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FLIGHT RESEARCH PROGRAM TO EVALUATE METHODS OF IMPROVING COMPOUND HELICOPTER MANEUVER CAPABILITY

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April 1968

U. S. ARMY AVIATION MATERIEL LABORATORIES
FORT EUSTIS, VIRGINIA

CONTRACT DA 44-177-AMC-151(T)

KAMAN AIRCRAFT CORPORATION
BLOOMFIELD, CONNECTICUT

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FLIGHT RESEARCH PROGRAM TO EVALUATE METHODS OF IMPROVING COMPOUND HELICOPTER MANEUVER CAPABILITY

W. E. Blackburn, et al

Kaman Aircraft Corporated
Bloomfield, Connecticut

April 1968

DEPARTMENT OF THE ARMY
U. S. ARMY AVIATION MATERIEL LABORATORIES
FORT EUSTIS, VIRGINIA 23604

This report has been reviewed by the US Army Aviation Materiel Laboratories and is considered to be technically sound. It is published for the exchange of information and the stimulation of ideas.

The program described is basically an extension of previous flight test work performed under Contract DA 44-177-AMC-151(T) and reported in USAAVLABS Technical Report 67-12. The results further substantiate the higher performance potential of rotary-wing aircraft.

The Army is currently continuing to sponsor programs of similar nature to provide basic technology for the future design of high-performance rotary-wing aircraft.

No subsequent work with the compounded UH-2 is planned; therefore, it has been restored to its original configuration and returned to the Navy.

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FLIGHT RESEARCH PROGRAM TO EVALUATE METHODS OF IMPROVING COMPOUND HELICOPTER MANEUVER CAPABILITY

Final Report

Kaman Aircraft Corporation Report No. R-622A

By

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A. D. Rita

Prepared by

Kaman Aircraft Corporation
Bloomfield, Connecticut

for

U. S. ARMY AVIATION MATERIEL LABORATORIES

FORT EUSTIS, VIRGINIA

SUMMARY

This report presents the results of a 13-hour flight test program conducted on the UH-2 compound helicopter to investigate methods of improving the maneuver capability. The program consisted of three phases, the first of which investigated wing/rotor load sharing during a series of symmetrical pull-up maneuvers accomplished with preselected longitudinal cyclic inputs. Phase II examined similar maneuvers with variations in wing/rotor load sharing accomplished by automatically reducing collective pitch as a function of increased normal load factor. Phase III studied the effect of ailerons for augmenting rotor roll control at selected airspeeds.

Installation of a fixed wing on a rotary-wing aircraft is shown to increase the capability to develop normal load factor by a significant amount. For the UH-2 compound aircraft with a wing/rotor blade area ratio of approximately 1.0, the maneuver capability is increased by a factor of 1.78. The maneuver capability from the standpoint of the rotor may be increased even more extensively by automatic reduction of rotor collective pitch control as a function of normal load factor, allowing a greater percentage of the overall load factor to be assumed by the wing.

A reduction in longitudinal cyclic control sensitivity is found to be an additional benefit derived from the reduction of collective pitch with load factor. It is possible to optimize longitudinal cyclic control sensitivity while maintaining improved maneuver capability by selecting appropriate collective pitch feedback gain settings.

Roll control augmentation using ailerons is one satisfactory method for imparting acceptable handling qualities for lateral/directional maneuvers in compound aircraft. Rolling accelerations of 1.0 radian/second^2 per inch of control and maximum roll rates of 10 to 12 degrees/second per inch of control are found to be acceptable.

FOREWORD

This report summarizes the results of a flight research program directed toward further definition and improvement of the maneuvering characteristics of compound helicopters. The program was conducted by the Kaman Aircraft Corporation, Bloomfield, Connecticut, under Contract DA 44-177-AMC-151(T) with the U. S. Army Aviation Materiel Laboratories (USAAVLABS).

Research flights, beginning in October 1965 and ending in January 1966, were a continuation of an overall program to investigate methods aimed at extending the high speed capability of rotary-wing aircraft. Progress of the program, from the basic helicopter to the compound configuration, is reported in References 1, 2, and 3.

The program was conducted under the technical cognizance of Messrs. L. H. Ludi and J. P. Whitman of the Applied Aeronautics Division of USAAVLABS. Principal Kaman Aircraft Corporation personnel associated with the program were Messrs. A. Ashley, W. Blackburn, A. Rita, and A. Whitfield.

CONTENTS

ILLUSTRATIONS

SYMBOLS

Dimensional Quantities

A	main rotor disc area - feet^2
GW	gross weight, pounds
L	wing lift, pounds
R	rotor radius, feet
S	wing area (exposed), feet^2
T	rotor thrust, pounds
α	wing angle of attack, degrees
ρ	air mass density, slugs/feet^3
Ω	rotor angular velocity, radians/second
b	number of blades in rotor
c	rotor blade chord, feet

Nondimensional Quantities

C_T rotor thrust coefficient,

$$C_T = \frac{T}{\rho A (\Omega R)^2}$$

C_W gross weight coefficient,

$$C_W = \frac{GW}{\rho A (\Omega R)^2}$$

N_Z overall load factor, ratio of normal forces to gross weight,

$$N_Z = \frac{T+L}{GW}$$

N_{Z_R} rotor load factor, ratio of rotor thrust to gross weight,

$$N_{Z_R} = \frac{T}{GW}$$

μ tip speed ratio,

$$\mu = \frac{V}{\Omega R}$$

σ rotor solidity,

$$\sigma = \frac{bc}{\pi R}$$

Derivative Forms

$d\alpha / dN_Z$ rate of change of wing angle of attack with normal load factor

dN_{Z_R}/dN_Z rate of change of rotor load factor with normal load factor

$d(C_T/\sigma)/dN_Z$ rate of change of rotor blade loading parameter with normal load factor

C_{L_α} three-dimensional wing lift curve slope

INTRODUCTION

The Kaman Aircraft Corporation has been participating actively in the research program sponsored by USAAVLABS which has the objective of extending the high speed capability of the helicopter. To this end, the Kaman program has progressed from the installation of horizontal thrust on a pure helicopter to the installation of a wing for rotor lift augmentation combined with thrust augmentation. In the course of flight activity in a regime normally well above the pure helicopter speed capability, certain problems were uncovered which, although they did not seriously compromise the research flights, require some investigation from an operational standpoint. The most obvious of these is the maneuver capability of the aircraft near the blade stall-limited airspeed and the apparent reduction in roll control power accompanying increased roll inertia and damping of the wing.

This report concerns itself with the results of an investigation of the effect of variations in longitudinal cyclic control inputs on the rotor load buildup in symmetrical pull-up maneuvers with collective control both fixed and variable as a function of normal load factor. A second phase examines the effectiveness of conventional aileron control surfaces in augmenting rotor roll control power.

DESCRIPTION OF TEST VEHICLE

The test vehicle made available for the program was the UH-2 compound helicopter described in Reference 3 and illustrated in Figure 1. Modifications and additions to the control system and components of the automatic stabilization equipment were accomplished to satisfy the test objectives. Configuration details and a tabulation of pertinent dimensional data are shown in Figure 2.

The pitch channel of the automatic stabilization equipment (ASE) was reconfigured to provide the ability to apply repeatable longitudinal cyclic inputs for the development of load factor in symmetrical pull-up maneuvers to define the wing/rotor load sharing characteristics. The amount of control input was variable in flight from 0 to 1.0 inch of stick displacement at rates varying from .5 inch/second to 5.0 inches/second.

A vertical accelerometer, sensing normal load factor, was added to the collective channel to reduce automatically the collective pitch of the rotor as a function of increasing load factor. The sensitivity of the system was variable in ten steps from 0 to 25 percent of total collective control per unit load factor.

