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FLIGHT CHARACTERISTICS DESIGN AND DEVELOPMENT OF THE MBB/KHI BK 117 HELICOPTER

H. Huber
Messerschmitt-Bölkow-Blohm GmbH
Munich, Germany

T. Masue
Kawasaki Heavy Industries
Gifu, Japan

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H. Huber
Messerschmitt-Bölkow-Blohm GmbH
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Kawasaki Heavy Industries
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Abstract

The BK 117 light, twin-engine helicopter is a joint development product of Messerschmitt-Bölkow-Blohm and Kawasaki-Heavy-Industries. The design was based upon a combination of many proven components (BO 105), and on the incorporation of new technologies. Key design objectives were aimed to high flexibility of operations, attractive performance characteristics, and outstanding handling qualities.

Dominant features result from the hingeless rotor system, which provides inherent high control power and high angular velocity damping. Further optimization is achieved through refinement of the fuselage aerodynamic design, and by a proper layout of the empennage configuration, taking into account the interactional aerodynamic phenomena. The design and development program involved fuselage model wind tunnel tests, rotor whirl tower tests, computer model simulations, and an extensive developmental flight test program.

The paper reviews the particular design features and describes and discusses their impact on the helicopter flight characteristics. The results obtained in the areas of static and dynamic stability (longitudinal, lateral-directional), control response and maneuver characteristics, aeromechanical stability and loads and vibrations are presented, including correlation of flight test data with computer model simulations.

1. Introduction

Following market analyses and conceptual layout studies in the early 1970 ies, the Messerschmitt-Bölkow-Blohm GmbH (Helicopter Division) of Germany, and the Kawasaki Heavy Industries Ltd. (Aircraft Group) of Japan agreed in 1975 to enter into a joint design and development program for a new civil light helicopter, the BK 117. The twin-turbine aircraft of the eight to ten seat class should be specifically designed for high operational flexibility, attractive performance characteristics, and outstanding flying qualities (Reference 1).

Figure 1 BK 117 Helicopter Prototype (MBB)

Figure 2 BK 117 Helicopter Prototype (KHI)

Corresponding to the overall program work share, design and development activities took place at both companies, with the technical responsibilities being clearly defined. After start of the development phase in 1977, first flight of prototype was in June 1979. Figure 1 shows the BK 117 aircraft in a flight test configuration being flown at MBB Ottobrunn/Germany, and Figure 2 shows a prototype during flight at KHI Gifu/Japan.

2. Design Requirements and Objectives

Market studies clearly showed that in the light twin-engine helicopter class a new model of the MBB/KHI helicopter family would complement well the BO 105 model. Some of the main design goals and objectives were for example:

(1) High flexibility of operations; i.e. light transport, off-shore, rescue, external load operation, and executive transport;

(2) Attractive performance characteristics, specified by a high OGE hover altitude capability (> 2500 m, ISA +20°C, 25 kts sidewind), high maximum cruise speed (> 260 km/h), long range with normal fuel (> 550 km), and the capability for FAR 29 Cat. A. one-engine-inoperative flight at max. gross weight and high temperatures;

(3) Handling qualities in accordance with IFR-criteria with a minimum of stability augmentation; ride comfort and vibration levels meeting stringent demands;

(4) Reduced development and manufacturing cost through commonality with BO 105-components, wherever possible.

3. Basic Design Approach

The following part will shortly describe the major steps of the BK 117 design phase, with main emphasis being placed on flight characteristics. The general aircraft arrangement is shown in the 3-view drawing of Figure 3. Pertinent aircraft design parameters are presented in Table 1.

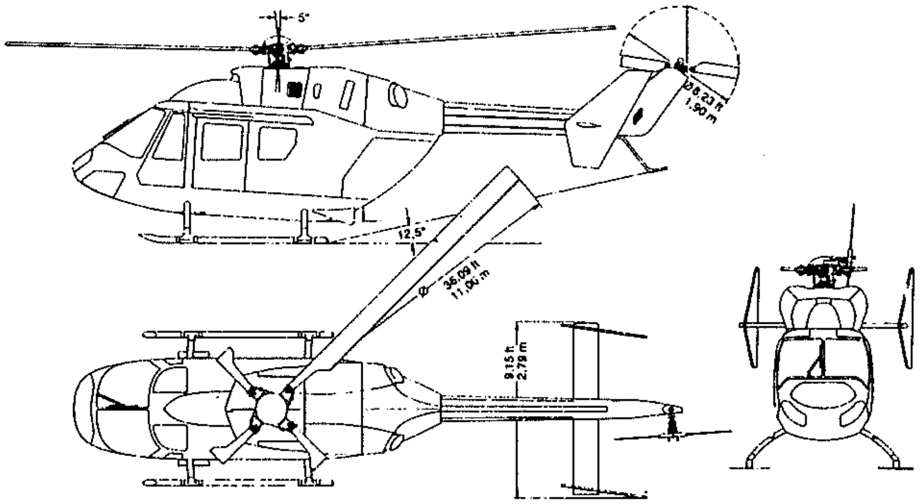

Figure 3 BK 117 3-View Drawing

3.1 Main Rotor Design

Aerodynamic Rotor Design: The selection of overall dimensions and specific aerodynamic design parameters was largely dominated by the key performance requirements of high altitude hover capability, high cruise speed potential, and the Cat. A climb out capability with one engine inoperative. Initial performance analysis indicated that a rotor diameter of 11 m was adequate with the selected powerplant installation. Rotor tip speed and blade chord of the four-bladed rotor were designed to provide

Table 1 BK 117 Design Parameters

General Data		Horizontal Stabilizer	
Max. Design Gross Weight	2850 kg	Area	1.0 m^2
Max. C.G. Range (STA data)	FWd 4310 mm Aft 4670 mm	Span	2.5 m
Engines (2)	AVCO Lycoming LTS 101-650 B		
Main Rotor (Hingeless)		Vertical Tail	
Diameter	11.0 m	Area	0.68 m^2
Number of blades	4	Span	1.0
Chord	0.32 m		
Solidity	0.074	Endplates (2)	
Tip speed	220.8 m/sec	Area	1.11 m^2
Nominal twist	-10 deg	Span	1.63
Fundam. flap frequency	1.101	Section	Flat plate
Fundam. lag frequency	0.645	Incidence	8 deg
Equiv. flap hinge offset	12%		
Shaft tilt angle	-5 deg		
Tail Rotor			
Diameter	1.90 m		
Number of blades	2		
Solidity	0.12		
Tip speed	215,7 m/sec		

moderate blade loading at the high altitude, high speed and maneuver conditions. Selection of high blade twist (-10° per radius) and of tapered blade thickness distribution (12% to 10%) was governed by high rotor efficiency and low rotor loading in forward flight. The 12% thick airfoil NACA 23012 (modified) was selected for the inboard blade station (root to 80% radius), and the 10% thick airfoil V 23010-1.58 is used at the blade tip; both sections are well proven airfoils, showing universal aerodynamic characteristics within their corresponding flow environment.

