

Rotor Speed Load Calculation and Analysis

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Abstract. In this paper, on the basis of accurate calculation, combined with the test data, summarize the rotor aerodynamic load and load some change rules and characteristics of the blade structure, we can be used as the basis for correct calculation model and the research on mechanism of load and the foundation of blade optimization design.

Introduction

A helicopter has a unique ability to fly, is the only area of the vehicle can reach any terrain, in the national economy construction, disaster relief and the role of modern war is increasingly prominent. Helicopter rotor as the main lifting surface, thrust and control surfaces, are the root causes of helicopter dynamics problems.

Rotor system load is the core of the helicopter throughout the design process always tasks, the load fast accurate forecasts, both in the concept design phase and in the detailed design stage has significant engineering value and can effectively shorten the development cycle, reduce the physical test, save the test cost, avoid the risk of potential design.

State before flying state before flying at low speed and high speed is a helicopter rotor in high vibration load of typical area. At the same time, under the condition of high speed rotor load is the focus and difficult problem in the design of rotor. This chapter in view of the difficulties in typical condition, application of comprehensive gas bomb load calculation method of SA349/2 "small antelope" helicopter before flying under the condition of the typical flight status is shown in Fig. 1, including a small forward than the state, a big progress than state, etc. For example, rotor load calculation.

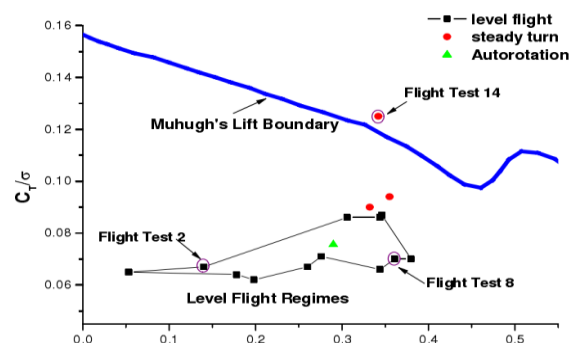


Figure 1. The typical flight status

Based on this, calculates the range extends to the high speed condition, by flight test comparison of measured data with the calculated value, summed up the blade vibration load and aerodynamic load change rule, and the different flight state of the

main factors influencing the rotor load calculation is analyzed.8 for high-speed flight test state steady state before flying, main flight state parameters in the following table.

Blade Aerodynamic Load, High Speed Condition

Although 8 forward flight test state is bigger, but from the measured data (as shown in Fig. 2, Fig. 6), you can see that propeller vortex interference and dynamic stall caused dramatic change load factor is not obvious, on the one hand is good OA209 airfoil aerodynamic characteristics of airfoils in the azimuth and exhibition stall to the location are not beyond the boundary; On the one hand, are also associated with balancing state at this time, the blade tip vortex was blown away from the blade that followed, large forward than make induced velocity tend to be even, these factors have lowered the difficulty in solving complex aerodynamic load and improve the precision and rotor load of the calculated value with the measured data. Can be seen from the Fig. 2 with the increase of the forward blade plate for high aerodynamic load area gradually expanded, on blade section, high load area mainly to the central blade, for retreating blade, tip will load more aerodynamic load. To move forward at the same time, the blade and the blade after asymmetric aerodynamic force distribution, the trend of roll effect would be strengthened, relative to the medium and small forward than state, disc will have a more roll. In addition, the azimuth range 0 degrees to 90 degrees, tip the aerodynamic load peak is due to the sample helicopter rotor blade adopts nonlinear negative twist distribution.