The compound configuration reported in Reference 3 utilized the outboard wing control surfaces as flaps. These surfaces were reconfigured as ailerons and mechanically coupled through an overload limiting device to the primary lateral cyclic control system. Seven variations in the aileron deflection per inch of lateral cyclic stick from 0 degree/inch to 3.57 degrees/inch were obtainable by ground adjustment.

Appropriate proof load and functional tests of the modified systems were made prior to flight.

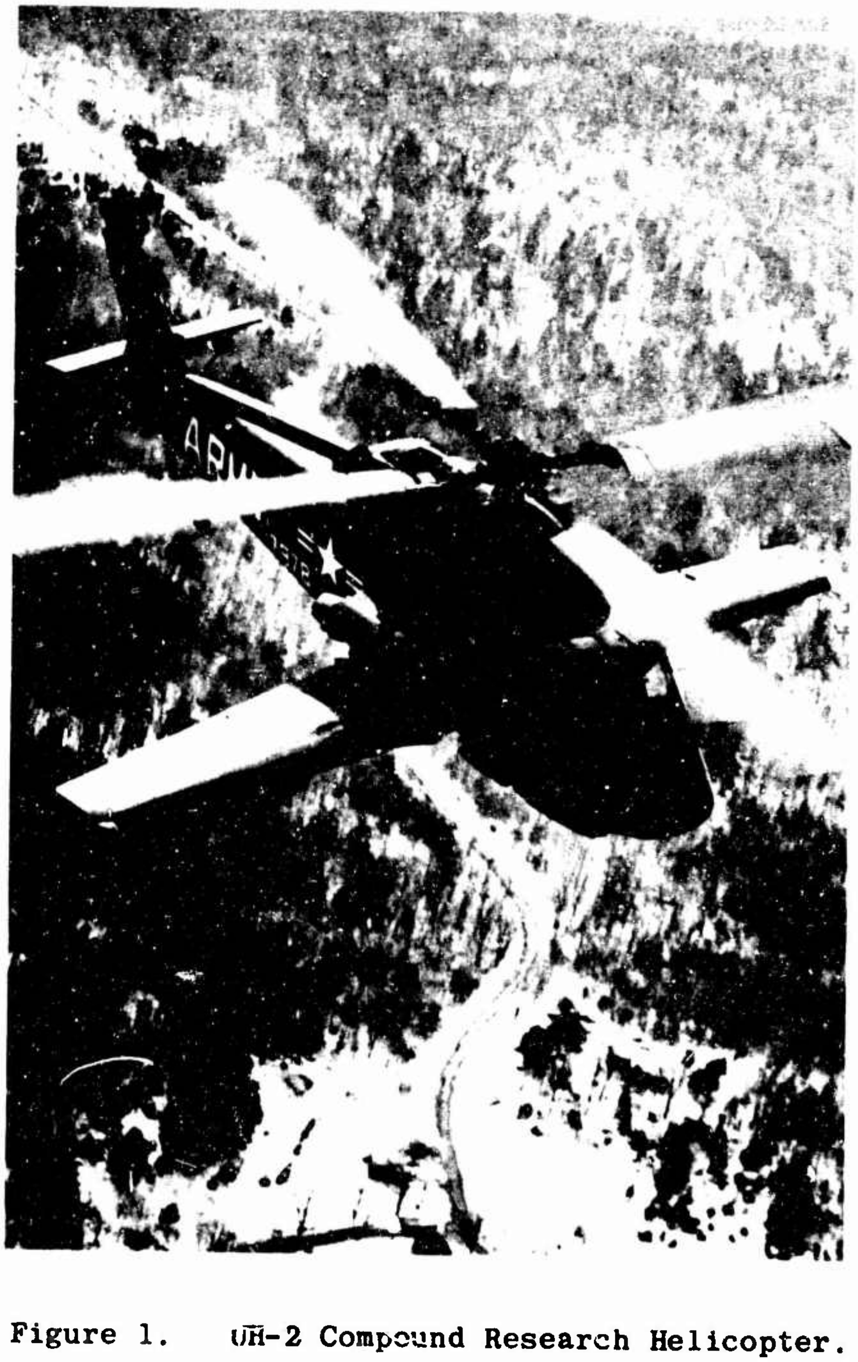

Figure 1. UH-2 Compound Research Helicopter.

Blade and Control Surface Areas	
Projected Disc Area	1520.50 ft^2
Total Blade Area Including Servo Flaps	134.00 ft^2
Servo Flaps, Total	9.98 ft^2
Horizontal Tail	14.50 ft^2
Vertical Tail	29.50 ft^2
Airfoil Sections	
Blade, Main Rotor	NACA 23012 (Modified)
Blade, Tail Rotor	NACA 63_1-012
Servo Flap Main Rotor Blade - NACA 63_3-018 (27 deg to -35 deg Max Travel)	
Horizontal Tail - NACA 0013 - Adjustable, Trailing-Edge Dn 16 deg, Trailing-Edge Up 12 deg	
Vertical Fin	NACA 0025
Tail Rotor Surface Areas	
Projected Disc Area	50.4 ft^2
Total Blade Area	6.5 ft^2
Wing Area (Overall Exposed)	144.0 ft^2
Ailerons, Total Area	17.4 ft^2
Takeoff Gross Weight	10,200.0 lb
100 Percent Rotor Speed is Equivalent to	276.7 RPM

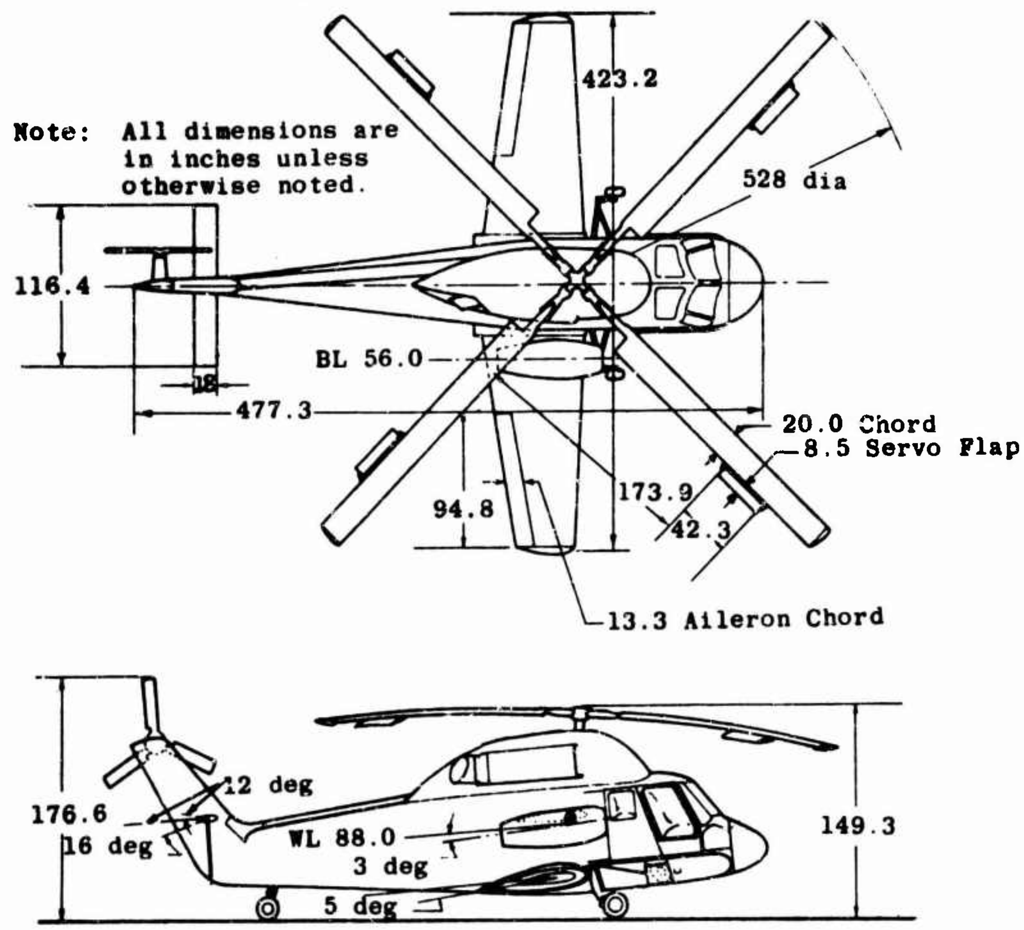

Figure 2. General Arrangement - UH-2 Compound Helicopter.

