NACA TN 3237

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 3237

HOVERING PERFORMANCE OF A HELICOPTER ROTOR USING NACA 8-H-12 AIRFOIL SECTIONS

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Washington
August 1954

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SUMMARY

A helicopter rotor employing an NACA 8-H-12 airfoil section has been tested on the Langley helicopter test tower. Two blade surface conditions were investigated, first with a filled blade which was within 0.002 inch of true airfoil shape obtained by use of plastic filler, and second with the filler removed resulting in a surface condition within 0.020 inch of true airfoil shape. Tests were conducted for the two surface conditions at a tip speed of 455 feet per second and over a tip-speed range from 455 to 650 feet per second for the blades with filler removed. The NACA 8-H-12 blades with the filled surface showed an average reduction of 6 to 7 percent in total torque coefficients.

INTRODUCTION

As previously reported in reference 1, the problem of designing a rotor for minimum induced power is fairly well understood and further increases in rotor performance must come from a decrease in the profile power losses. In this connection, the National Advisory Committee for Aeronautics has derived a group of airfoil sections having low profile-drag characteristics that have been developed specifically for use on helicopter rotor blades. From this group of airfoils the NACA 8-H-12 airfoil section, which appeared to be the most promising, was incorporated in a rotor blade for tests on the Langley helicopter test tower.

SYMBOLS

R	blade radius, ft
b	number of blades
c	blade section chord, ft
α	angle of attack, deg

σ	rotor solidity, $bc/\pi R$
ρ	density of air, slugs/cu ft
T	rotor thrust, lb
Q	rotor-shaft torque, lb-ft
M_b	measured rotor-blade pitching moment, positive for moment tending to increase blade pitch, lb-ft
Ω	rotor angular velocity, radians/sec
c_{d_o}	section profile-drag coefficient
c_l	section lift coefficient
C_T	rotor thrust coefficient, $\dfrac{T}{\pi R^2 \rho (\Omega R)^2}$
C_Q	rotor-shaft torque coefficient, $\dfrac{Q}{\pi R^2 \rho (\Omega R)^2 R}$
C_{Q_o}	rotor-shaft profile-drag torque coefficient
$C_{m_{c/4}}$	rotor-blade pitching-moment coefficient, $\dfrac{M_b}{\frac{1}{2}\rho (\Omega R)^2 cR}$
θ	blade-section pitch angle measured from line of zero lift, radians

APPARATUS

The present investigation was conducted on the Langley helicopter test tower (fig. 1) described in reference 2. The only change in the instrumentation was the addition of individual blade pitching-moment indicators. This addition consisted of a ring strain gage mounted on the pitch control rod; the signal from the strain gage was transmitted through a silver slip ring to the oscillograph where it was recorded.

The two rotor blades were of fiber-glass construction and were covered with a 0.004- to 0.005-inch-thick stainless-steel skin. The blades had a radius of 18.63 feet from the center line of rotation, a constant chord of 1.2 feet, zero twist, a rotor solidity of 0.041, a torsional stiffness of 600 in-lb/deg of twist, and an NACA 8-H-12 airfoil section. Plan-form views of one of the test blades are shown in figure 2. A cutaway view showing the details of the blade construction is shown in figure 3. The inner core of the blade was made of strips of foam plastic wrapped with one layer of 0.005-inch fiber glass. The trailing-edge core was made of birch veneer and was bonded to the fiber glass and plastic foam core. A birch veneer block was also bonded to the forward section of the plastic core. This assembly was then covered (except for the forward part of the birch veneer block) with several layers of fiber-glass cloth impregnated with Paraplex resin. Blade chordwise balance was obtained by bonding a steel leading edge to the birch veneer block. The entire assembly was then covered by bonding a stainless-steel skin to the core. The stainless-steel skin served to carry about 20 percent of the centrifugal loads and gave a uniform and corrosion-proof exterior surface.