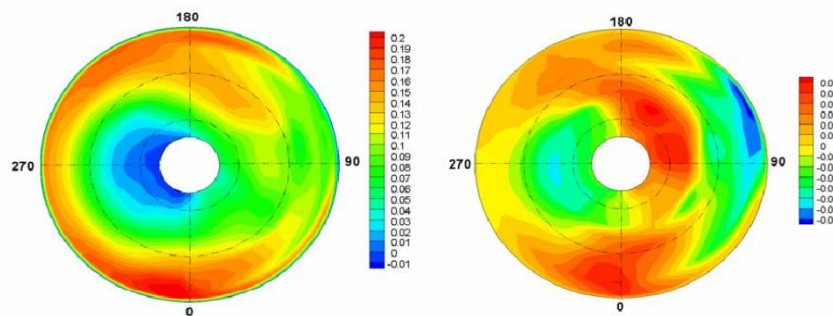


Figure 2. Flight 8 disc vertical force distribution

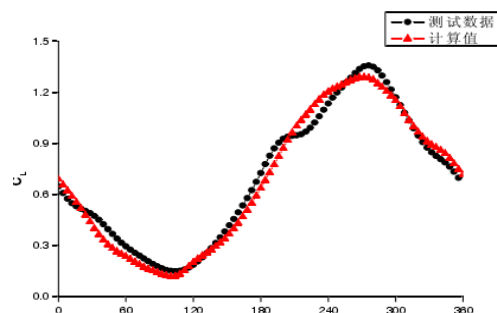


Figure 3. The radius of 75% the vertical force coefficient

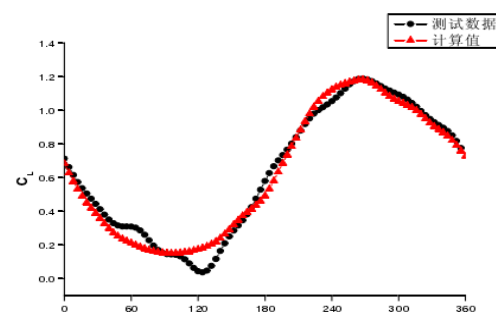


Figure 4. The radius of 88% the force coefficient

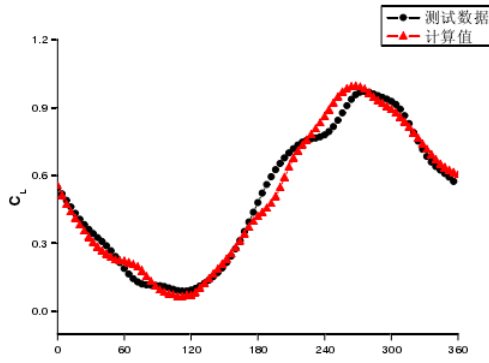


Figure 5. The radius of 97% the vertical vertical the azimuth change curve

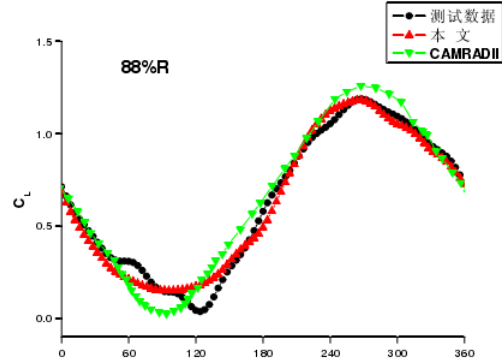
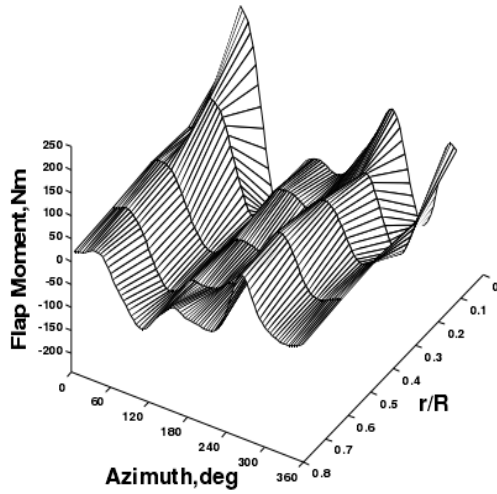