TEST INSTRUMENTATION

Test instrumentation was installed to record flight test data pertinent to the objectives of the program.

Basic aircraft instrumentation consisted of an airborne recording oscillograph and photopanel in conjunction with an air-to-ground telemetry data system. This installation is essentially that used in the compound configuration as reported in Reference 3, except for minor changes.

A summary of the parameters measured is presented in Table I.

TABLE I

SUMMARY OF PARAMETERS RECORDED

1. Longitudinal cyclic control position	22. Wing lift strain gages
2. Lateral cyclic control position	23. Pitch attitude gyro
3. Stabilizer angle	24. Roll attitude gyro
4. Aileron angle	25. Roll rate gyro
5. Directional control position	26. Sideslip angle
6. Collective control position	27. Yaw rate
7. Tail rotor blade flapping	28. Airspeed
8. Tail rotor chordwise bending - Station 12	29. Altitude
9. Tail rotor flapwise bending - Station 12	30. Rotor speed
10. Main rotor hub flapping moment	31. Wing angle of attack
11. Main rotor hub torque	32. Critical transmission mount load - Tube 4
12. Main rotor servo-flap bending	33. T-58 critical mount loads
13. Main rotor chordwise bending - Station 43.5	34. YJ-85 critical mount loads
14. Main rotor flapwise bending - Station 190	35. Horizontal tail flapwise bending
15. Pilot seat vertical acceleration	36. Horizontal tail chordwise bending
16. CG vertical acceleration	37. Horizontal tail aft spar load
17. Transmission lateral acceleration	38. YJ-85 compressor discharge pressure
18. Station 50 vertical acceleration	39. YJ-85 thrust
19. Station 400 vertical acceleration	40. T-58 gas-producer speed
20. Monitor strain gages for wing bending	41. YJ-85 gas-producer speed
21. Wing attachment strain gages	42. CG vertical load factor
	43. YJ-85 fuel flow
	44. YJ-85 exhaust gas temperature
	45. Outside air temperature
	46. Main rotor control load
	47. T-58 torque pressure

EXPERIMENTAL PROCEDURES

The flight test program was conducted in the three phases described below.

Phase I. Wing/Rotor Load Sharing

The wing/rotor load sharing characteristics were investigated in symmetrical pull-up maneuvers resulting from the selected longitudinal cyclic inputs with fixed collective control. The effects of two cyclic input displacements and two rates were examined at 150, 165, and 180 knots TAS.

Phase II. Automatic Collective Pitch Reduction

Automatic collective pitch reduction as a function of load factor buildup was examined in maneuvers comparable to those accomplished in Phase I. The effects of three collective feedback sensitivities were investigated at 150, 165, and 180 knots TAS for one cyclic input displacement at two rates.

Phase III. Effect of Aerodynamic Surfaces to Augment Roll Control

Basic roll accelerations were established at 150, 165, and 180 knots TAS for two values of wing lift without aileron deflection. The roll augmentation afforded by three values of aileron deflection per unit of lateral cyclic displacement was examined at 150, 165, and 180 knots TAS. The maneuver consisted of a series of rolls produced by lateral cyclic displacement held until the maximum roll velocity was attained and then reversed. Rudder and longitudinal control were applied as required to maintain nearly constant heading and pitch attitude.

All flights were conducted at a takeoff gross weight of approximately 10,000 pounds with a minimum terrain clearance of 2000 feet. The main rotor speed was maintained at approximately 97 percent with 2400 pounds of jet thrust augmentation. The horizontal stabilizer angle was set at 3 degrees trailing-edge down with respect to the aircraft waterline for Phases I and II and 3 and 8 degrees trailing-edge down for Phase III to obtain the desired variations in wing lift. The wing incidence angle was set at 5 degrees trailing-edge down for all flights.

EXPERIMENTAL RESULTS

The effect of variations in longitudinal cyclic control input characteristics on the history of rotor load buildup is summarized in Figure 3. The test data are reduced to the nondimensional form, $d(C_T/\sigma)/dN_Z$ plotted versus the rotor tip speed ratio, μ . A typical relationship, showing the rotor load factor versus the conventional overall load factor during a symmetrical pull-up maneuver, is presented in Figure 4. The data plotted in this figure were obtained with the longitudinal cyclic input programmed through the specially modified pitch channel in the automatic stabilization system. For comparison, similar data are shown for the same maneuver with longitudinal cyclic applied by the pilot rather than by automatic programming and with the collective feedback system operative.

The extent to which the rotor load factor may be modified during accelerated flight by manipulation of rotor collective pitch with specific longitudinal cyclic inputs is shown in Figure 5. These data were obtained in a manner similar to that used in evaluating various cyclic inputs except that, as the load factor built up, the rotor collective pitch was reduced automatically by specific increments per unit load factor, depending upon the sensitivity selected by the pilot. Data were obtained at two different longitudinal cyclic step control input rates. Since the results were nearly identical in either case, the data are presented only for the higher rate.

The relationships presented in Figures 3 and 5 result from the conversion of raw test data to a form which relates the rotor load factor, defined as the ratio of rotor thrust to gross weight, to the overall load factor, which represents the ratio of total lift to gross weight. The slope of the linear portion of this relationship, inserted into the definition of rotor thrust coefficient, results in an expression which permits evaluation of the total derivative,

$$\frac{d(C_T/\sigma)}{dN_Z} = \frac{C_W}{\sigma} \cdot \frac{dN_{Z_R}}{dN_Z} \qquad (1)$$

The change in wing angle of attack per unit change in load factor may also be established from the data obtained during this phase of testing according to the expression

$$\frac{d\alpha}{dN_Z} = \frac{C_W\left(1 - \frac{dN_{Z_R}}{dN_Z}\right)}{\frac{C_{L_\alpha} S \mu^2}{2A}} \qquad (2)$$

The results of the investigation of roll control augmentation with ailerons are summarized and compared with theoretical calculations in Figure 6. The trends shown are derived from the analysis of test data which consisted of a time history of rolling velocity attained following lateral cyclic displacement to the right and left. Since these data show the steady rolling velocity with the roll control essentially fixed, they also define the initial rolling moment imposed by control input as well as the damping in roll. A typical time history of the roll maneuver is presented in Figure 7.

EVALUATION

MANEUVER CAPABILITY IN SYMMETRICAL PULL-UPS

The data in Figure 3 show that the rate of change of the rotor blade loading parameter with normal load factor is essentially unaffected by the amount of longitudinal cyclic control input and only slightly affected by the rate at which the control is applied. Over the range of airspeeds tested, the average value of $d(C_T/\sigma)/dN_Z$ is about .0445. In the helicopter configuration (without wings), this value is equal to the weight parameter, C_W/σ, since the rotor load factor is equal to the overall load factor (see Equation 1). For all maneuvers evaluated during this phase of the program, the average weight coefficient was .079.