Flying qualities - being a significant factor on the BK 117 design - were considered simultaneously during the aerodynamic layout, since they can be strongly affected by aerodynamic design parameters. Advanced theoretical models incorporating full nonlinear aerodynamic theory and adequate dynamic blade modelling were most helpful in providing insight into the flight characteristics sensitivities.

Dynamic Rotor Design: Rotor dynamic characteristics and flying qualities of the aircraft are dominated by the hingeless rotor system, which supplies high moment capability and constant control characteristics throughout the flight speed and maneuver range. With the rotor hub identical to that used on the BO 105, an effective flap hinge offset of 12 percent (zero spring), and a corresponding flap frequency ratio of 1.10 was achieved. Corresponding blade mass and stiffness distributions are illustrated in Figure 4.

Selection of inplane stiffness and frequency placement was governed by the trade-off between stability requirements (ground-/air resonance) and blade inplane stresses of the soft-inplane rotor. The frequency was

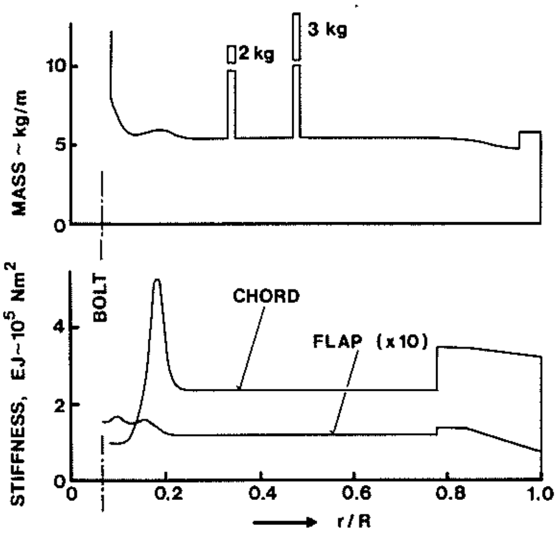

Figure 4 Blade Structural Properties

finally fixed at 0.65Ω for 100 percent rotor speed. Torsional stiffness at the blade tip section (0.8 to 1.0 R) is increased by using carbon-fiber blade skin.

Means of incorporating favourable couplings were also studied during the design phase, the knowledge being available from previous research programs (Reference 2). Based on the results of dynamic stability studies, an offset between center of gravity and aerodynamic center was realized through a blade c.g. location at 23,5 percent of chord. Aft blade sweep was also investigated during these studies and a rear-sweep of 1 degree was incorporated in the final design, generating a moderate positive δ_3-effect.

Control of vibration was a further significant factor in the BK 117 rotor design. Blade mass distribution was tailored to detune higher blade mode frequencies from principal excitation frequencies; tuning masses are seen in the mass distribution diagram of Figure 4.

3.2 Airframe and Empennage Configuration

Major configuration studies were concentrated on the integration of rotor, airframe and stabilizer areas. Trim and performance studies showed that increase of rotor shaft inclination would give a reduction of fuselage drag and would provide comfortable pitch attitude during forward flight speeds. A value of -5 degrees shaft forward tilt was selected for the final design.

The empennage configuration is based on the application of the BO 105 standard tail boom and side fin. Horizontal tail area was increased to 1 m^2 to provide sufficient stabilizing contribution for the longitudinal dynamic stability. Tail effectiveness was additionally increased by the choice of a highly cambered, supercritical airfoil, which provides a

12 percent higher lift curve slope, compared to symmetrical sections. The incidence setting was optimized later in the development phase. In order to compensate the yawing moment of the bigger BK 117 airframe, total vertical effectiveness was increased by enlarged endplate areas at each end of the horizontal tail. This configuration proved to be highly effective, because this position is outside of the main hub/pylon flow interaction area, and tail rotor blockage is negligible.

3.3 Tail Rotor

The existing 2-bladed tail rotor of the BO 105 was chosen for the BK 117 as common part between these two aircraft. The tail rotor blades used for the BK 117 show a new airfoil section (S102E), successfully used also on the BO 105 military aircraft. The maximum lift capability of this 8.3 percent, cambered section is about 15 percent higher (Ma = 0.6), when compard to the standard NACA 0012-section, thus providing a 40% greater useable maneuver thrust at the same power level.

4. Wind Tunnel Testing

Wind tunnel tests were conducted in the Kawasaki low speed wind tunnel, having a test section size of 3.5 x 3.5 m (closed section), and of 2.5 x 2.5 m (open-section), respectively. The model, shown in Figure 5, represents the complete airframe configuration including the basic fuselage, main and tail rotor hub, landing gear skid, horizontal, vertical tail and endplates, and other aerodynamic components (hub cap, spoiler), Reference 3.

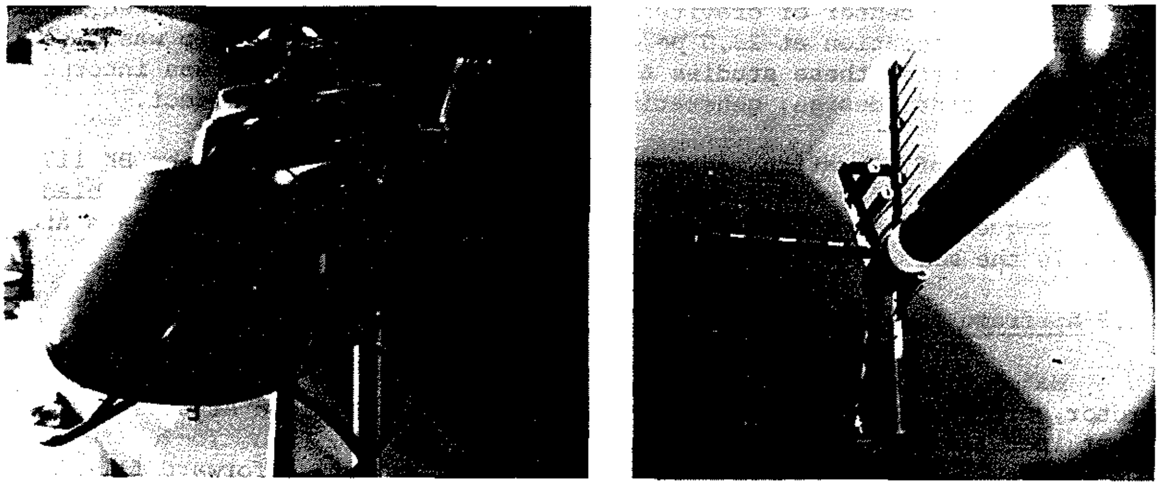

Figure 5 1/5 Scale Wind Tunnel Model (left),
Pitot Rake and Pressure Sensors Installation (right)

Main test activities were aimed (1) to obtain fundamental aerodynamic forces and moment data of the basic airframe, (2) to evaluate the body to tail flow interactions, and to (3) study the influence of airframe and empennage modifications on airframe characteristics.

