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FORT EUSTIS, VIRGINIA

PRELIMINARY FLIGHT TEST DATA.
XH-51A RIGID ROTOR HIGH SPEED FLIGHT PROGRAM,

INTERIM REPORT NO. 4.

12 29p.

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The information contained herein has been reproduced to disseminate to Government and industry, as rapidly as possible, current data vital to Army rotary-wing progress and objectives. In this respect, it is emphasized that the data, although measured flight data, are preliminary; therefore the contents of this document are subject to revision.
This report summarizes the flight test results of the three-bladed rotor testing on the XH-51A "rigid rotor" helicopter. The object of this testing was to obtain data on maneuver limits and center-of-gravity offsets needed to proceed with the high speed flight testing of the XH-51A with wing and jet pod installed. A total of 39 flights were made with 11.6 hours of flight time during this testing.

Discussion and Results

Maneuver Envelopes

Two maneuver envelopes were defined as a research objective for this testing, the smaller envelope being associated with the specified target C.G. offsets of 16,000 inch-pounds both longitudinally and laterally. Both envelopes are shown in figure 1, together with the points flown. None of the points were considered by the pilot to be beyond the acceptable limits of stability, handling, vibration, or performance. The pilot stated that the lines AA - BB would probably be a natural vibration boundary beyond which pilots would not go. There is no structural limit, however, and on the rare occasion when it is necessary to pull very high g's, the vibration level would be acceptable. The C.G. was extended to 16,000 inch-pounds in both lateral directions and tests were flown in excess of 95 knots. The aerodynamic nature of the ballast rig, being non-representative of any future configuration, negated the usefulness of any testing above this speed. The longitudinal C.G. range had been investigated to 8,000 inch-pounds aft and 11,000 inch-pounds forward prior to these tests. It was considered that the value of extending the investigation to 16,000 inch-pounds fore and aft did not warrant the aircraft and calendar time required at this stage. No longitudinal C.G. extension tests were made.

Configuration

The configuration for this phase was exactly that flown at Patuxent River, Maryland, except that the speed sensor was not used.

Structures

The results of the strain gauge program are presented here in terms of bending moments and stress. The calibrations were effected in terms of bending moment which are readily convertible into stresses from the known section structural properties along the span of any particular hub or blade design.

Preliminary measurements obtained on the main rotor early in the program indicated hub station 7.4 as the most critical area of the hub and blade. The primary objective of these tests was the extension of the flight envelope and the major effort during the program was, therefore, directed to the consideration of loads and stresses at the critical station. The stresses quoted for station 7.4 are calculated from the bending moments measured at station 6.0.
a. Average Bending Stresses - Station 7.4

The highest values recorded were in the flapping plane. The average flapping stress variation was linear with load factor, being zero at 1.3 g with a mid-C.G. and zero at 1.15 g with a lateral C.G. offset and increasing 32,000 psi for each 1.0 g increment. The change of load factor for zero bending stress is due to the somewhat higher average test weight at the offset C.G. The maximum flap bending stresses were 37,000 psi at 0.07 g and 34,000 psi at 2.3 g. The average chordwise stresses were not significantly g sensitive; the level varied from 1,300 psi to 4,800 psi generally.

b. Cyclic Stresses - Station 7.4

A stress concentration factor of less than 3 has been estimated for station 7.4. The conservative use of a factor of 3 realizes an endurance stress of 26,000 psi. For average pull-up conditions, the cyclic flapping stress is around 20,000 psi and the cyclic chordwise stress around 9,000 psi. Assuming the moments are in phase, the average combined stress in maneuvers is about 29,000 psi which is only slightly above the estimated endurance stress of 26,000 psi. The number of cycles of stress above the endurance limit that would be accumulated due to maneuvers is at 26,000 psi; therefore, normal maneuvers should have very little damaging affect on the fatigue life. The highest combined cyclic stresses for the whole series of maneuvers were obtained in the pushover to .063 g's at 50 knots airspeed. Assuming the loads are in phase, the combined stress would be 44,000 psi. The combined stresses for the pull-up to 2.34 g-s were 40,400 psi. These results illustrate that the cyclic stresses at the critical section are mainly a function of severity of pilot control input (which governs the blade flapping moment) rather than the load factor obtained (which has an affect mainly on the chordwise moments). The type of transient loads and stresses described above are included in the fatigue analysis and in the fatigue tests.