Examination of Figure 4 and Figure 5 shows that the addition of the load factor sensing function to collective pitch is an extremely effective means for unloading the rotor during accelerated flight. Figure 4 illustrates typically the rotor load relief attributable to the feedback to the collective pitch control. In the range where the output of the collective feedback system is essentially linear as a function of normal load factor, as shown on Figure 4, the rate of change of rotor load factor is reduced from 0.52 to 0.316 using only 13 percent of collective travel per unit load factor. Note that the increased slope of the curve above ΔN_Z = 0.8g reflects a limitation imposed by feedback system hardware and not a change in aircraft response at this point. Similarly, below about 0.25g the load factor signal is apparently not strong enough to actuate the collective stick, so this level of load factor represents the threshold sensitivity for this particular experimental system.

Figure 5 summarizes the data obtained at three airspeeds over a range of collective feedback ratios. Here it is shown that the rotor can actually be unloaded as the overall load factor builds up. This is accomplished at the expense of the wing, which must pick up the load taken off the rotor. Consequently, a practical limit to which the rotor load may be relieved is established by the wing. For the UH-2 compound aircraft, the wing angle of attack changes with load factor are plotted versus $d(C_T/\sigma)/dN_Z$ in Figure 8, from which it will be seen that the change in rotor loading in maneuvers below a value of .031 would require over a 5.5-degree change in wing angle of attack at 180 knots to achieve an overall load factor in excess of 2.0g. Depending on the trim wing lift, then, it is entirely possible to limit maneuver capability to the g-level attainable at the maximum wing lift coefficient. However, it appears feasible to substantially increase the maneuver capability of compound aircraft relative to retreating blade stall by an optimum choice of wing/rotor load sharing which would result in simultaneous stall of both the wing and rotor.

To establish the order of magnitude of the penalty involved, an analysis has been made to compare the maximum load factor that can be obtained with the "ideal" feedback ratio to that obtained with a constant feedback ratio equal to the ideal at maximum airspeed and of sufficient magnitude to preclude retreating blade stall at speeds below the maximum level flight speed of the aircraft. The calculations are based on characteristics of the UH-2 compound; therefore, the results shown in Figure 9 must be interpreted as establishing a trend rather than precise definition for any configuration. There should be enough generality, however, to substantiate that a constant feedback ratio is acceptable provided a maximum maneuver penalty of about 10 percent can be tolerated. Note, however, that at the maximum airspeed, the maneuver penalty is zero because the ideal and constant feedback ratios are identical at this point.

The technique whereby rotor thrust is reduced during maneuvering flight prompted pilot comments pertaining to improved handling qualities stemming directly from the collective feedback principle. Although the benefit to be derived in this respect may not be unexpected, it is instructive to consider the pilot remarks from an analytical point of view to establish the reason for them.

There are at least two aspects of helicopter handling qualities that are affected by increasingly higher forward speeds: the sensitivity to longitudinal cyclic control input and the maneuver stability at constant airspeed. Both of these properties depend upon the relative airspeed of the rotor blade sections, since they are defined by the speed-dependent rate of change of lift with respect to angle of attack. This can be seen by examination of Equation 13 on Page 189 of Reference 4, which shows the elemental blade thrust as a function of the pitch angle, θ , and the velocity components, U_P and U_T, perpendicular and parallel to the reference plane. Further clarification is presented in Chapter 11 of Reference 4, where helicopter control and stability are qualitatively discussed.

Longitudinal cyclic control power increases with increasing forward speed as a result of the effect of the higher flight dynamic pressure on blade lift. Rotor damping also increases, but at a slower rate, resulting in lower effective damping. The net effect is an increase in longitudinal cyclic sensitivity, defined in Reference 4 as control power/rotor damping.

The influence of the feedback to the collective stick is illustrated in Figure 10 in terms of the helicopter response to a step input of aft cyclic control at the highest speed at which data were obtained, 180 knots TAS. The marked improvement obtained in the maneuver stability can be attributed to the reduction in collective pitch as a function of normal load factor, which appears to the pilot as an increment of positive static stability with respect to angle of attack opposing the inherent static instability of the rotor with no feedback.

From the above observations, it is concluded that the pilot opinion pertaining to improved flying qualities of the compound with collective feedback should be attributed to the significant improvement in maneuver stability which results in desensitized longitudinal control. The divergent response is eliminated and the aircraft pitch rate and load factor both show slightly positive stability at 150 knots, which deteriorates to a very docile oscillatory divergence with increasing airspeed. Rotor speed changes are effectively minimized by the engine governor in spite of substantial main rotor torque changes occurring with cyclic and collective inputs. It is noteworthy, also, that torque changes are not as severe with feedback as they are without it.

ROLL CONTROL AUGMENTATION

The results obtained in this portion of the investigation demonstrate that an integrated rotor/aileron lateral control system is a practical means of attaining satisfactory lateral/directional flying qualities. In addition, it has been shown that present analytical methods are adequate, with certain refinements, for design purposes.

Figure 6 compares roll sensitivities obtained by flight test with analytically predicted values. At zero aileron gearing ratio, measured results were found to be slightly lower than predicted. Since the relationship shown in Figure 6 is indicative of control power as well as damping, the discrepancy between test and analysis appearing at zero aileron gearing ratio can be attributed either to overestimating control power or to underestimating the damping. Detailed analysis indicates that the rotor damping, which is shown by calculation to decrease from 45.5 percent of the total at 150 knots to 13 percent of the total at 180 knots, is underestimated by 25 percent at each airspeed investigated. Also, it is noted that the analysis did not account for any damping contributed by the fuselage vertical stabilizer and horizontal stabilizer, which makes the total calculated damping derivative somewhat low.

With increasing aileron gearing ratio, there is a higher calculated rolling velocity than was measured (see Figure 6); this is attributed to overestimation of aileron control power. With the rotor damping increased by 25 percent, the calculated roll control sensitivity would be only 15 percent greater than that measured at any given aileron gearing ratio.

Figure 7 illustrates the response characteristics of the UH-2 compound, which was judged by contractor pilot evaluation to give satisfactory maneuver stability and response to control input at the maximum aileron gearing ratio tested at 165 knots. Note that the lateral cyclic displacement at trim is not at the neutral position (50 percent). As a result, the ailerons, which were rigged to zero deflection at neutral stick, are deflected. It is pointed out that the lateral cyclic, in general, will not be zero for all flight conditions, since it is essentially a function of the tail rotor thrust, which varies with main rotor torque and airspeed. Yaw response during the maneuver was maintained near zero by pilot input; pitch response was not compensated, and a slowly diverging oscillation of the pitch attitude appears. Roll rates of 10 to 12 degrees/second/inch of lateral cyclic, about double the rates achieved without ailerons, were developed with an aileron gearing ratio of 1.6 degrees/inch of control. However, the roll damping is high enough to prevent overshoot of the roll attitude at the high roll rates; this characteristic, in conjunction with the threefold increase in roll acceleration achieved with the ailerons, contributes strongly to the pilot's impression of distinctly improved handling qualities.