Figure 6 shows aerodynamic pitching and yawing moments vs. angle of attack and sideslip angle of the final airframe configuration, indicating highly stable characteristics in both axes and a strong restoring directional moment to unload the tail rotor in forward flight.

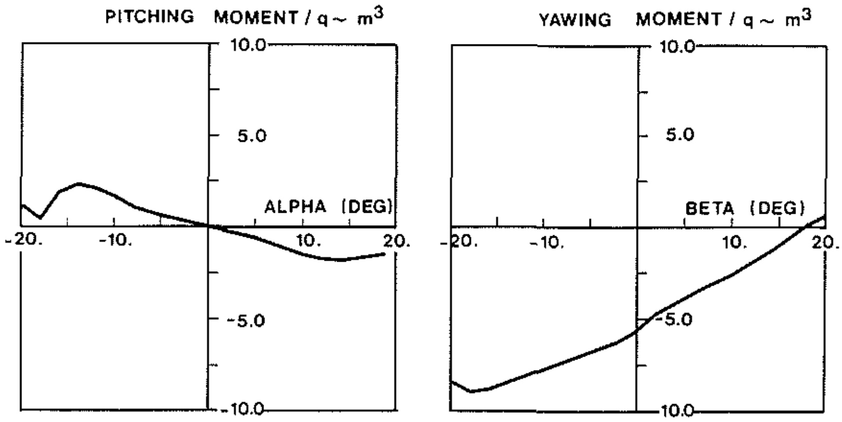

Figure 6 Static Longitudinal and Directional Stability Characteristics

Figure 5 illustrates the test installation for measurements of the static/dynamic pressure distribution over the tail area. A pitot rake consisting of 29 probes is fitted to the tail boom, wake total pressure is measured by pressure sensors. Time history of body surface pressure was sensed by flush-mounted pressure sensors. Measured pressure distribution at the location of tail rotor is shown in Figure 7. It is seen that the main rotor hub wake is moved downward and the flow condition over the tail rotor plane is significantly improved by the effect of hub cap, especially at positive angles at attack.

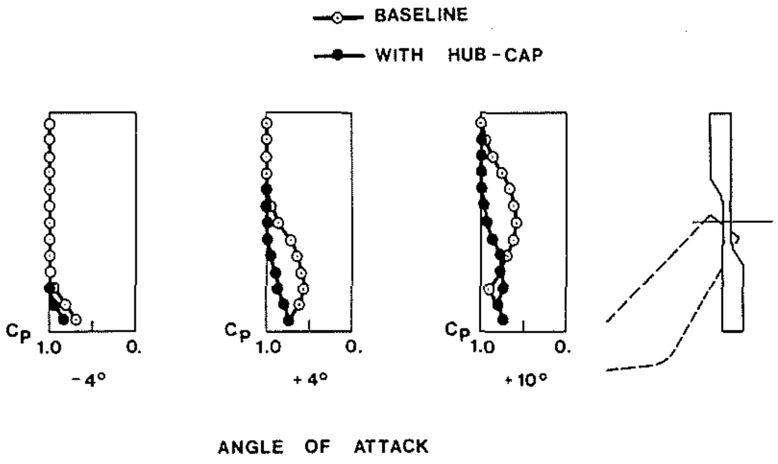

Figure 7 Total Pressure Distribution at Tail Rotor Disc Area

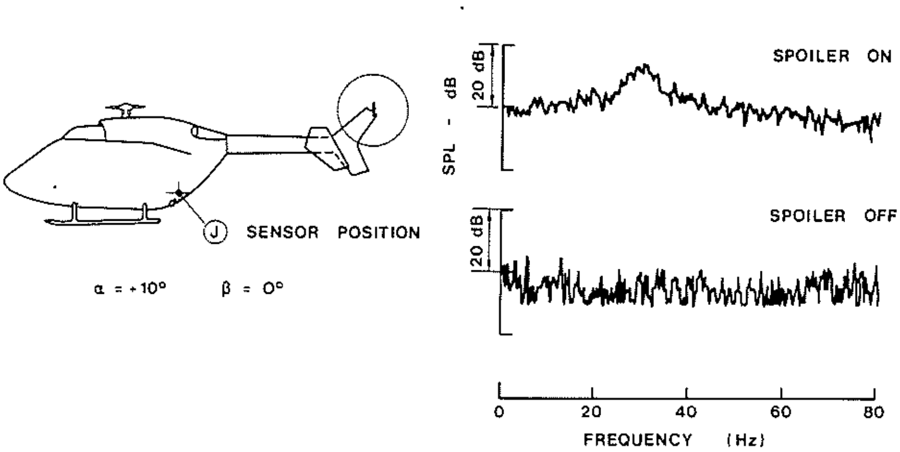

Figure 8 Frequency Spectrum of Surface Pressure at Sensor Position (Fuselage Spoiler on/off)

It was further found from body pressure measurements that strong concentrated vortices were formed at the tips of the rear fuselage spoiler, whose frequency was near 31 Hz, as shown in Figure 8 (for positive angle of attack). When converted to full scale dimension, these vortices have the frequency near 1/rev. of main rotor and also coincide roughly with tail boom bending frequencies. Flight tests confirmed that these effects caused tail shake in descending flight condition. Finally, with the fuselage spoiler removed and the hub cap installed tail shake was completely eliminated, as discussed in a later section.