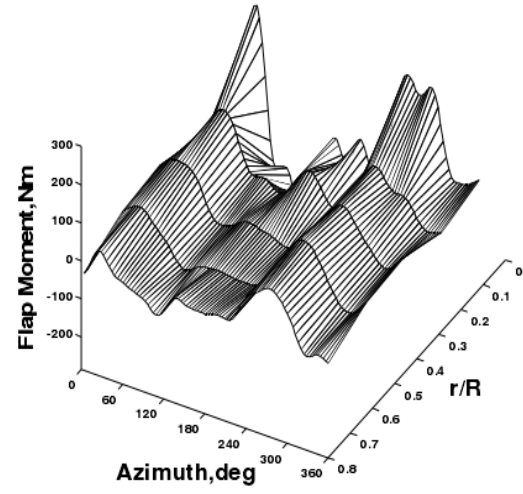
Figure 6. Calculated value and the force coefficient CAMRADII contrast

High Speed Blade Structure under Load

Like little speed case, waving movement of the three times of harmonic components is still there. Due to fly in this state, the pneumatic load Lotus is not affected by unsteady effect, therefore, the high frequency of wave load component is not outstanding, the exhibition to the general first-order vibration mode distribution. And small forward than the situation is different, 180 degrees of attachment of the peak load was suppressed, and near 30 degrees and 270 degrees near peak load of the strengthened as Fig. 7. For articulated rotor inertia of rigid body movement dominated the blades sharp movement. Near 0 degrees azimuth Angle and blade aerodynamic load alternating component to place all their peak as shown in Fig. 4, and the inertial load, elastic response will lag behind incentives, so will be in the subsequent 30 degrees azimuth near peak. And azimuth Angle corresponding to 0 degrees, near 180 degrees of the aerodynamic force alternating part also reached the peak, but distribution is relatively close to the blade root, because of the inertial load and the reverse at the same time, lead to its peak is inhibited. Load trough of near 90 degrees and 270 degrees near the peak corresponding to the blade in the two azimuth inertial wave load on the reverse, that is caused by disc tilt.



(a) Calculated value



(b) test values

Figure 7. Wave bending moment distribution of flight

Near 90 degrees to the aerodynamic load bearing show alternating component is 180 degree phase difference as Fig. 2, negative wave vibration load along the exhibition will be a certain degree of compensation, and through the azimuth on the tip of the central and reflected wave bending moment amplitude difference, as shown in Fig. 9, Fig. 11 and Fig. 12, the aerodynamic load and inertial load along the exhibition to the integral forming load trough of the roots. By contrast, in this paper, in terms of wave bending moment calculation accuracy is better, and slightly better than CAMRADII.