RESULTS AND DISCUSSION

Figure 4 shows some of the results of the tests of the two-dimensional airfoil (ref. 3) together with data from tests of the NACA 0012 airfoil section (ref. 4) which are presented for comparison purposes. Before describing the basic airfoil-section characteristics, it might be of interest to consider the reason for the shape of the NACA 8-H-12 airfoil. Since the interest is in the low drag, a low-drag thickness form was used. The airfoil was cambered so that the low drag would be realized at positive lift coefficients. This effect also means a high lift-drag ratio is achieved. In order to counteract the pitching moments introduced by camber, the trailing edge was reflexed. Figure 4 shows section drag coefficient plotted against section lift coefficient. These tests showed that the smooth NACA 8-H-12 airfoil had very good low profile-drag characteristics as compared with the NACA 0012 airfoil section, especially in the lift-coefficient range in which most of the rotor disk operates. Therefore, any decrease in drag in this range is very important. At the higher lift coefficients, the NACA 8-H-12 airfoil section does not look as attractive because of its higher drag; however, this high drag is out of the region of major power losses, at least until the stall limit in forward flight is approached.

It is of interest to know that, if these two airfoils are compared for the condition with leading-edge roughness, the profile polars are practically identical. The only difference is that for the NACA 8-H-12 airfoil, because of its camber, the minimum drag occurs at a positive lift coefficient rather than at zero lift coefficient.

It is important to know whether this low profile drag can be achieved on actual rotor blades. Therefore, a program was initiated to build a set of NACA 8-H-12 airfoil blades to as near perfect contour as possible and to test them on the Langley helicopter test tower (fig. 1). When the blades were completed, the departure from true airfoil contour was within 0 to -0.020 inch. A filler was then applied to the blades over the top 40 percent and bottom 80 percent of the chord which represent the theoretical extent of laminar flow on this airfoil. After careful sanding and polishing, the blade contour was within 0 to -0.002 inch of the true airfoil contour. The general smoothness and fairness was such that laminar flow could be reasonably expected on at least half the blade if it were tested as a two-dimensional airfoil.

The effect of the surface condition on the profile torque is shown in figure 5 where the thrust-coefficient—solidity ratio is plotted against profile torque coefficient for the NACA 8-H-12 blades. The data were obtained at a tip speed of 455 feet per second with a rotor solidity of 0.041. The profile torque coefficient was obtained by subtracting the calculated induced torque coefficient from the total measured torque coefficient. The calculated curve to the left indicates the profile torque that would have been obtained if the smooth drag curve shown in the two-dimensional-airfoil results had been realized. The middle curve represents the experimentally determined profile torque for the blades with the filled surface. The curve to the right represents the experimental data for the blades with their original surface (filler removed).

Over a representative range of thrust-coefficient—solidity ratios, from about 0.05 to 0.10, the profile power would have been reduced from 45 to 60 percent if the smooth-two-dimensional-airfoil results had been obtained from the rotor. Actually, only about half this reduction was obtained with the filled blades, which amounted to a reduction in the total power being absorbed by the rotor of the order of 6 to 7 percent.

Figure 6 shows a comparison between the results obtained for the blades with their original surface and a calculated curve based on the empirical drag polars (ref. 5) that has been found from experience to be representative of well-built rotor blades having conventional airfoil sections. Most of the published NACA rotor-performance charts are based on this polar.

The curves show that there is very little difference in rotor performance except at the very high thrust coefficients above a thrust-coefficient—solidity ratio of 0.10. This increase in profile torque was indicated by the two-dimensional-airfoil results and may not be of great importance because helicopters very seldom hover in this range. In the range from 0.06 to 0.09 where they do operate, some small benefits may be derived.

In the course of the investigation, data were obtained at various tip speeds. Figure 7 shows a plot of thrust coefficient against total torque coefficient for the NACA 8-H-12 blades with their original finish at tip speeds of 455 and 650 feet per second. These two curves show very little difference in rotor performance. At the lower rotor thrust coefficients there was a slight scale effect and at the higher thrust coefficients there was an increase in power required as a result of compressibility losses. In general, there are no gross effects for the two tip speeds shown.