5. Whirl Stand Testing

A BK 117 whirl test stand was set up at the MBB helicopter test plant, shown in Figure 9. The first test run of the complete rotor took place in end of 1978, seven month before first flight. Test objectives were pri-

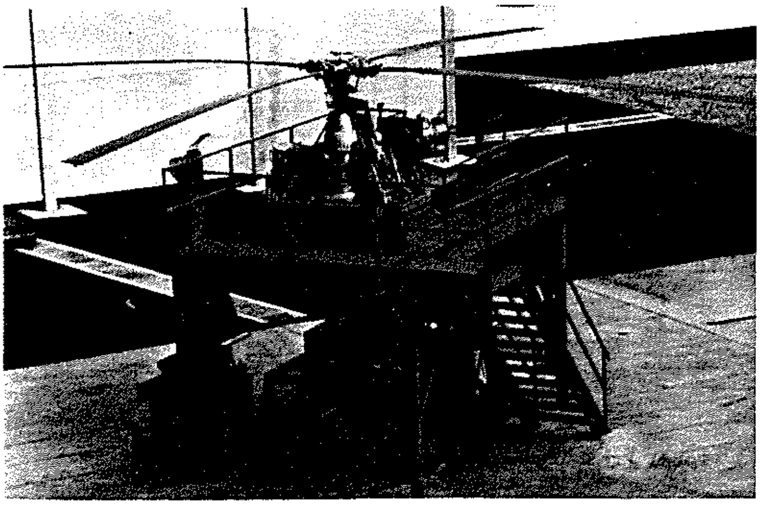

Figure 9 Main Rotor Whirl Test Stand

marily to evaluate performance characteristics, to obtain basic rotor and control loads data, and to verify the blades dynamic characteristics. Excitation of modes was achieved by a hydraulic actuator in the cyclic channel, allowing sinusoidal excitation up to 10 Hz. Test results obtained from blade resonances are illustrated in Figure 10, indicating good agreement between test and predicted values. Figure 11 shows the rotating blade damping variation with rotor thrust at 100 percent rotor speed in hover. Damping of the BK 117 rotor proved to be higher than for the BO 105 rotor at higher thrust levels, which can partly be related to the more favourable pitch-flap-coupling.

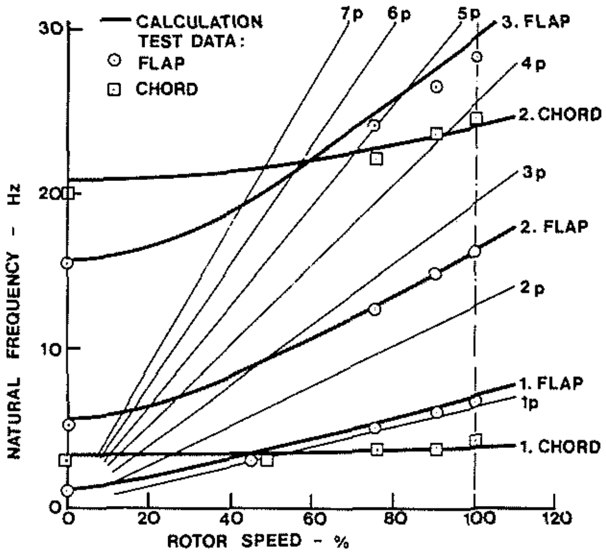

Figure 10 Main Rotor Blade Natural Frequencies

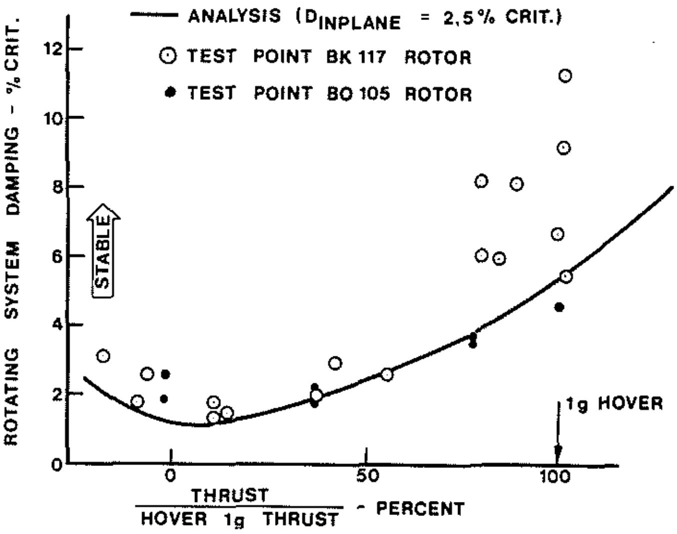

Figure 11 Inplane Mode Damping vs. Thrust, (Hover, 100% RPM)

6. Final Flight Characteristics Development

Flight test development program was started at both companies in mid 1979. First flight of MBB-prototype P2 took place on 13. June 1979, and first flight of KHI-prototype P3 followed on 11. August 1979.

6.1 Ground-Air Resonance Stability Verification

First test activities were concentrated on ground and air resonance testing, in order to ensure freedom from aeromechanical instability of the soft-inplane hingeless rotor.

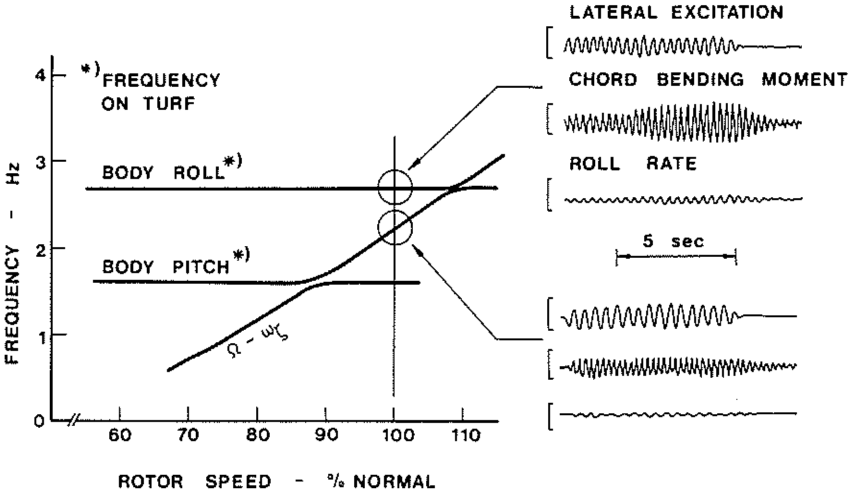

Figure 12 Ground Resonance Time Histories on Turf, Minimum Collective Pitch

Figure 12 shows typical ground resonance test data for a critical condition, i.e. helicopter standing on turf, minimum collective pitch. The rotor and body modes are excited by periodic rotor cyclic input; the time histories of the chord bending moment shows a rapid amplitude decay after the stop of excitation, indicating high damping. Likewise, resonance tests in the air were also conducted by periodic rotor excitation. All test results were most satisfactory, showing that the BK 117 is completely free from any ground- and air resonance problems.

6.2 Airframe Aerodynamic Refinement

Early test experience showed that the initial flight configuration had difficulties in some flight regions obviously resulting from wake flow interaction between the rotor hub and tail rotor/empennage areas. The phenomenon, also known from various other helicopters as the "tail shake" phenomenon, was felt as a stochastic lateral excitation in the cabin, the worst condition being encountered in the higher flight speed range, and particularly at moderate to high descent rates, as is shown in Figure 14 (baseline configuration).

