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SUPPLEMENTARY CHARTS FOR ESTIMATING PERFORMANCE
OF HIGH-PERFORMANCE HELICOPTERS

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FOR REFERENCE
Supplementary Charts for Estimating Performance of High-Performance Helicopters

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SUMMARY

Charts published in NACA TN 3323 for estimating the performance of high-performance helicopters were applicable to rotors having hinged rectangular blades with a linear twist of \(-8^\circ\). Supplementary charts are presented herein covering twists of \(0^\circ\) and \(-16^\circ\).

INTRODUCTION

Charts for estimating the performance of high-performance helicopters were published in reference 1. Those charts are applicable to rotors having hinged rectangular blades with a linear twist of \(-8^\circ\). Although the effect of blade twist on the rotor profile-drag power is not very significant at certain flight conditions, differences in profile-drag power between blades of different twist can become appreciable at other flight conditions, particularly at high tip-speed ratios. Accordingly, charts similar to those of reference 1 were prepared, covering twists of \(0^\circ\) and \(-16^\circ\), and are presented herein.

SYMBOLS

\(a\)  slope of curve of section lift coefficient against angle of attack per radian (assumed equal herein to 5.73)

\(b\)  number of blades per rotor

\(C_P\)  rotor-shaft power coefficient, \(\frac{P}{\pi R^2 \rho (\Omega R)^3}\)

\(C_{P0}\)  rotor-shaft profile power coefficient
CT \quad \text{rotor thrust coefficient; } 
\frac{T}{\pi R^2 \rho (\Omega R)^2}

c \quad \text{blade section chord, ft}

c_e \quad \text{equivalent blade chord (weighted on thrust basis),}
\int_0^R \frac{c r^2 dr}{\int_0^R r^2 dr}, \text{ ft}

P \quad \text{rotor-shaft power, ft-lb/sec}

R \quad \text{blade radius measured from center of rotation, ft}

r \quad \text{radial distance from center of rotation to blade element, ft}

T \quad \text{rotor thrust, lb}

V \quad \text{true airspeed of helicopter along flight path, fps}

v \quad \text{induced velocity at rotor (always positive), fps}

x \quad \text{ratio of blade-element radius to rotor-blade radius, } r/R

\alpha \quad \text{rotor angle of attack; angle between axis of no feathering}
\quad \text{(that is, axis about which there is no cyclic-pitch change)
\quad \text{and plane perpendicular to flight path, positive when axis
\quad \text{is inclined rearward, deg)

\alpha(x)(\psi) \quad \text{blade-element angle of attack at any radial position } x \text{ and}
\quad \text{at any blade azimuth angle } \psi, \text{ deg; for example,
\quad \alpha(1.0)(270^\circ) \text{ is blade-element angle of attack at tip of
\quad retreating blade at } 270^\circ \text{ azimuth position

\alpha(u_T=0.4)(270^\circ) \quad \text{blade-element angle of attack at radius at which
\quad tangential velocity } u_T \text{ equals } 0.4 \text{ tip speed
\quad and at } 270^\circ \text{ azimuth position, deg

\theta_{0.75} \quad \text{blade-section pitch angle at } 0.75 \text{ radius; angle between line
\quad of zero lift of blade section and plane perpendicular to
\quad axis of no feathering, deg}
\[
\lambda \quad \text{inflow ratio, } \frac{V \sin \alpha - V}{\Omega R}
\]

\[
\mu \quad \text{tip-speed ratio, } \frac{V \cos \alpha}{\Omega R}
\]

\[
\rho \quad \text{mass density of air, slugs/cu ft}
\]

\[
\sigma \quad \text{rotor solidity, } \frac{b_c e}{\pi R}
\]

\[
\psi \quad \text{blade azimuth angle measured from downwind position in direction of rotation, deg}
\]

\[
\Omega \quad \text{rotor angular velocity, radians/sec}
\]

**PERFORMANCE CHARTS**

Charts giving the relation between thrust-coefficient—solidity ratio, inflow ratio, and pitch angle at the three-quarter radius for tip-speed ratios ranging from 0.05 to 0.50 are presented in figures 1 and 2 for blade twists of 0° and -16°, respectively. Corresponding charts relating profile power, total shaft power, thrust coefficient, and pitch angle for specified values of tip-speed ratio are given in figures 3 and 4 for blade twists of 0° and -16°, respectively. These charts were computed and used in the same way as those of reference 1 and are subject to the same limitations.

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**REFERENCE**

Figure 1. - Thrust-coefficient-solidity ratio as a function of inflow ratio and pitch angle for blades having 0° twist.
Figure 1. - Continued.

(b) \( \mu = 0.10 \).

Figure 1. - Continued.
Figure 1. Continued.

(c) \( \mu = 0.15 \).

Thrust coefficient - solidity ratio, \( \frac{2C_T}{\sigma_a} \)

Inflow ratio, \( \lambda \)

\( \theta_{75} = 25^\circ \)

\( \alpha (u_T = 0.4) (270^\circ) = 16^\circ \)

\( \alpha (u_T = 0.4) (270^\circ) = 12^\circ \)
(d) \( \mu = 0.20 \).

Figure 1.- Continued.
Inflow ratio, $\lambda$

(e) $\mu = 0.30$.

Figure 1.-- Continued.
Figure 1.- Continued.
(g) $\mu = 0.50$.

Figure 1.- Concluded.
(a) \( \mu = 0.05 \).

Figure 2.- Thrust-coefficient—solidity ratio as a function of inflow ratio and pitch angle for blades having \(-16^\circ\) twist.
(b) $\mu = 0.10$.

Figure 2. - Continued.
Figure 2. Continued.

(c) $\mu = 0.15$.

Figure 2. Continued.
Figure 2. - Continued.

(d) $\mu = 0.20$. 
Figure 2. - Continued.

(e) \( \mu = 0.30 \).
Figure 2.- Continued.

(f) \( \mu = 0.40 \).

Figure 2.- Continued.
Figure 2.— Concluded.
(a) \( \mu = 0.05 \).

Figure 3. - Profile-drag—thrust ratio for blades having \( 0^\circ \) twist.
Figure 3 continued.

(b) $\mu = 0.10$. 

Figure 3. - Continued.
Figure 3.- Continued.

(c) \( \mu = 0.15 \).

(c) \( \mu = 0.15 \).

Figure 3.- Continued.
(d) \( \mu = 0.20 \).

Figure 3. - Continued.
(e) \( \mu = 0.30 \).

Figure 3. - Continued.
Figure 3.- Continued.

(f) \( \mu = 0.40 \).
(g) \( \mu = 0.50 \).

Figure 3.- Concluded.
(a) $\mu = 0.05$.

Figure 4.- Profile-drag—thrust ratio for blades having -16° twist.
(b) \( \mu = 0.10 \).

Figure 4.- Continued.
Figure 4.- Continued.

(c) $\mu = 0.15$. 
Figure 4.—Continued.

(d) $\mu = 0.20$. 

Figure 4.—Continued.
(e) \( \mu = 0.30 \).

Figure 4.- Continued.
(f) $\mu = 0.40$.

Figure 4. - Continued.
Figure 4.— Concluded.

(g) \( \mu = 0.50 \).