The blade pitching moments were also measured during the tests; figure 8 shows the variations of the pitching-moment coefficient about the quarter-chord point as a function of blade pitch angle in degrees for a tip speed of 455 feet per second. The NACA 8-H-12 blade pitching moments tend to remain zero from about 3° to 9°. Slightly positive pitching moments are indicated at zero blade pitch and increasingly negative pitching moments are indicated at the higher blade pitch angles. In general, the pitching moments were similar to those that have been measured on rotor blades having conventional airfoil sections. The variation shown is typical of all the measured pitching moments on the NACA 8-H-12 blades with their original surface at the various tip speeds.

CONCLUDING REMARKS

From an investigation of the hovering performance of a helicopter rotor using NACA 8-H-12 airfoil sections it appears that the performance of the NACA 8-H-12 blades in the condition in which they arrived from the shop, that is, smooth and fair and within 0.020 inch of the true airfoil contour, was comparable to what might be expected from good practical-construction rotor blades. Improving the surface-contour accuracy to within 0.002 inch of the true airfoil contour resulted in getting about half the theoretical reductions in profile drag that would be expected on the basis of tests of the smooth two-dimensional airfoil. This effect amounted to an average reduction in total torque coefficients of 6 to 7 percent.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., June 10, 1954.

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3. Schaefer, Raymond F., and Smith, Hamilton A.: Aerodynamic Characteristics of the NACA 8-H-12 Airfoil Section at Six Reynold Numbers From 1.8×10^6 to 11.0×10^6. NACA TN 1998, 1949.

4. Smith, Hamilton A., and Schaefer, Raymond F.: Aerodynamic Characteristics at Reynolds Numbers of 3.0×10^6 and 6.0×10^6 of Three Airfoil Sections Formed by Cutting Off Various Amounts From the Rear Portion of the NACA 0012 Airfoil Section. NACA TN 2074, 1950.