In order to obtain a better understanding of the rotor/empennage flow interactions, in-flight measurements of the dynamic pressure at the empennage and tail rotor area, and of the vertical and lateral flow angles at the

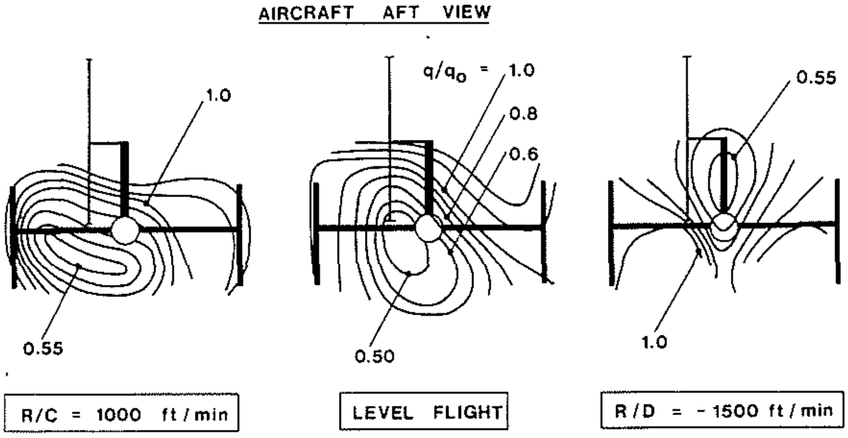

Figure 13 In-Flight Pressure Measurement at Tail Area, V = 80 KIAS

endplates leading edges were conducted. Figure 13 shows dynamic pressure maps, for climbing, level flight and descending flight condition as interpolated from the test points. The curves indicate a large depression area, which obviously moves downward during climb rates, and moves upward during descent rates. These results are in agreement with the findings in References 4, 5. The flow angle measurements further indicated, that a constant lateral flow angle of about 8 degrees occurs at the right endplates station, obviously resulting from the trim sideslip angle, and from the tail rotor induced lateral velocity component. At this station an unsteady lateral flow angle of about 3 to 5 degrees was found.

In accordance with the positive effects found from the wind tunnel model tests (see Figure 7), flight tests with hub cap installed showed a significant reduction of the tail-shake oscillation, as demonstrated Figure 14 . A further reduction, particularly at descent rates was achieved by removal

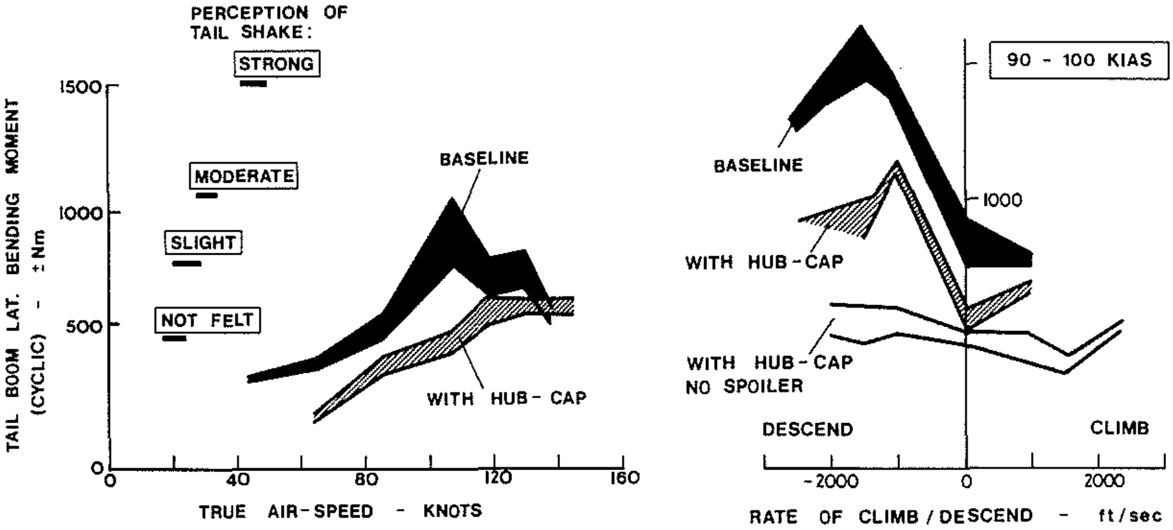

Figure 14 Effect of Airframe Modification on Tail Shake, during Horizontal Flight and Rates of Climb/Descent

of the aft fuselage spoiler. With this final configuration (hub cap-on, fuselage spoiler-off) tail-shake is completely eliminated throughout the whole flight regime.

Further aerodynamic refinements were made during this test phase in order to reduce helicopter drag and to improve performances. Table 2 presents a summary of speed gains and corresponding drag reductions due to airframe modifications.

Table 2 Speed Gains and Drag Reduction due to Airframe Modifications

Item of Modification	Increase in Max. Cruising Speed	Reduction of Equivalent Drag Area
Reduction of Engine Cowling Intake Area	3,5 kts	0,11 m^2
Main Rotor Mast Fairing		
- without Hub-Cap	4,3 kts	0,14 m^2
- with Hub-Cap	0 kts	0
Engine Exhaust Cowling Fairing	0,7 kts	0,02 m^2

6.3 Handling Qualities

Longitudinal Trim and Stability: The expected trim characteristics were verified by flight test, Figure 15 showing main rotor control positions and longitudinal pitch attitude vs. flight speed. Shaft tilt angle selection of -5 degrees and horizontal stabilizer setting proved to be successful in providing a highly comfortable pitch attitude at the cruise and maximum horizontal flight speeds, as shown in the right-down picture of Figure 15.

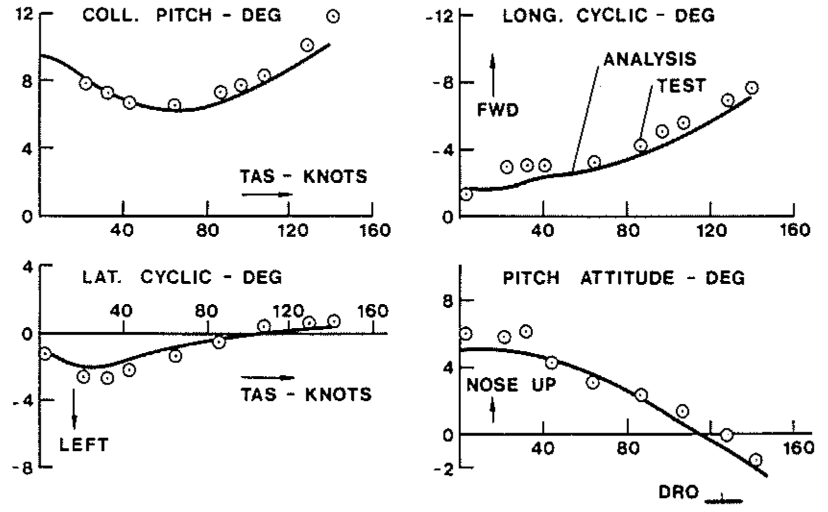

Figure 15 Trim Characteristics, GW = 2850 kg, mid C.G., z_σ = 5000 ft

To achieve longitudinal stick stability vs. speed with collective pitch fixed, horizontal tail leading and trailing edge spoiler modifications were tested. A local rotor blade trailing edge tab-deflection produced a further improvement in the stick gradient curve, as shown in Figure 16.

