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防冰层对螺旋桨性能的影响

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一、前　　言

目前国产飞机螺旋桨的电加热防冰层是加在理论外形表面，它局部地改变了桨叶的气动外形（图 1）。据资料介绍（AGARE CP-366 1985 年）这种形式的防冰层使翼型的最小阻力系数（CDmin）提高 50%，而使螺旋桨效率降低 1～3%。国外有些螺旋桨已使用不破坏桨叶气动外形的电加热防冰层。

某型螺旋桨模型在风洞试验时，首先对未模拟防冰层的螺旋桨（以下简称光桨）进行试验，桨叶角从 25°至 42.5°每改变 2.5°测一次参数。然后对有模拟防冰层的螺旋桨（以下简称防冰桨）在典型桨叶角进行测量。即接近起飞爬升状态的小桨叶角 27.5°和接近巡航状态的大桨角 40°。

二、数 据 整 理

表 1 为小桨叶角风洞试验时测得的性能参数。表中 J 为进距比；C_P 为功率系数；C_T 为拉力系数；η 为效率；$\Delta\eta = \eta_o - \eta_i$ 为效率增量。符号下标加“o”为光桨，下标加“i”为防冰桨。表 2 为大桨叶角风洞试验数据。

表 1　小桨叶角（$\beta = 27.5°$）性能对照表

序　号	J	C_{To}	C_{Ti}	C_{Po}	C_{Pi}	η_o	η_i	$\Delta\eta = \eta_o - \eta_i$
1	0	0.224	0.224	0.230	0.229	0	0	0
3	0.2	0.219	0.225	0.221	0.223	0.198	0.202	－0.004
5	0.4	0.202	0.208	0.200	0.204	0.402	0.408	－0.004
7	0.6	0.174	0.173	0.169	0.173	0.617	0.599	0.018
9	0.8	0.128	0.132	0.136	0.143	0.755	0.735	0.020
11	1.0	0.070	0.059	0.089	0.083	0.789	0.706	0.083

表 1、2 和图 2 已表明了防冰层局部地破坏了桨叶的气动外形后对螺旋桨性能的影响。但为了更准确地进行分析，两种桨必须在同一使用条件，即在相同的进距比和功率系数条件下进行对比。以防冰层桨为基础，用线性插值法求出光桨对应的拉力系数，计算效率及效率增量。其结果列在表 3 和表 4。

图 2 为有、无防冰层对螺旋桨效率影响随进距比变化曲线，$J-\Delta\eta$ 曲线。图 3 为在同一工作状态有、无防冰层效率增量随进距比的变化，$J-\Delta\eta$ 曲线。