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Figure 1

PLAN-FORM VIEW OF NACA 8-H-12 ROTOR BLADE
SHOWING 80% OF BOTTOM SURFACE FILLED

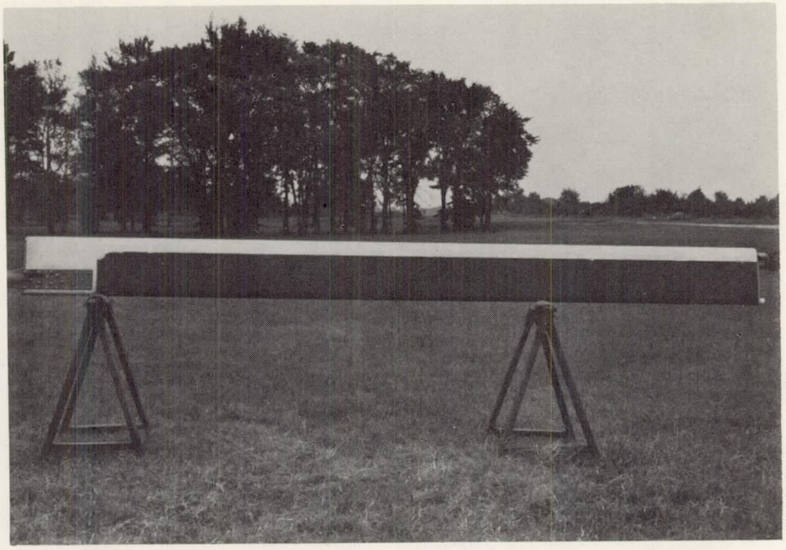


Figure 2(a) L-85619

PLAN-FORM VIEW OF NACA 8-H-12 ROTOR BLADE
SHOWING 40% OF TOP SURFACE FILLED

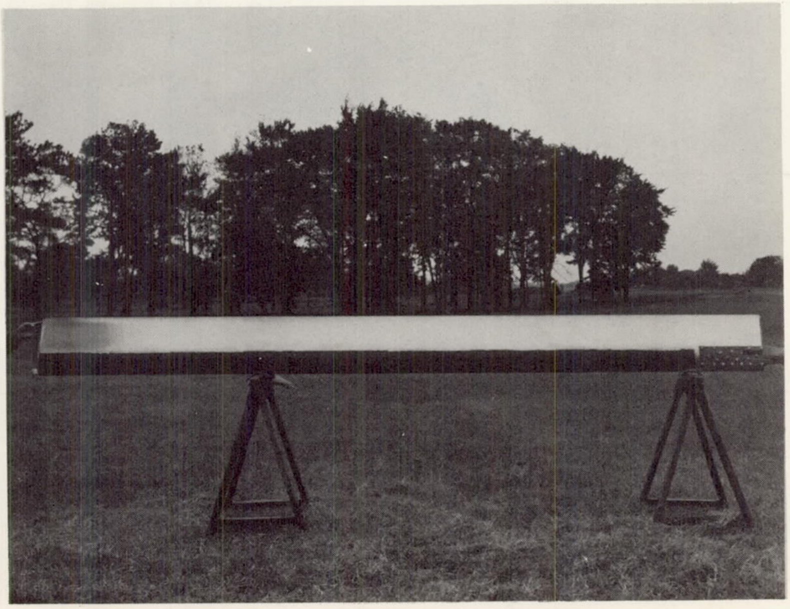
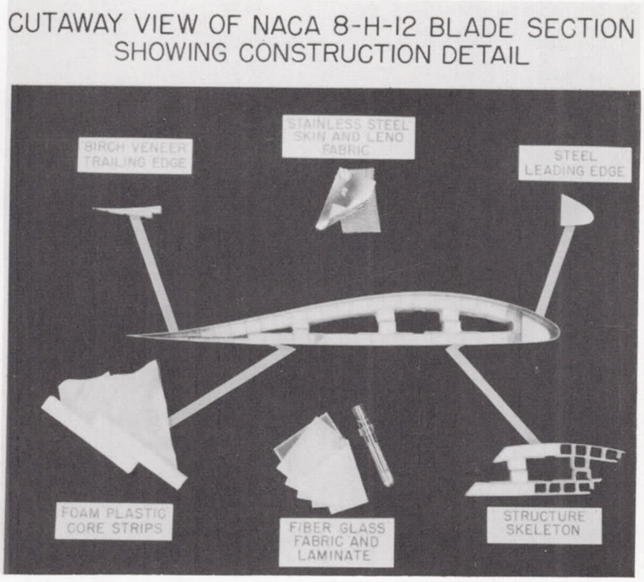