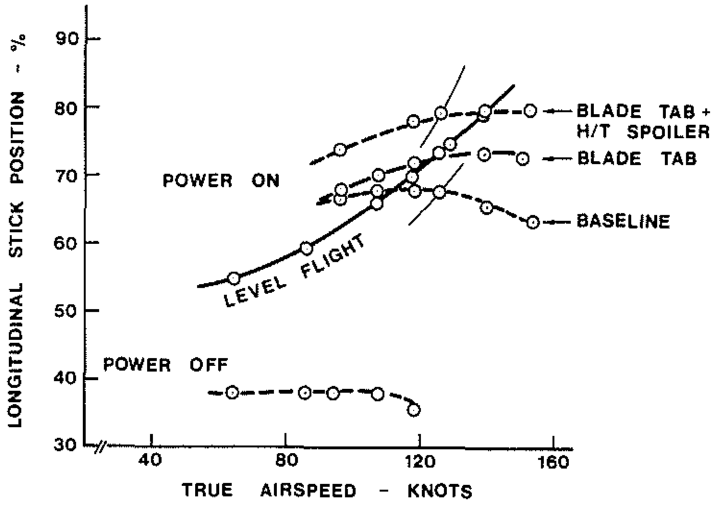

Figure 16 Static Longitudinal Stick Stability

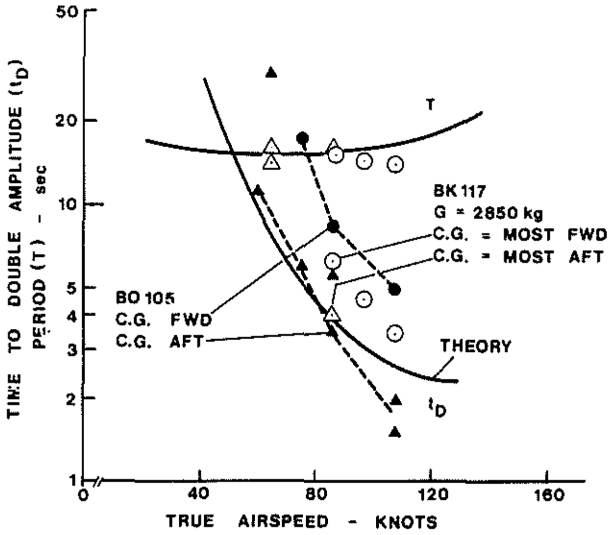

Figure 17 Dynamic Longitudinal Stability

The attention paid to flight characteristics since the early design phase resulted also in attainment of the envisaged dynamic stability characteristics. Figure 17 illustrates longitudinal dynamic stability for extreme loading conditions of maximum gross weight with c.g. most forward and most aft. Results show that stability is similar to that of the BO 105. Likewise as on this aircraft, flight experience has again demonstrated that the amount of dynamic instability does not affect pilots work-load, overall flight behaviour is judged primarily from control characteristics.

Lateral-Directional Stability: In the early flight test program of the initial configuration, weak directional stability was encountered at high speed and higher rates of climb. The low frequency (0.3 Hz) oscillations, coupled between the roll and yaw axes (dutch roll), were fully controllable, but this stability characteristic was considered to be unacceptable.

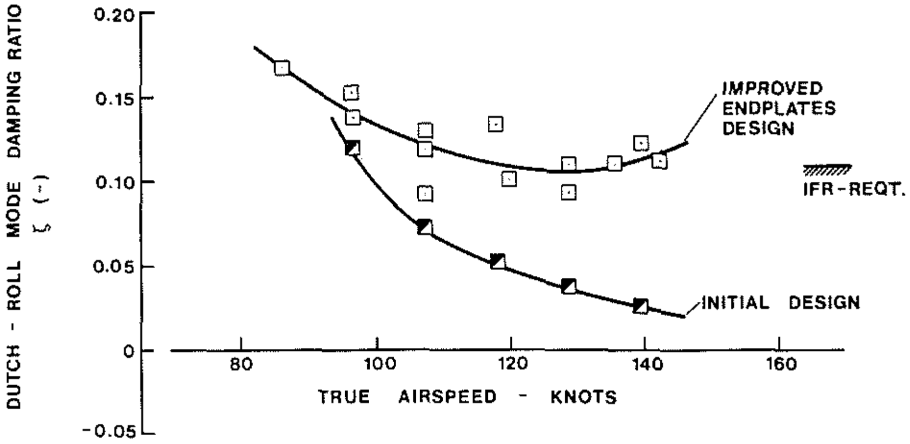

Figure 18 Lateral-Directional (Dutch-Roll) Mode Damping vs. Flight Speed (GW = 2850 kg, mid C.G.)

It was found from analytical studies and from test results that the primary reason was poor static yaw stability in combination with the sideslip-roll moment derivative, which increases with flight speed and/or high power setting.

Certain improvements of the dutch-roll stability evolved from the aerodynamic refinements, as previously discussed; the main solution was achieved by a change of the endplates configuration, consisting of an increase of the fin area, and of optimization of the fin shape for negative flow angles of attack. The impact of the endplates configuration on directional stability is illustrated in Figure 18, indicating high dutch-roll mode damping throughout the speed range. As a further benefit, the large sidefin area allows steady flight after a complete tail rotor loss within the full airspeed range at reasonable sideslip angles, even in climbing flight. This was demonstrated by flight tests with simulated zero-thrust of the tail rotor.

Control Characteristics: Likewise as an BO 105, the flying qualities of the BK 117 are dominated by the hingeless rotor control sensitivity and damping. Damping and control power derived both from analytical simulations, and from in-flight test data are illustrated in Figure 19. Note that both data were obtained under consideration of rotor transient effects. Figure 19 demonstrates that the BK 117 is highly controllable and excessively damped, falling well within the most stringent limits and requirements. The relative reduction compared to BO 105 corresponds with the ratio of rotor moment capacity and aircraft inertias. Simular data were confirmed for the pitch axis.