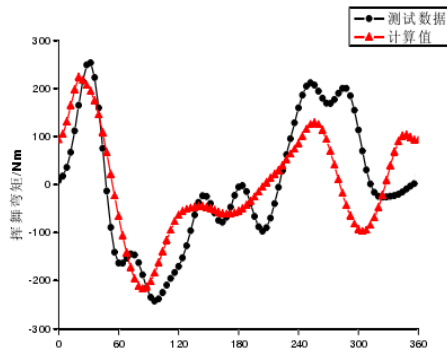


Figure 8. The radius of 12% the the azimuth change curve

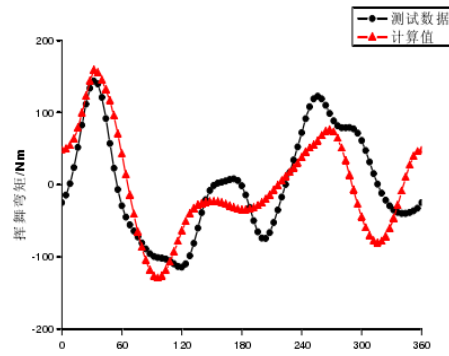


Figure 9. The radius of 20% the azimuth change curve

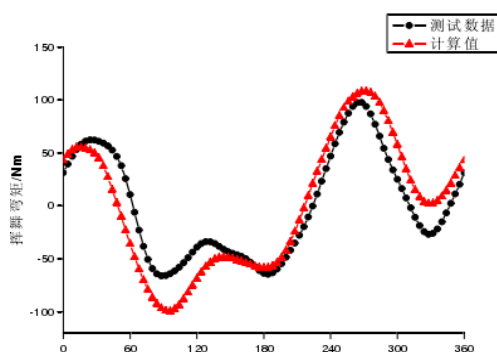


Figure 10. The radius of 46% the azimuth change curve

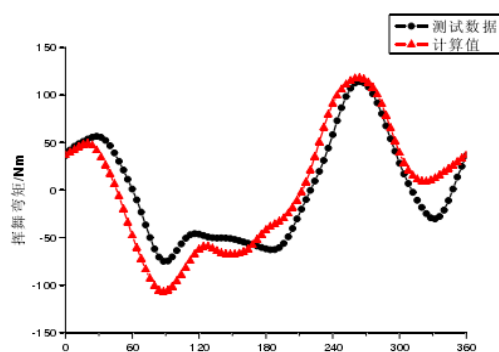


Figure 11. The radius of 54% the azimuth change curve

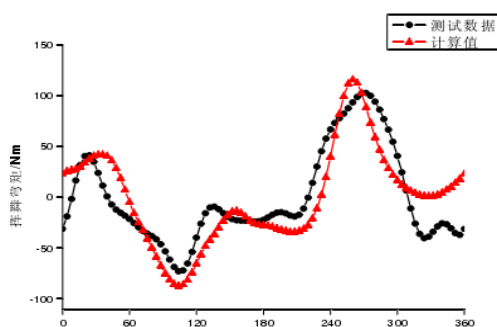


Figure 12. 80% radius of wave bending wave moment change curve

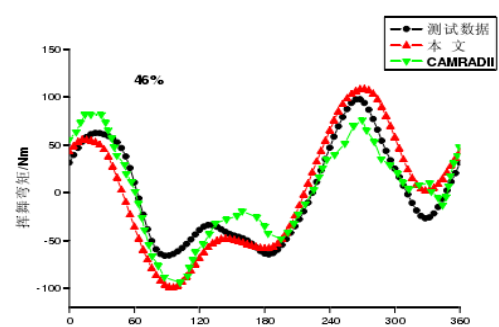


Figure 13. Calculated value of bending change curve

Relative to the small forward than state, state of flight test 8 shimmy load is "clean". The high frequency components.

This paper applies comprehensive gas spring analysis method to calculate the SA349 "small antelope" helicopter rotor vibration load of typical high speed flight state. By contrast, on the whole, this paper calculated value is good agreement with experimental data, the calculation accuracy is not lower than CAMRADII, fully proves the effectiveness and applicability of the method.

Summary

Pneumatic load calculation determines the rotor vibration load calculation accuracy. In the condition of small forward than, free wake model can effectively Manifests the propeller vortex interference effect, therefore, by using the free wake model helps to promote small forward than under load calculation precision. Big advance ratio, high inflow than state, induced inflow to weaken the influence of load calculation, accurate grasp the unsteady blade/dynamic stall characteristics are more important.

References

- [1] Popescu B, Hodges D H and Cesnik C E S. Obliqueness effects in asymptotic cross-sectional analysis of composite beams. Computers and Structures, 2000, 76(4).

- [2] Yu W B, Hodges D H, Volovoi V V and etc. On timoshenko-like modeling of initially curved and twisted composite beams. *International Journal of Solids and Structures*, 2002.
- [3] Yu W B, Volovoi V V, Hodges D H and etc. Validation of the variational asymptotic beam sectional analysis. *AIAA Journal*, 2002, 40(10).
- [4] Yu W B, Hodges D H. Generalized timoshenko theory of the variational asymptotic beam.
- [5] Sectional analysis. *Journal of the American Helicopter Society*, 2005, 50(1): 46~55.
- [6] Johnson, W., *Rotorcraft Dynamics Models for a Comprehensive Analysis*, 54th Annual Forum of the American Helicopter Society, Washington D.C, May 20-22, 2008.