Figure 2(b) L-85618



CUTAWAY VIEW OF NACA 8-H-12 BLADE SECTION SHOWING CONSTRUCTION DETAIL

Figure 3

AERODYNAMIC CHARACTERISTICS OF NACA 8-H-12 AIRFOIL SECTION AS COMPARED TO AN NACA 0012 AIRFOIL SECTION

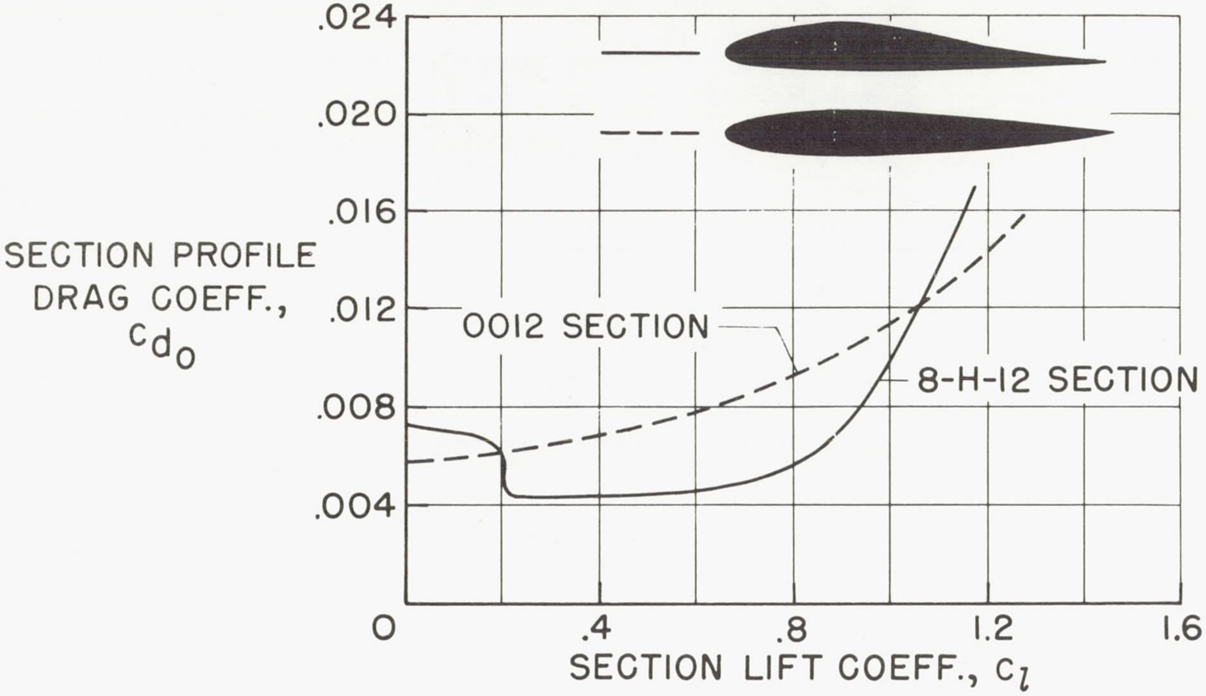


Figure 4