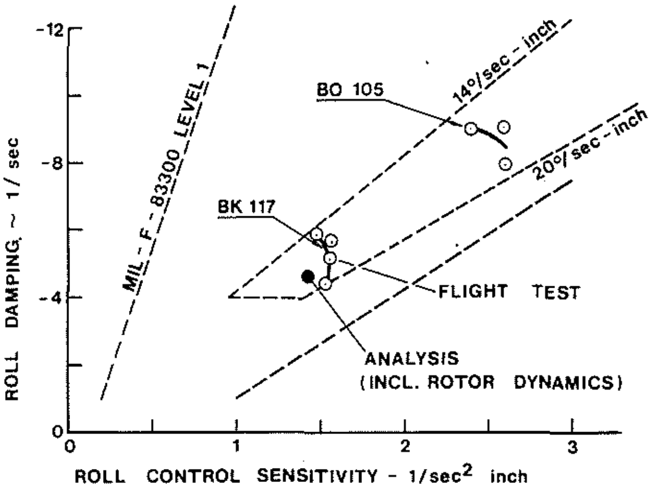

Figure 19 Control Power - Damping Characteristics (Roll Axis)

In the yaw axis, total control range of the tail rotor control system were increased and pedal control sensitivity was reduced, compared with the BO 105 pedal characteristics. The successfull design was confirmed by the flight tests, showing favourable yaw response characteristics throughout the speed range. Yaw axis control in sideward flight is illustrated in Figure 20. Test data up to 40 knots sideward flight are shown, which is well in excess of the 17 knots sidewind requirement (FAR 29), and also far above of the 25 knots sidewind design objective.Hover tests under turbulent wind show adequate control margin for compensating the gust penetrations.

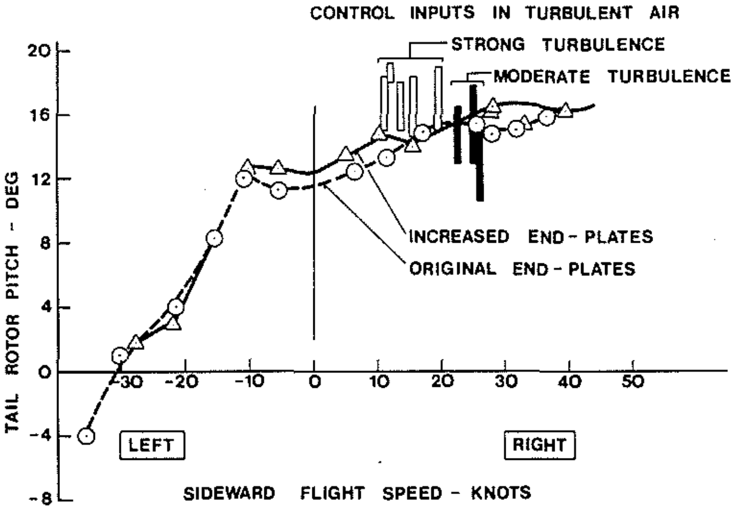

Figure 20 Sideflight Trim Characteristics, (Maximum Gross Weight)

Further, a wide slope landing envelope is achieved due to the hingeless rotor control characteristics, as was demonstrated during flight test (Figure 21). With maximum gross weight (2850 kg) slope angles of 9 degrees (right skid down) and of 13 degrees (left skid down) were demonstrated, without reaching control stops or rotor load limits. Figure 21 shows the main rotor hub bending moment vs. slope angles for the different slope directions.

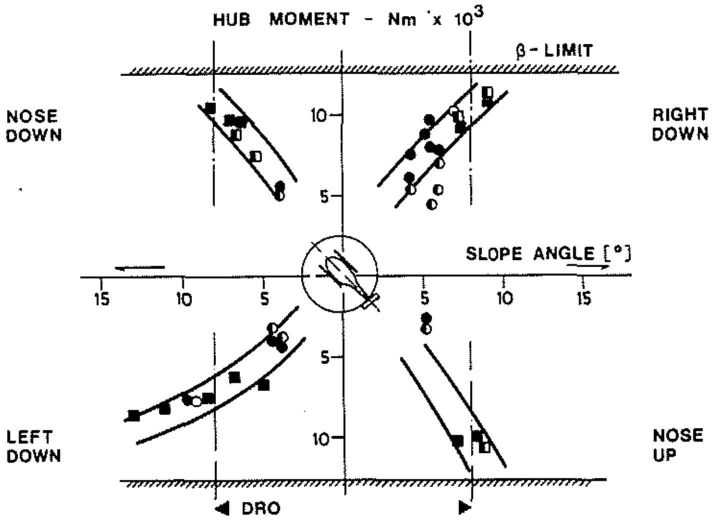

Figure 21 BK 117 Slope Landing Capability, (Maximum Gross Weight, Most Fwd. C.G.)

6.4 Control and Stability Augmentation

The basic design of the BK 117 helicopter took into account full requirements necessary for VFR flight, and the more stringent requirements necessary for the IFR-conditions. As part of a further enhancement of the inherent flying qualities, and for satisfying the IFR stability requirements, a control and stability augmentation system was also envisaged at the beginning of the project.

Although flight experience with hingeless rotor helicopters of this class indicates that instrument flight is possible without any additonal stability augmentation, a flight control and stability system is desirable for further reducing pilots workload, especially during single-pilot IFR-conditions. The flight stability system provides additional damping and attitude hold for the pitch and roll axis; current investigations indicate that the inherent stability in the yaw axis is sufficient for the IFR-requirements.

Inherent in the stability augmentation system design is a further option of an autopilot, consisting of flight director and coupler. The following operation modes are envisaged: Altitude, horizontal and vertical speed hold, heading hold, as well as the normal navigation modes, for example glide slope, VOR, ILS. The system is currently undergoing development and is expected to be available for the IFR-certification program.

6.5 System Loads and Vibrations

Loads: One of the major design objective was aimed on achieving low levels of rotor loads. The selection of moderate aerodynamic blade loading, the choice of low chordwise blade stiffness, and optimization of the empennage configuration were main provisions for achieving this goal. Calculated and measured rotor hub moments in level flight and during maneuvers are presented in Figure 22, showing that the rotor loads are far below the established endurance and maneuver limits. A nearly identical loading behaviour is also found for the flap and chordwise bending moments at the blade root section. Extrapolation of existing data to the most critical altitude/gross weight/ c.g. conditions shows that control loads also lie well within the strength capability of the control system.