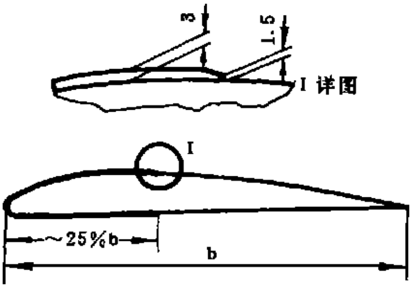

图 1　气动外型

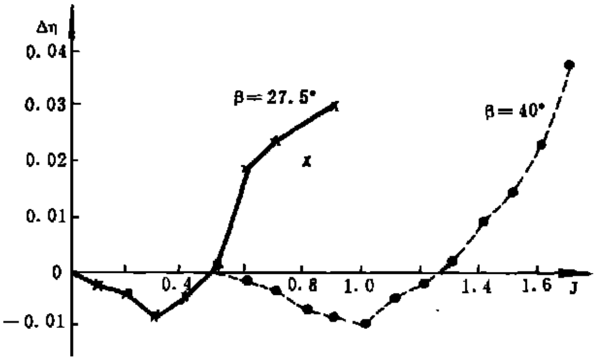

图 2　螺旋桨效率影响随进距比变化曲线

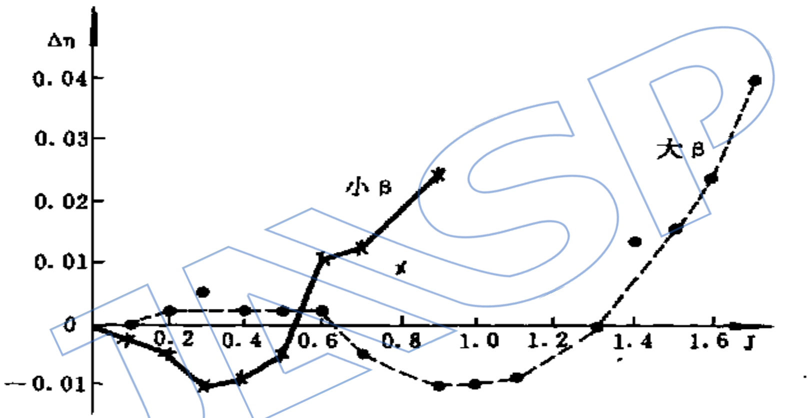

图 3　有、无防冰层效率增量随进距比的变化

表 2　大桨叶角（$\beta=40°$）性能对照表

序　号	J	C_{To}	C_{Ti}	C_{Po}	C_{Pi}	η_o	η_i	$\Delta\eta=\eta_o-\eta_i$
1	0	0.238	0.237	0.406	0.404	0	0	0
3	0.2	0.255	0.252	0.449	0.445	0.113	0.113	0.000
5	0.4	0.258	0.256	0.463	0.459	0.223	0.223	0.000
7	0.6	0.249	0.247	0.447	0.455	0.333	0.334	−0.001
9	0.8	0.233	0.241	0.416	0.422	0.447	0.455	−0.008
11	1.0	0.218	0.221	0.384	0.383	0.567	0.578	−0.011
13	1.2	0.200	0.201	0.342	0.343	0.702	0.704	−0.002
15	1.4	0.159	0.159	0.280	0.283	0.793	0.785	0.008
17	1.6	0.113	0.108	0.215	0.211	0.843	0.820	0.023
19	1.8	0.056	0.055	0.123	0.125	0.814	0.800	0.014

表 3　小桨叶角性能对照表

序　号	J	C_P	C_{To}	C_{Ti}	η_o	η_i	$\Delta\eta$
1	0	0.229	0.2238	0.224	0	0	0
3	0.2	0.223	0.2195	0.225	0.197	0.202	-0.005
5	0.4	0.204	0.2033	0.208	0.399	0.408	-0.009
7	0.6	0.173	0.1759	0.173	0.610	0.599	0.011
9	0.8	0.143	0.1330	0.132	0.744	0.735	0.009
11	1.0	0.083	0.0647	0.059	0.780	0.706	0.074

表 4　大桨叶角性能对照表

序　号	J	C_P	C_{To}	C_{Ti}	η_o	η_i	$\Delta\eta$
1	0	0.404	0.2379	0.237	0	0	0
3	0.2	0.445	0.2544	0.252	0.114	0.113	0.001
5	0.4	0.459	0.2572	0.256	0.224	0.223	0.001
7	0.6	0.445	0.2484	0.247	0.335	0.334	0.001
9	0.8	0.422	0.2350	0.241	0.445	0.445	0
11	1.0	0.383	0.2177	0.221	0.568	0.578	-0.010
13	1.2	0.343	0.2002	0.201	0.700	0.704	-0.004
15	1.4	0.283	0.1614	0.159	0.798	0.785	0.013
17	1.6	0.211	0.1113	0.108	0.844	0.820	0.024
19	1.8	0.125	0.0572	0.055	0.824	0.800	0.024