PROFILE TORQUE CURVES OF NACA 8-H-12 ROTOR BLADES

$\Omega R = 455$ FPS; $\sigma = 0.041$

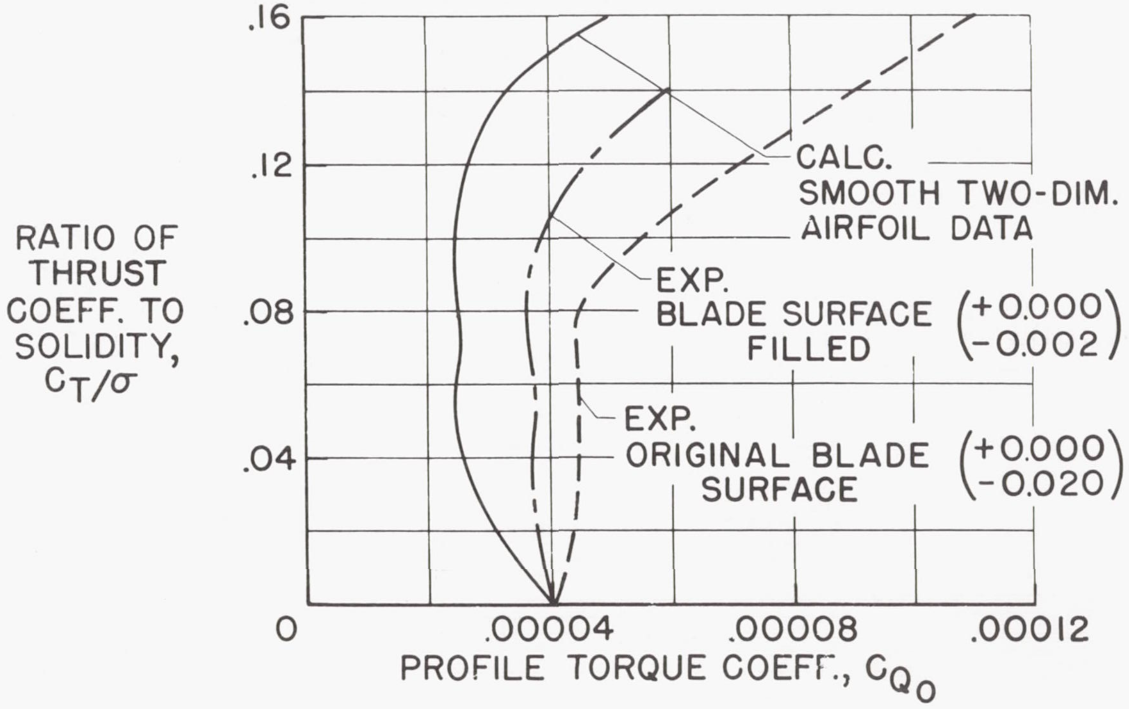


Figure 5

COMPARISON OF NACA 8-H-12 ROTOR (ORIGINAL SURFACE) WITH CALC. USING EMPIRICAL DRAG POLAR