Nominal Cyclic Input

Symbol	Magnitude	Rate
⊙	0.5 in.	0.3 in./sec
⊡	0.2 in.	0.38 in./sec
△	0.5 in.	1.6 in./sec

Takeoff GW = 10,000 lb
Rotor Speed = 97%
Wing Incidence = 5 deg Trailing-Edge Down
Horizontal Stabilizer Incidence Angle = 3 deg Trailing-Edge Down

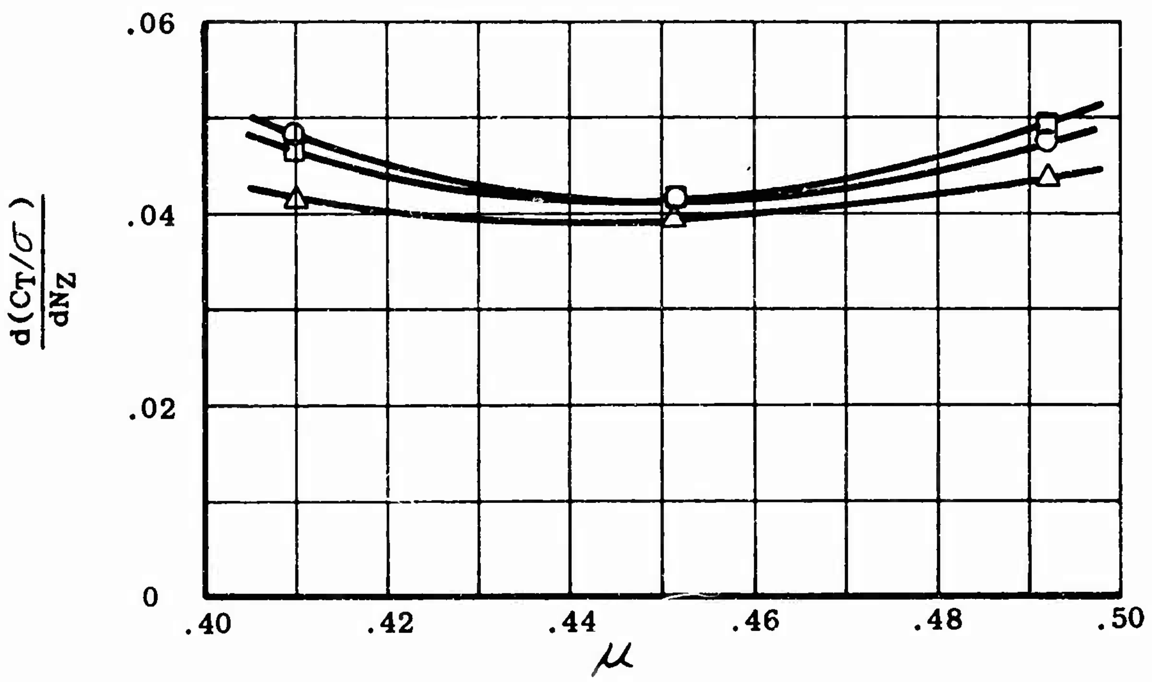

Figure 3. Change in Rotor Blade Loading with Normal Load Factor as Affected by Longitudinal Cyclic Input.

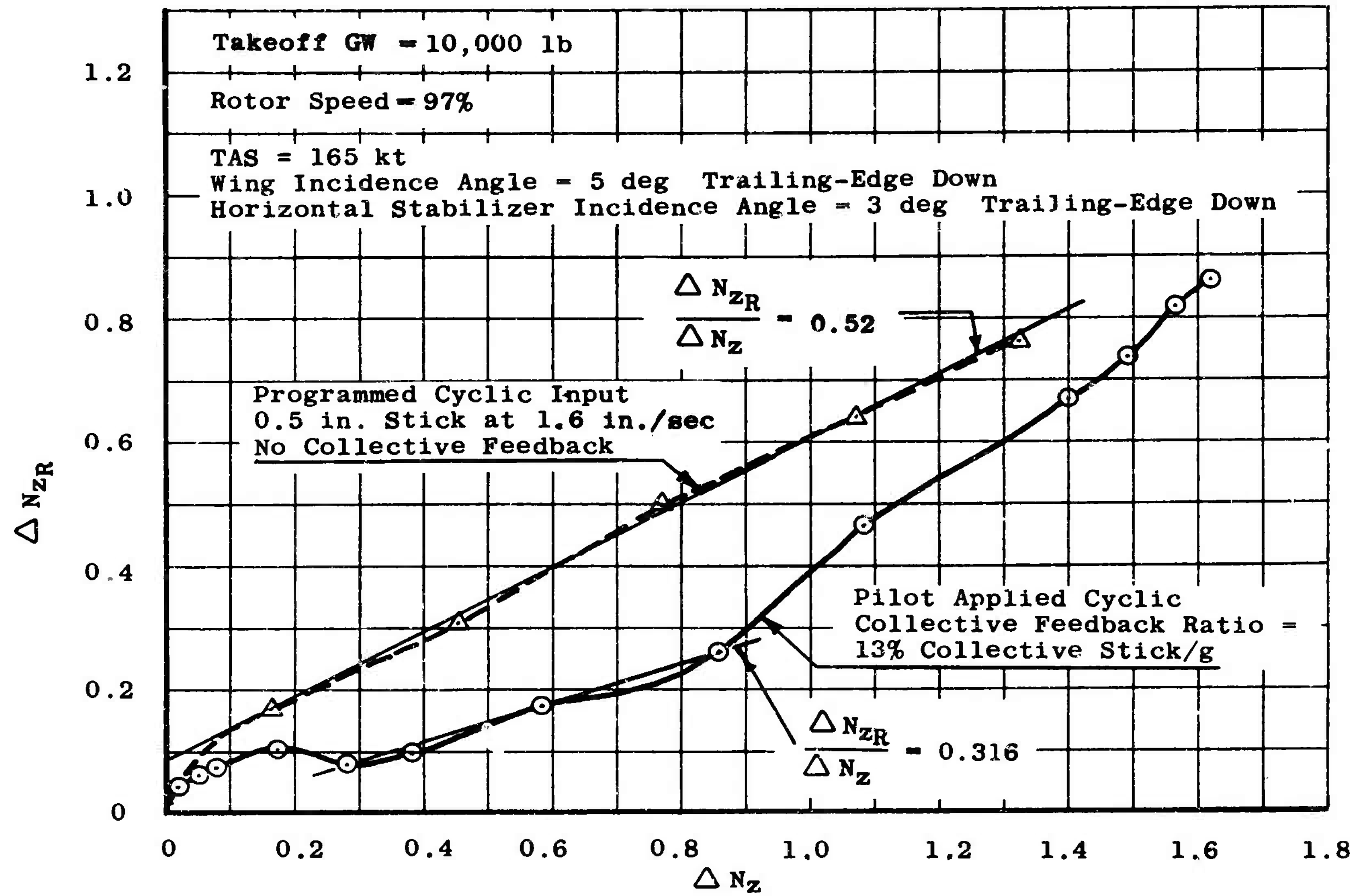

Figure 4. Typical History of Rotor Load Factor Buildup with Normal Load Factor.

Takeoff GW = 10,000 lb
Rotor Speed = 97%
Wing Incidence Angle = 5 deg Trailing-Edge Down
Horizontal Stabilizer Incidence Angle = 3 deg Trailing-Edge Down
Cyclic Input = 0.5 in. at 1.6 in./sec

