The MITSUBACHI Human Powered Helicopter

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1. Summary

In May 1980, the American Helicopter Society announced the Igor I. Sikorsky human powered helicopter (HPH) competition. [1] People all around the world began developing HPH's by trial and error. In Japan, Nihon University and the Japan Cash Machine Company (JCM) are cooperating in research and development of HPH's. This paper describes the MITSUBACHI (Honeybee) HPH now under development at JCM by Toshio Kataoka and the author.

2. Introduction

The 'A Day Fly' [2,6] (1984-86), had double contra rotating blades that gave the craft high thrust (lifting ability). The 'A Day Fly' flew once for a few seconds although we have no documented evidence to prove this. Lecturer Naito, of Nihon University, who lead the projects research team, reached the mandatory retirement age of 65 in March 1986. The Author piloted this helicopter, and is now working to keep the dream alive. The MITSUBACHI HPH that I am now building is based on 'A Day Fly'.

3. The Ground Effect Coefficient

A theory for rotor blades spinning near ground level has not yet been established so we experimented with a 1/20 scale model to measure the ground effect coefficient. The results are shown in figure 1 together with the Sherwin [3], McCooy [4] and the Nihon University lines for comparison. The ground effect coefficient we measured was very large, this is perhaps due to the low Reynolds number of the model tests. We think that the line for the full size helicopter will be lower then for the model tests, closer to the McCooy line, so we have chosen to base our design on the more pessimistic McCooy data.

4. Power for Hovering Flight

In 'Man Powered Flight' by Sherwin [3], the power required in hovering flight is expressed as follows:

$$P_{hover} = \frac{1.3\ K\ W\ (W/2\ pi\ R^2\ p)^{1/2}}{550} + \frac{0.78\ W\ V_r\ C_d\ /C_L}{550}$$

1.3 is the hovering efficiency factor; K, the ground effect factor; W, the all up weight (1b); R, the rotor radius (ft) and V_r, the tip velocity of the blade (ft/sec). The variation of K with the rotor height radius ratio, h/r, is discussed above and is shown in figure 1. Equation 1 consists of two terms: i. power lost to induced drag and ii. power lost to profile drag. The rotor weight was calculated by assuming fully cantilevered blades, accurate values for the components of the ?rotor weight were known from previous HPH and HPA experience. The power required to maintain hovering flight decreases as rotor radius increases, however beyond a certain point the advantages of a large rotor are more than offset by its higher weight, consequently the power required increases, the results of this trade-off are shown in figure 2. Although minimum power occurs at a rotor radius of 14m we were forced to use 12m radius blades because there are no buildings capable of holding a craft with 28m diameter rotors available to us in Japan. The power required for the 12m radius rotor is 600 Watts, but since the transmission efficiency is 72% the pilot must provide 833 Watts of power.

5. Generating Power

The pilot of A Day Fly generated power with only his legs, bicycle style. The rotor velocity varied due to lack of torque at the top and bottom positions of the crank during the pedal cycle. Thus, ‘A Day Fly’ was not stable in flight and suffered from ‘jumping’. There are several ways to eliminate these power fluctuations, for example oval gears, cam springs, fly wheels, swinging lever drives etc. But we chose to use hand power along with leg power, which is common in HP land vehicles. We constructed a rudimentary test rig for measuring combined hand and leg power production and connected an ergometer to it. A picture of the test rig is shown in figure 3. Figure 4 shows the power output of the author measured on the test rig. Although we have not yet measured the torque throughout all phases of the power cycle, the hand-leg combination seems to reduce torque fluctuation, (figure 5). We have also found that the hand-leg combination reduces movement of the pilot’s centre of gravity during peddling which of course reduces movement of the helicopter.

6. Configuration

It is generally accepted that the tail rotor consumes 10-30% of the total power. We therefore used double contra rotating rotors similar to ‘A Day Fly’s’ to avoid this power loss and the increased structural weight of a tail rotor.

7. Spar

The spar constitutes most of the weight of the helicopter. We tested 3 types of spar on our (1/3) scale model: square, I and tubular. As a result we chose to use a tube spar.

8. Power Transmission

We considered many methods for the transmission of power, for example, gears, chains, belts etc. We finally decided on a winch-type pulley system with a Kevlar rope long enough to last for 90 seconds.

9. Stability

It is said that a motorised flying platform is dynamically stable, if the centre of gravity is just above the rotor disk. Our own tests with a rubber powered scale model confirmed this theory. However, we feel that the slow revolutions of the rotor blade enhanced the stability of the scale model and that it will be more difficult to stabilise the full scale helicopter in flight.

10. Blade Geometry

The ‘A Day Fly’ had a constant chord length, but the MITSUBACHI has a more complex spanwise chord distribution. Over the outer section of the rotor, the chord length is a reverse ratio of the distance of the blade element from the rotor axis. This ratio may be expressed as C ?o ?R/r, where r is the blade element radius and C is the chord of the rotor tip. The inner half of the rotor has a constant chord to simplify construction. A drawing of the Mitsubashi is shown in figure 6. We originally thought it best to separate the blade root from the axis by 2-3 metres, however as a result of our tests with the scale model, we decided to separate the blade from the axis by only 1 metre. The blade has no twist.

11. Airfoil

We chose the DAE 21 section because of its aerodynamic characteristics at the low Reynolds numbers of the rotor. However, we suspect that the aerodynamic advantages of the airfiol [2,5,6] will be lessened for two reasons: ground effect and the low Reynolds number (10,000, on the inner portion of the blade). We modified the bottom of the airfoil according to the Serendensky method [7] and cut out the ribs using both waterjets and lasers.

12. Summary

We measured the ground effect coefficient using a 1/20 scale model and found much higher values than previously observed by other experimenters. We also found that using combined hand-leg power increased stability and available short term human power output and decreased torque fluctuations. Although the predicted power required to hover appears high, we believe that the combined hand and leg power transmission system should enable the MITSUBACHI to fly.

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References

1. ‘Igor I. Sikorsky Human Powered Helicopter Competition’, American Helicopter Society, May 1980. Revised July 23, 1986.

2. Naito, A. ‘Review of Developments in Human-Powered Helicopters’. HUMAN POWER Technical Journal of the International Human Powered Vehicle Association. Vol.9, No.2 Summer 1991.

3. Sherwin, K. ‘Man Powered Flight’ (Argus Books. 1975)

4. McCooy, F.W., ‘Human Powered Helicopter Design’, Copyright 1987.

5. Akira Naito, Personal communication 1986-

6. Naito, A. ‘A study of HPH in Japan’, Society of Allied Weight Engineers Inc., Chandler Arizona, 14-16 May 1990.

7. Pope, A. and Harper J.J., ‘Low-Speed Wind Tunnel Testing’. J. Wiley & Sons 1966.