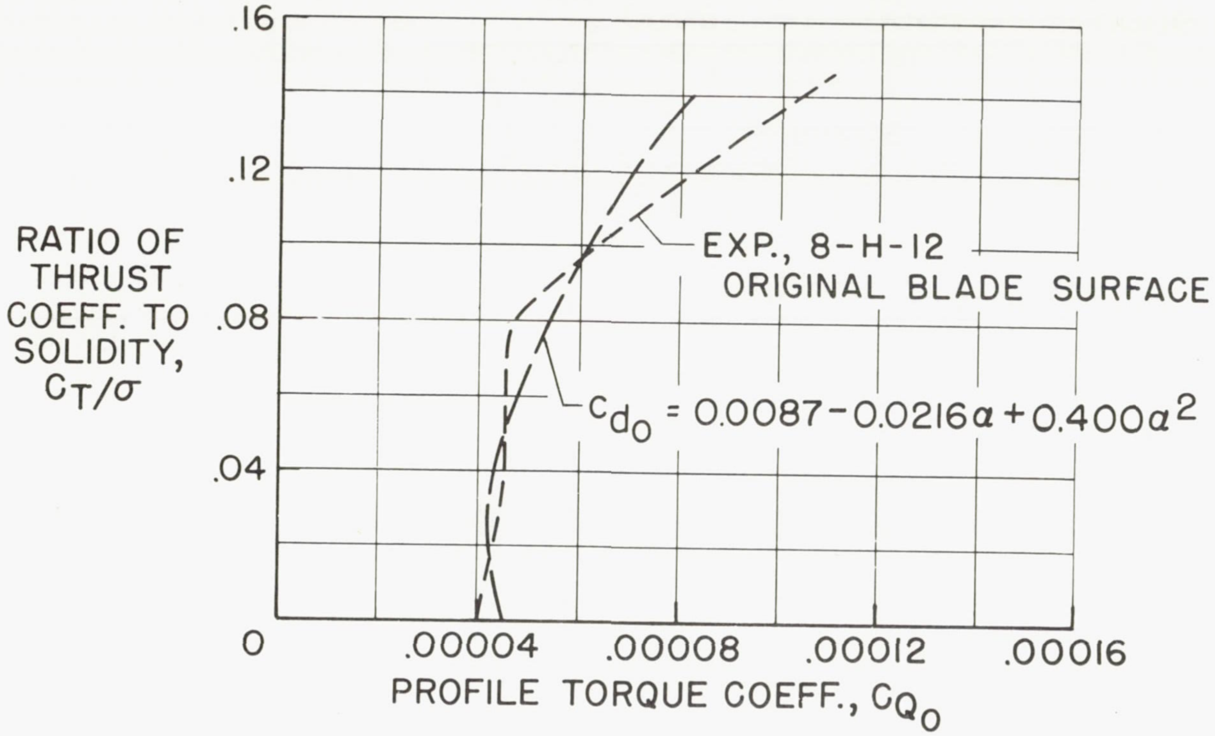


Figure 6

HOVERING PERFORMANCE OF NACA 8-H-12 BLADES AT TWO TIP SPEEDS

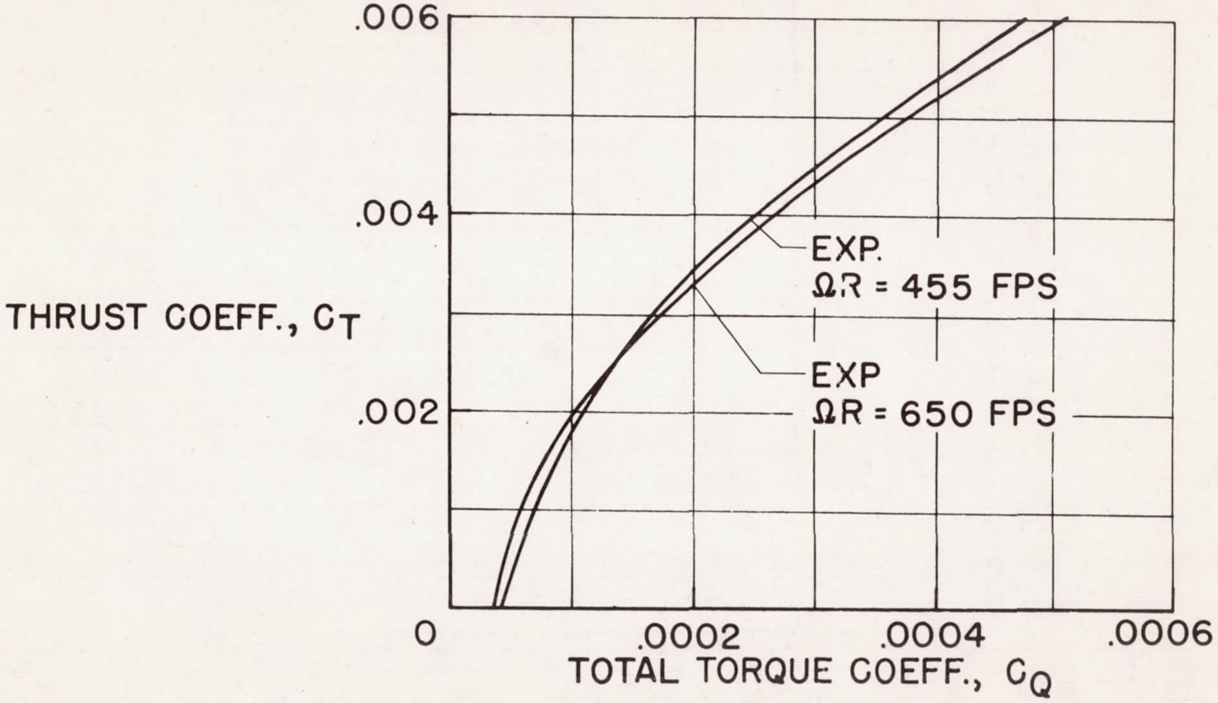


Figure 7

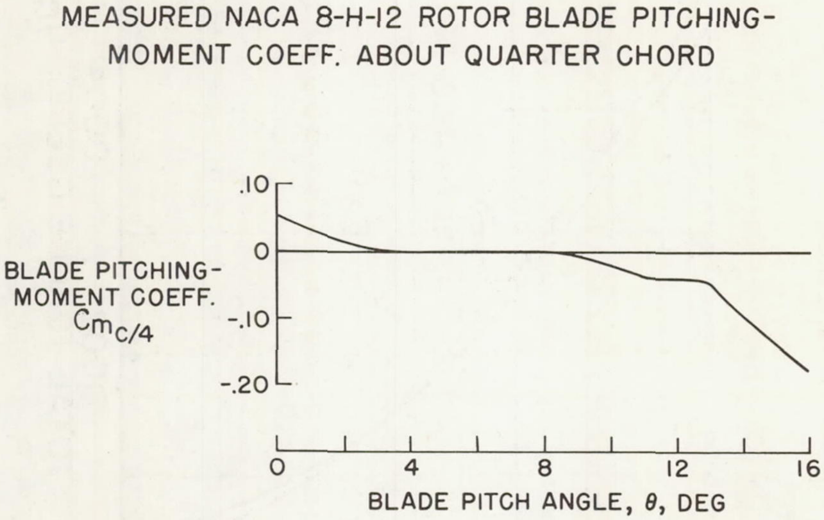


Figure 8

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