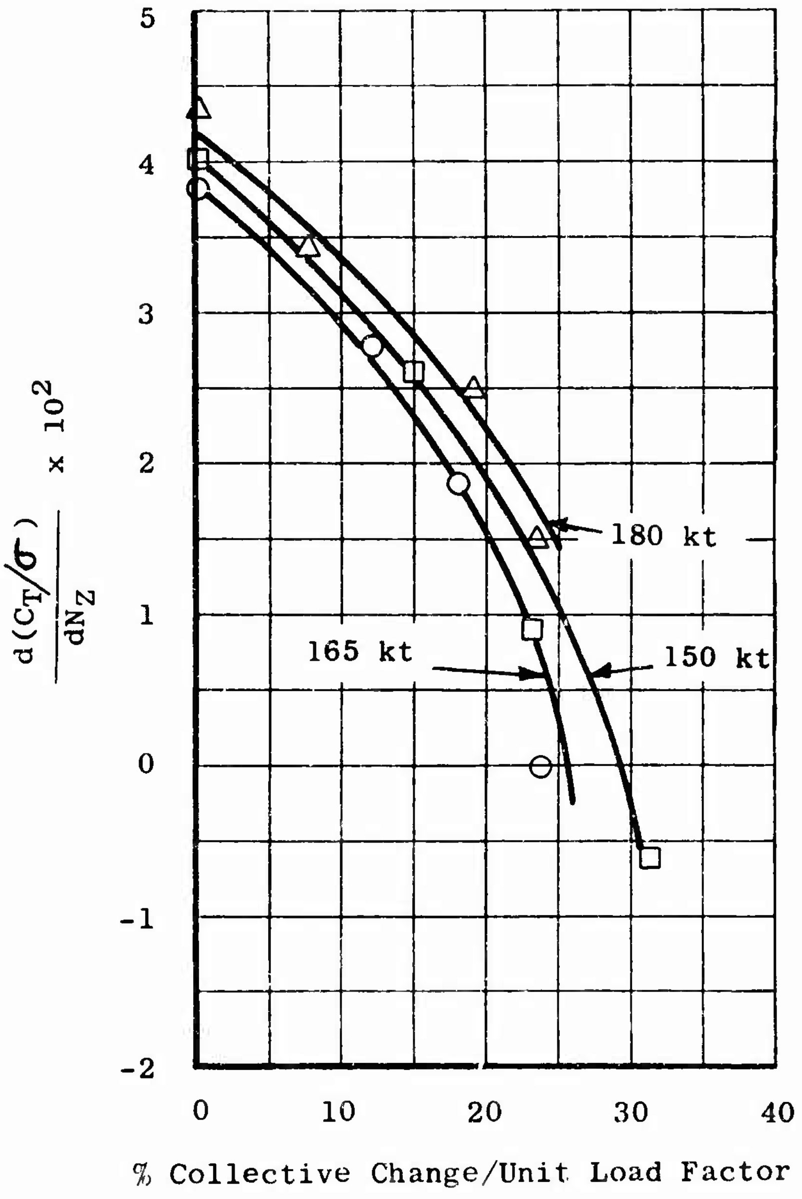

Figure 5. Effect of Collective Pitch Reduction on Rotor Blade Loading Change With Normal Load Factor.

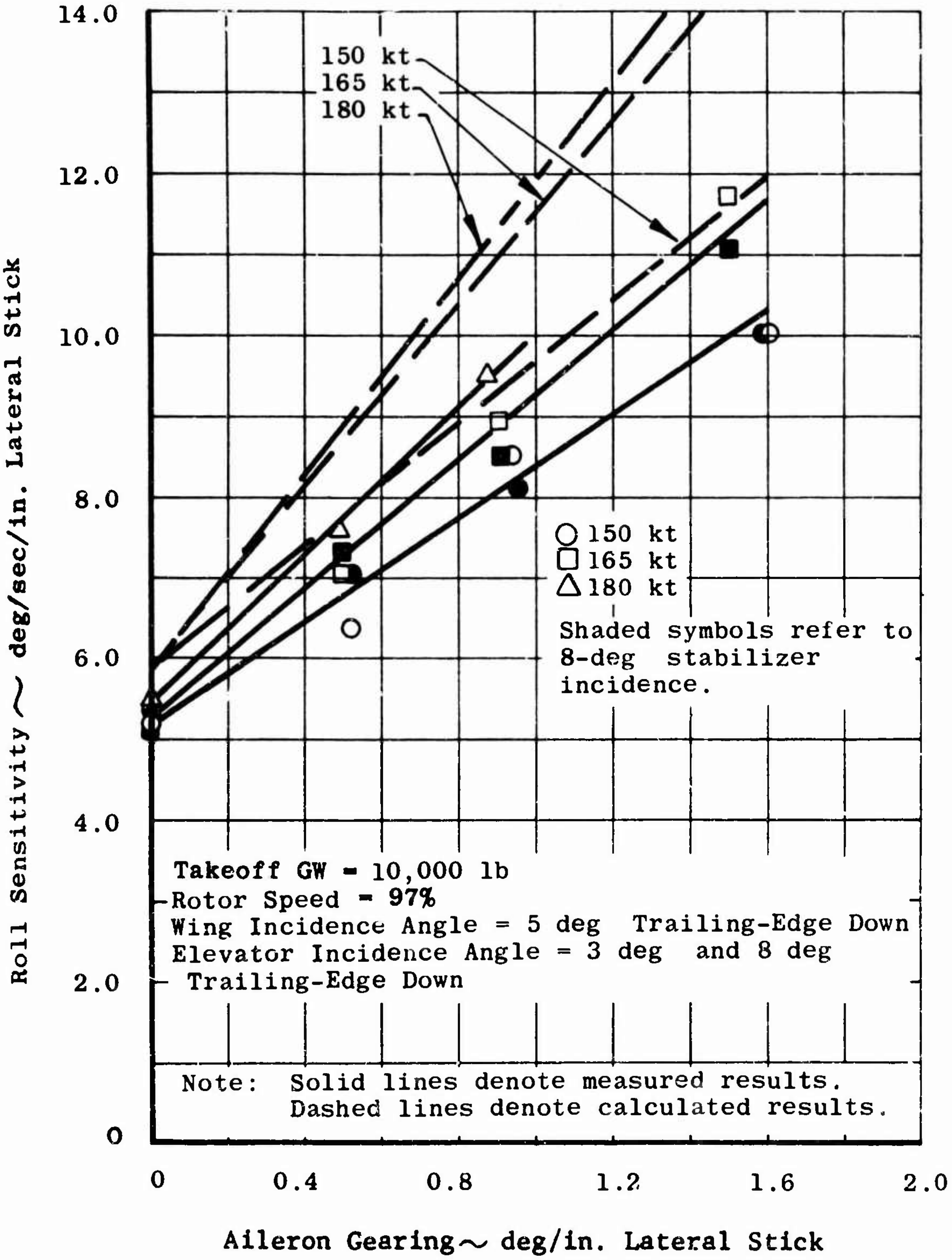

Figure 6. Variation of Roll Rate Sensitivity with Roll Control Augmentation.

