beforehand according to numeric fluid analysis (CFD) and the wind tunnel test.

$$I\ddot{\alpha} = qAC_{m\alpha}\alpha + qAC_{m\delta}\delta \quad (1)$$

$$\frac{\alpha}{\delta} = P_{(s)} = \frac{qAC_{m\delta}}{Is^2 - qaC_{m\alpha}} \quad (2)$$

Moreover, external input torque $C_{(s)}$ (control power) in the controller part becomes expression (3) at the PD control.

$$C_{(s)} = \left(k_p + k_d s\right) \qquad (3)$$

The numerical simulation model was made by using the above-mentioned result and using MATLAB/simulink. The PD control model is shown in Fig. 3. α : Attack angle, δ : Steering angle. q change in this faction at time. This shows that the plant is a strangeness system of time.

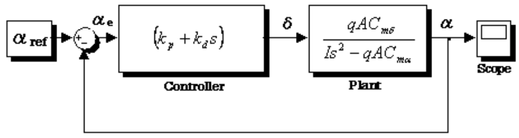

Fig.3 PD control model

4.2 Examination of inducement rule

The inducement rule that should be thought here is the one at the supersonic flight time to give the target value history of Attack angle so that the maximum Mach number may grow as much as possible. However, the target value attack angle gives the definite value here in 0 until a certain time for the simplification after that. It was assumed the limiting condition (dynamic pressure × Attack angle) in this inducement and the high altitude. It shows in Table 1.

Table 1 Constraint condition of flight

Constraint condition	Maximum
(DP×AA)[kPa deg]	300
Altitude [km]	10

The(DP×AA) condition was provided as a limit value that the airframe breaks by the air power. The lower limitation of the altitude is highly developed of the supersonic experiment end. The purpose of this is to develop the parachute safely.

5. Consideration by numerical simulation

5.1 Orbit control of flight body

The Attack angle instruction value was put the nose up controlled as a parameter. Fig.4 shows the simulation result. The Attack angle instruction value α : 2, 4, 6, 8, 10, 12, 14 deg from the left.

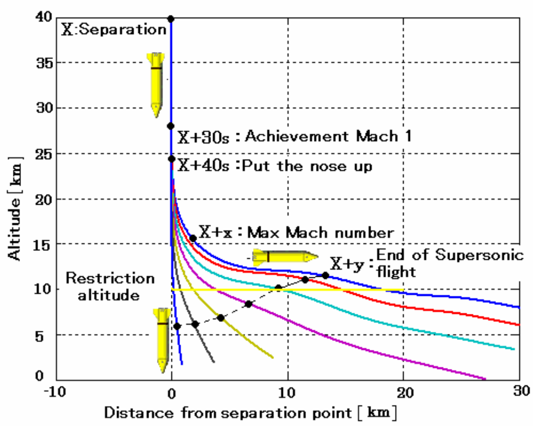

Fig.4 Flight path of each attack angle

In this simulation, after the separation, in is 40 seconds when beginning to put the nose up control. This is because the speed direction vector doesn't change by there is an influence in posture air is thin because of times at most even if the put the nose up control with the steer wing is started immediately after the separation. Moreover, the Attack angle instruction value is a target value of Attack angle in the airframe coordinate system. Thus, it is understood that there is a change in the put the nose up condition depending on the instruction value. The maximum at this time attainment Mach number was in any case before and behind M=1.9, and did not have a big difference by the instruction value. On the other hand, the supersonic flight time becomes the high altitude 10 km from Fig. 4 in Attack angle instruction value α : 2～8 deg before it collides with an advanced restriction of Table 1, and it becomes Mach 1. Therefore, the supersonic flight time has shortened.

5.2 Simulation of imitates assist booster

As for the current simulation, it thought about the put the nose up control by a free fall. Here, to grope for the possibility of improving the Mach number or more and the supersonic flight time, the simulation imitated equipped with the assist booster. The result is shown in Table 2. The assist booster output: 10000 N and the operation time: 10 sec.

Table 2 Simulation results(Ver.Installation engine)

作動時 間帯[s]	最大 マッハ数	超音速 飛行時間[s]	マッハ2.5以上 の時間[s]
25-35	2.516	53.04	6.00
35-45	2.639	52.09	13.0
45-55	2.776	55.97	11.0
55-65	2.750	59.03	8.00
64-75	2.353	61.48	0.00
75-85	1.949	65.39	0.00
85-95	1.919	72.35	0.00

The maximum Mach number and

supersonic time have been understood from the change operation time zone of the engine. If the engine is operated in the first half of a supersonic flight, the maximum Mach number grows. However, the air resistance grows, and the supersonic flight time doesn't expand. Moreover, when the engine is operated in the latter half of a supersonic flight, the expansion of the maximum Mach number is not seen. The purpose of maximum speed is to pass already in this. However, it is understood to work remarkably in the extension of the supersonic flight time.

6. Conclusion

It has been understood to be able to do a supersonic flight and the put the nose up control in consideration of the limiting condition by applying the microgravity experiment model that uses the high altitude balloon. And, it was able to be confirmed that put the nose up was effective to extend the supersonic flight time. Moreover, it was able to be confirmed that it was effective to enlarge the maximum Mach number and the supersonic flight time equipped with an assist booster.

7. Future works

・Simulation with high accuracy
・Analysis by new aerodynamic data
・Design change of body

8. Reference

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