二、结　　论

观察图 3 可以看到以下规律: 大桨叶角, 小进距比($J<0.5$) 时增加防冰层对效率没有影响。大桨叶角, 中进距比($0.5<J<1.3$) 和小桨叶角, 小进距比($J<0.5$) , 防冰桨效率高于光桨效率, 最大增量为- 1% 。大桨叶角, 大进距比($J>1.3$) 和小桨叶角, 中进距比($J>0.5$) , 防冰层桨效率将明显下降。最大增量接近 4% 。增加防冰层后虽然只在某些工作状态使螺旋桨效率降低。但这些状态却是螺旋桨经常使用的范围内。如运七飞机在爬升时螺旋桨进距比 $J=0.618$, 功率系数 $C_P=0.1898$, 光桨桨叶角 $\beta=28.79°$; 从图可推测加防冰层后效率将降低～1.5%。巡航时 $J=1.6130$, $C_P=0.2213$, $\beta=40.41°$; 效率将降低～3% 。最终的结论是, 加在理论外形上的电加热防冰层局部地破坏了螺旋桨的气动外形, 螺旋桨在实际使用范围内效率将降低(最大 4%) 。消除电加热防冰层对气动外形的破坏可以提高螺旋桨的效率。

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EXPERIMENTAL MODAL ANALYSIS OF PROPELLER BLADES

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ABSTRACT The vibration characteristics of propeller blades have been investigated by using experimental modal analysis technique. The emphasis of the investigation is put on the effects of different joint conditions of blade root ends and mounting ways of blades on the nature frequencies and modes of propeller blade vibration. From the contrast analysis of the results it is concluded that in order to understand and analyze the dynamic characteristics of propeller blades precisely, the calculations and experiments of coupling dynamic characteristics of blade-hub-shaft of propeller assembly should be completed for simulating the joint and mounting conditions between propeller and engine practically.

VIBRATION CHARACTERISTIC ANALYSIS OF A PROPELLOR BLADE

Kong Ruilian and Wang Yanrong (*APRDC, BUAA*)

ABSTRACT The subspace iteration method and Jacobi's method are used to solve the eigenvalue problem for the vibration of a propeller blade, in which the super-parametric quadratic thick shell element with eight nodes and forty degrees of freedom is used to govern the motion equation, considering the effects of shear transverse deformation on the accuracy. The frequencies and vibration modes calculated by the program written by authors are in quite good agreement with the experimental results, and they can be used to judge whether the resonance occurs in the operation of the propeller, considering the effects of aerodynamic force excitation only.

A METHOD OF RELIABILITY ANALYSIS FOR PROPELLER BLADES

Fu Huimin and Gao Zhentong (*APRDC, BUAA*)

ABSTRACT A distribution function of two-dimensional threshold is given for fatigue crack propagation. A two-dimensional stress-threshold interference model is set up. The model is applicable to the reliability analysis and design of infinite life for propeller blades or other structural members with initial defects and accident damage. The functional correlation between the reliability of no crack growth and the initial crack sizes is obtained from the model and the maximum permissible crack sizes can be determined according to a given reliability level. In consideration of the fact, that the longer the service time, the greater the probability of accident damage, the overhaul periods of propeller blades with high reliability are also given.

EFFECT OF ANTIICER ON PROPELLER PERFORMANCE

ZhangAikun (*APRDC, BUAA*)

ABSTRACT Comparative experiments of a propeller with and without the antiicer have been completed in a wind tunnel. The analysis of the experimental data shows that the effect of the anticer depends on the advance ratio (J) and the blade angle (β). First, the antiicer has no effect on the performance of the propeller when the blade angle is big enough and the advance ratio is small ($\beta=40°$, $J<0.5$). Second, the efficiency of the propeller with antiicer increases when the blade angle is big enough and the J is moderate ($\beta=40°$, $0.5<J<1.3$) or the blade angle is smaller and the J also small ($\beta=27.5°$, $J<0.5$). Third, the attached antiicer reduces effficiency at the big blade angle with a large advance ratio ($\beta=40°$, $J>1.3$) or at a smaller angle with a moderate ratio ($\beta=27.5°$, $J>0.5$). In fact, when aircraft is flying, its propeller is almost running at the third condition. When the airarft takes off ($J=0.618$, $\beta=28.79°$), the antiicer reduces the propeller efficiency by 1.5 percent, and by 3 percent when the plane cruises ($J=1.6130$, $\beta=40.41°$).