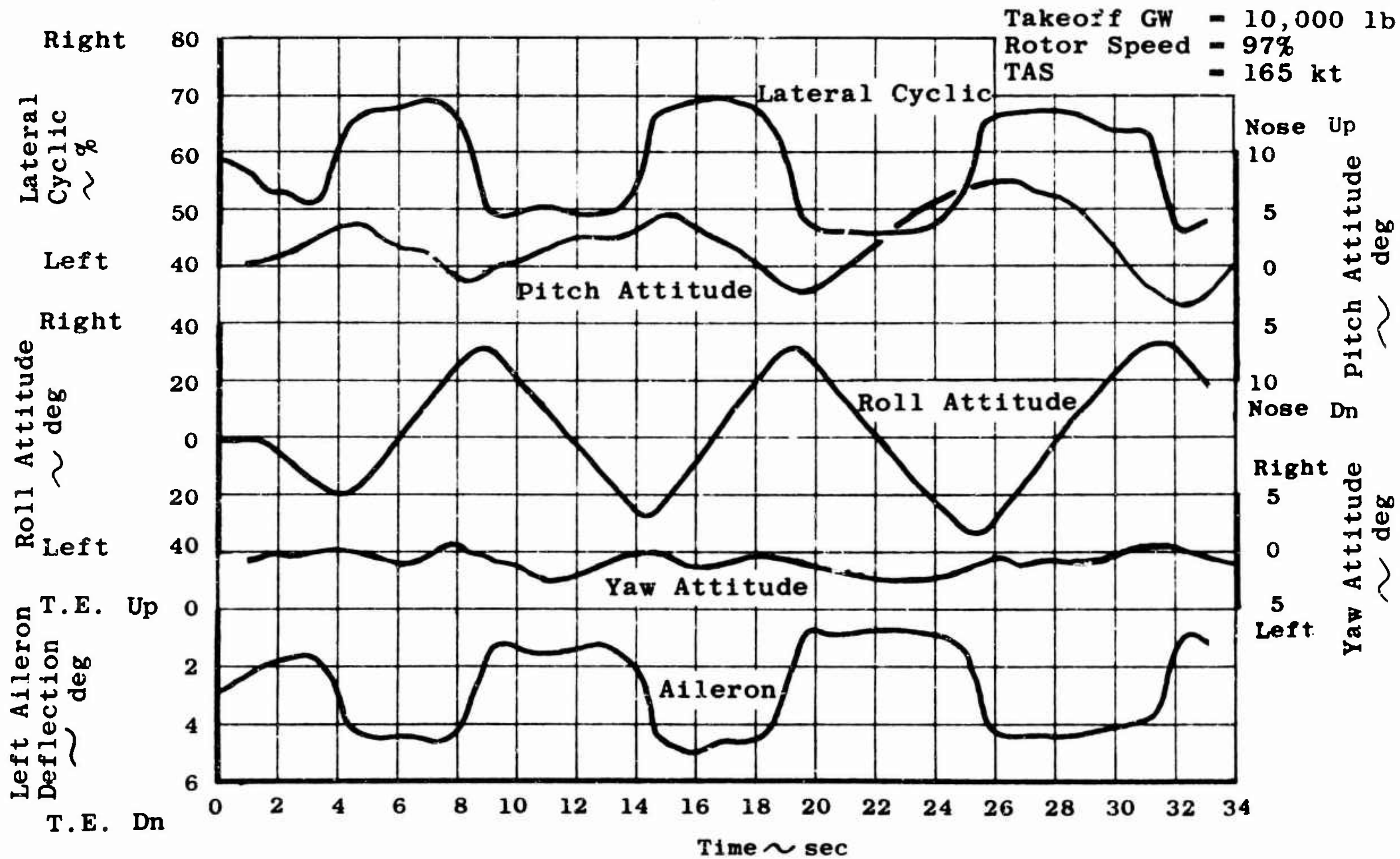

Figure 7. Typical Time History of a Rolling Maneuver for Evaluating the Effectiveness of Roll Control Augmentation.

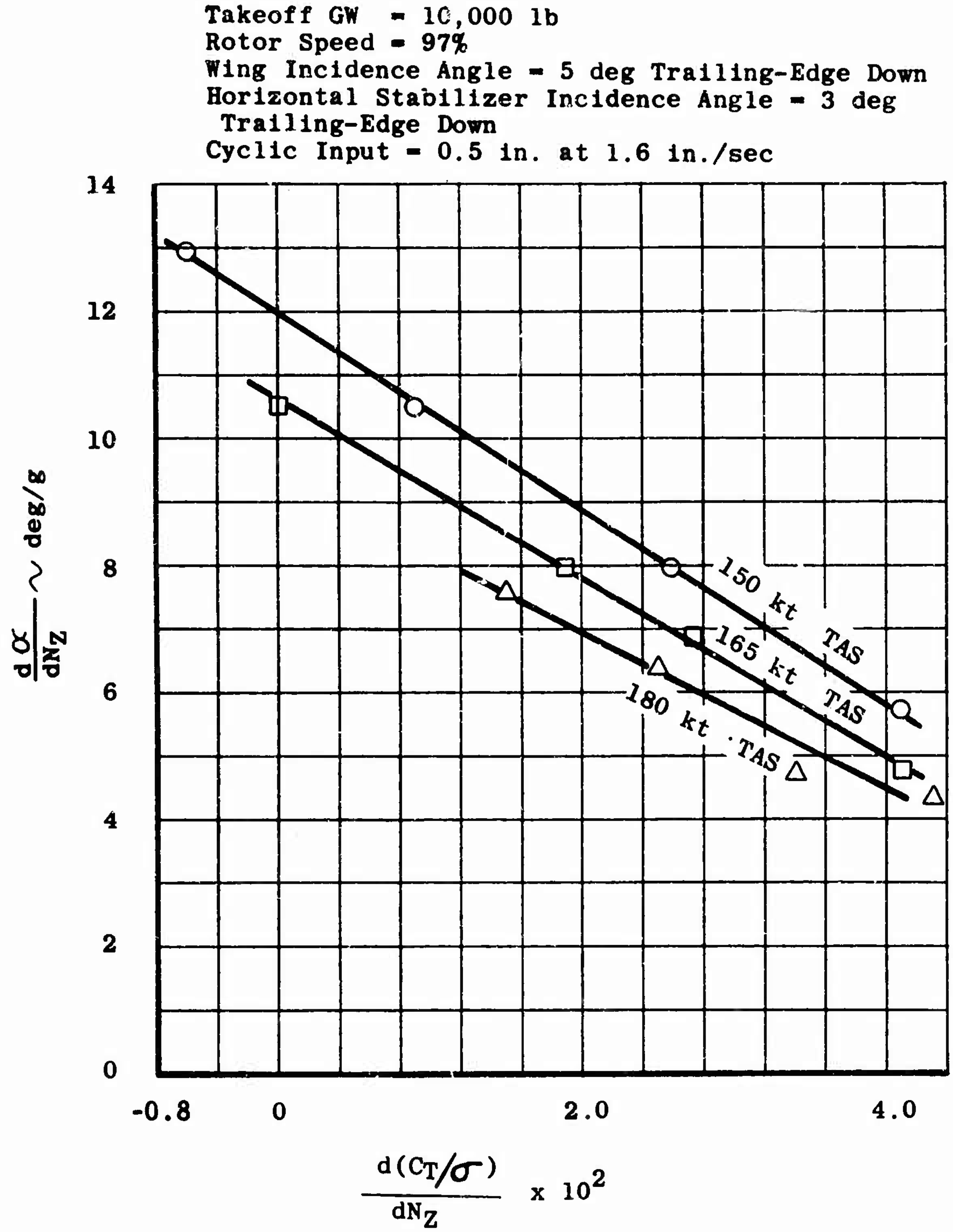

Figure 8. Effect of Rotor Blade Loading Change on Wing Angle of Attack in Accelerated Maneuvers.