The lateral C.G. displacements did not have a deleterious effect on the stresses obtained at the load factors flown. Each stress value shown on all curves versus load factor is the maximum value recorded during the maneuver and is not necessarily associated with the maximum load factor or the maximum average stress.

The stresses recorded line up well with the values anticipated for this hub design and only minor design changes are required to reduce the levels should such a move be desired.
The hub for the four-blade rotor tests incorporates a design change that further improves the critical area and reduces the stress concentration. For a given set of loads, the stresses in the critical area will be reduced by about 5 per cent and the stress concentration factor should be lower. The bank angle versus velocity envelope flown during these tests is presented in figures 14 and 15.

Vibration

The vibration levels recorded during the testing are shown in figure 16.

Flying Qualities

The philosophy in this area was to rely on pilot qualitative evaluation with regard to handling characteristics and to investigate quantitatively only those areas in which problems were indicated. Static longitudinal stability characteristics were evaluated and the results are presented in figures 18 and 19. The control required to trim data presented in figure 17 is from the quasi-stabilized conditions employed in the structural tests. The flying qualities are considered very good from a qualitative standpoint. At the higher speeds, longitudinal control sensitivity increases and reduced cyclic pitch to stick gearings were tried. The results indicate that a change of gearing over the speed range may be necessary. This may be accomplished by a simple two position control selection device to be activated by the pilot as required, or a more sophisticated "q" sensed automatic device. The control forces recorded during the envelope expansion are plotted against the normal acceleration in figures 20 and 21. The trim or zero force point was recorded at the trim speed in level flight prior to the initiation of the turn. Cyclic pitch only was employed on the turns up to about 1.8 g; beyond this load factor, collective was added. Throughout the envelope, the helicopter has exhibited stick fixed, stick free static and dynamically stable characteristics.

Performance

The sea level standard day level flight speed power polar presented on figure 22 is in good agreement with previous results.
# Data Appendix

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FIGURE 4

MEASURED BENDING MOMENT AT 15.35 LEVEL 

SPAN AT 1455 KT LEVEL 

LEVEL FLIGHT AT 1455 ANGLE 5 HAR.

- AVERAGE LOAD
- CIRCLE LOAD
FIGURE 10

ALIFLE FLAP BENDING MOMENT STA. 6.75 LOAD FACTOR

10,000 IN. 18,000 LATERAL C.G.

TEST AMOUNT OF DEFLECTION

\( \Delta \) 3/4.75"" at 7.38
\( \Delta \) 1.75"" at 7.88

DARKER SYMBOLS = CYCLIC LOAD

OPEN SYMBOLS = AVERAGE LOAD

NUMBER TO RT. OF SYMBOL = APPROX. AMPLITUDE
MAIN ROTOR BLADE LOADS vs. CALIBRATED AIRSPEED

DARKENED SYMBOLS = CYCLIC LOAD
OPEN SYMBOLS = AVERAGE LOAD

CALIBRATED AIRSPEED - KNOTS
Cyclic Control to Trim - Level Flight

Diagram showing cyclic control settings for different CAS (Knots) and trim points.
STATIC longitudinal STABILITY

BASIC XH-51H AIRCRAFT

Ship: BUMC 15262

Configuration Notes:

1. Cyclic Stick Pitch Sensitivity = 100%

2. Landing Gear Down

3. Speed Sensor Off

4. Trim

5. Return

Figure 18
**Static Longitudinal Stability**

Right Hand Lateral Offset +10000 Nom

**Construction Notes**

1. Cycle Stick Back
   Sensitivity - 100%

2. Landing Gear Down

3. Speed Signal Off

- Trim
- Ratchet

**Diagram Details**

- Scale: 1 unit = 1000 ft
- Calibration: 0.01 in

Figure 19