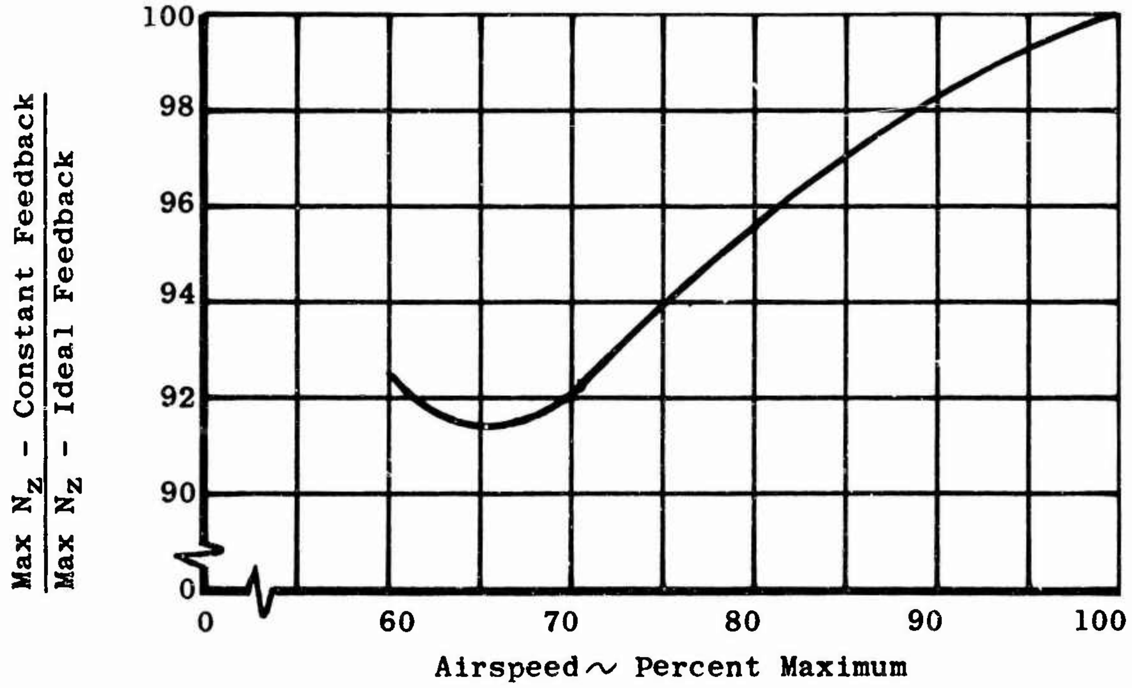

Figure 9. Penalty Imposed by Constant Collective Feedback.

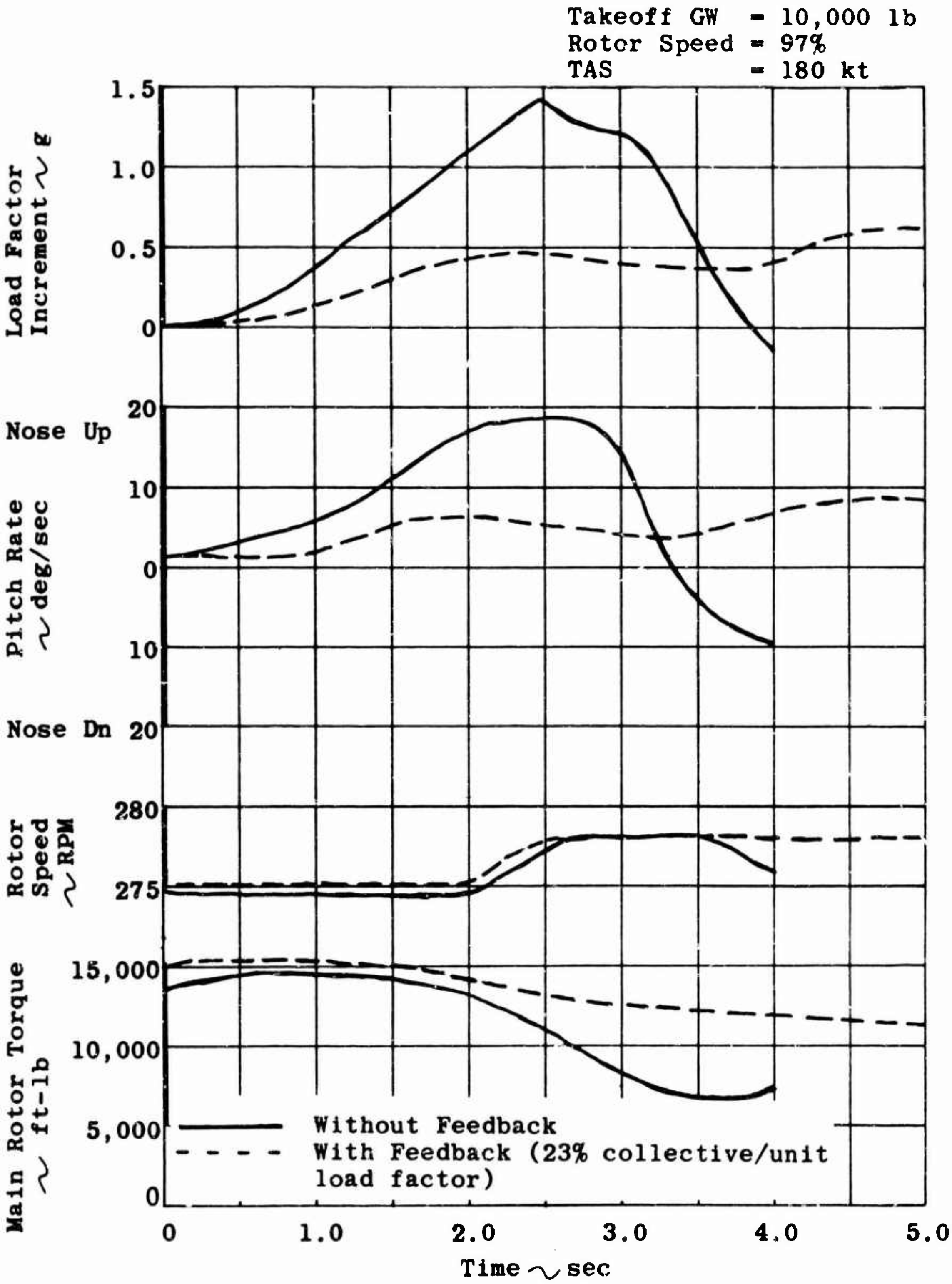

Figure 10. Influence of Feedback on Aircraft Maneuver Stability.

CONCLUSIONS

The addition of a wing to a pure helicopter significantly increases the maneuver capability as defined by retreating blade stall at a given airspeed. For the UH-2 compound configuration with a wing-to-rotor blade area ratio of approximately 1.0, the maneuver capability, based on the criterion describing the rate of change of the blade loading parameter, C_T/σ , with normal load factor is increased by an average factor of 1.78 over the pure helicopter. This, combined with the greater stall margin derived from the rotor load reduction in trimmed level flight due to the wing, precludes the requirement for rotor collective pitch reduction as a function of normal load factor for the test configuration. This device is shown to be extremely effective in reducing the rotor load factor in accelerated flight, and it offers the additional advantages of reducing the longitudinal cyclic sensitivity and of enhancing static stability with respect to angle of attack.

The predicted decrease in lateral control sensitivity and roll damping of the pure helicopter at high airspeed was confirmed during this investigation, and the requirements for a means of roll control augmentation were established for the test vehicle configuration. Conventional ailerons were found to be an effective means for offsetting the decreasing rotor control sensitivity and the increased inertia and roll damping of the wing installation.

RECOMMENDATIONS

In the design of compound helicopters, studies should be made which would consider incorporation of collective feedback to reduce main rotor pitch as a function of normal load factor to optimize rotor/wing load sharing and to improve the handling qualities of the aircraft at high speed.

Ailerons should be considered as an effective means of roll control augmentation to assure that roll control power is adequate to develop at least 1 radian/second^2 per inch of control input and to achieve roll rates of 10 to 12 degrees/second per inch of control input.

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* Now U. S. Army Aviation Materiel Laboratories.

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13. ABSTRACT

The results of a flight research program conducted to investigate methods of improving maneuvering capability of the UH-2 compound helicopter are presented. The effects of wing/rotor load sharing were determined during symmetrical pullup maneuvers using preselected longitudinal cyclic inputs. The wing/rotor load sharing ratio was varied by automatically reducing collective pitch as a function of normal load factor. This was found to increase the attainable maximum normal load factor by 78 percent.

Automatic reduction of collective pitch also reduced longitudinal cyclic control sensitivity during maneuvering flight.

Roll control augmentation using ailerons was found to be one satisfactory method for imparting acceptable handling qualities for lateral/directional maneuvers in compound aircraft.

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Wing/Rotor Load Sharing						
Load Factor						
Collective Pitch						
Maneuvering Flight						
Roll Control Augmentation						
Handling Qualities						
Desensitized Rotor						

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