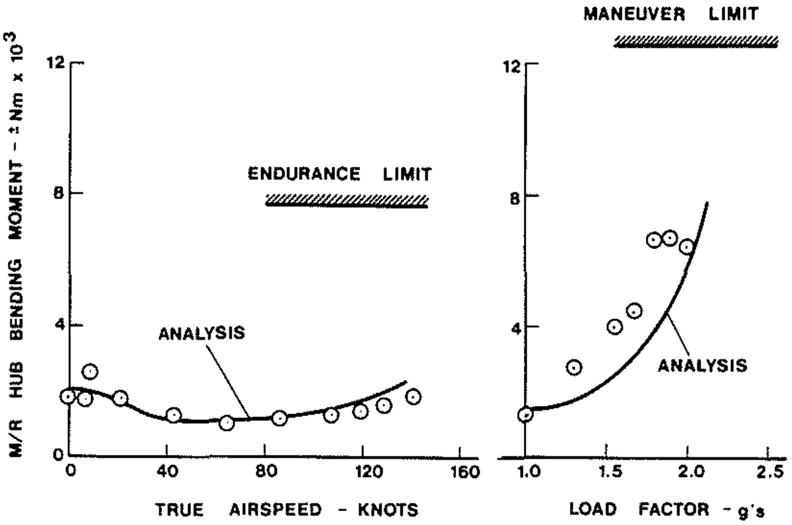

Figure 22 Rotor Hub Moment in Horizontal Flight and during Maneuvers (GW = 2850 kg, mid C.G.)

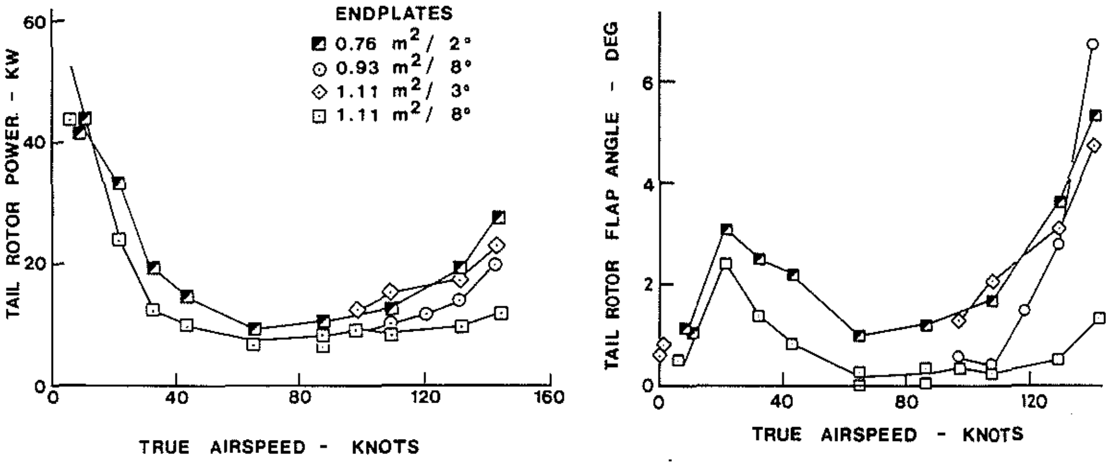

Figure 23 Effect of Endplates Configurations on Tail Rotor Deloading - Power and Cylic Flap Angle Reduction

A substantial loads reduction on the tail rotor evolved from the endplates configuration tests (Figure 23). Endplate inclination of 8 degrees, derived from lateral flow angle measurements, was highly effective in providing a substantial reduction in tail rotor power, 1/rev flapping angle and of oscillatory blade and pitch link loads on the tail rotor.

Helicopter Vibrations: Helicopter vibration control was one major objective in the design and development. The philosoply was based on three principal methods, i.e. detuning of blade frequencies, minimizing of the fuselage response, and application of vibration absorbers or isolation systems, respectively.

The successfull blade design, showing favourable blade frequency tuning, has already been demonstrated (Figure 10). The helicopter in the baseline configuration showed moderate vibrations during the transition speed, with slightly increasing values during forward flight.

A NASTRAN-finite element model was developed to analyze the natural modes of the fuselage structure. Two modes (a warping mode in the roll and pitch axis) close to the 4/rev frequency were found from the fuselage analysis, and were verified by airframe shake-tests conducted at KHI. Subsequently, a local stiffening of the airframe was flight tested, showing a significant reduction of the roof structure vibrations, but only a minor effect on the cabin vibrations.

As a second step, flap pendulum absorbers on the rotating blades - as already demonstrated on the BO 105 (Reference 6) - were applied. As illustrated in Figure 24, this resulted in significant reductions in transition flight.

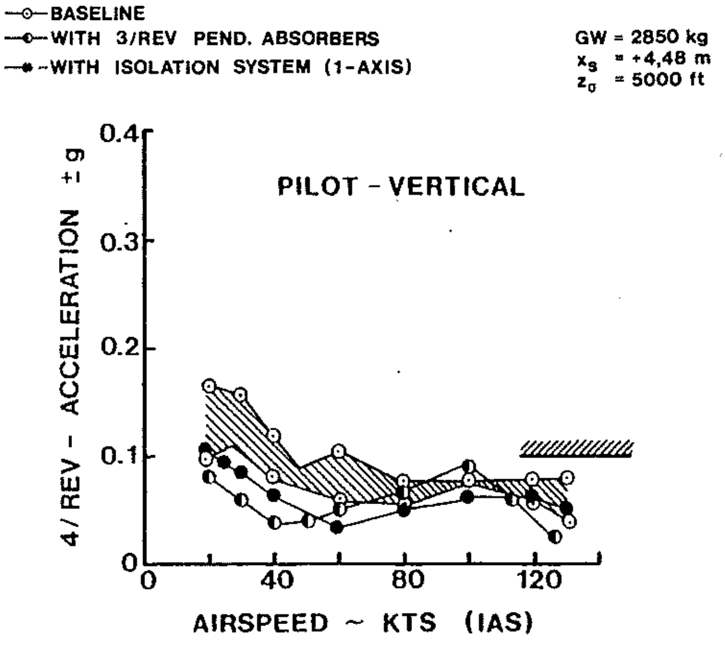

Figure 24 Cockpit Vibration Levels in Level Flight

A further step towards the vibration goal was the development of a multiaxis antiresonance isolation system based on a concept which has already been successfully demonstrated by Boeing-Vertol (Reference 7). A 4-degrees of freedom isolation system was selected for the BK 117, consisting of four mechanical isolators (vertical direction), and of one hydraulic isolator (lateral direction). An outline of the design principle and of the system development is given in Reference 8.

Flight test results of this system were exceptionally good, as is demonstrated by the data of Figure 24. Cockpit 4/rev-vibration levels are reduced to between 0.03 and 0.1 g throughout the forward speed and transition flight range. A dramatic vibration reduction is achieved during all transient flight conditions, where cockpit vibrations are nearly imperceivable.

7. Flight Envelope Tested

The flight envelope tested by the previous flight test program covers the envisaged certification envelope. Level flight speeds of 143 kt from near sea level to 10 000 ft density altitudes, 40 kt sideward flight speeds, and a true airspeed of 178 kt in dive have been flown. The excessive high altitude capability was demonstrated during OGE hover flights up to 12 000 ft and during maximum operating altitude flights up to 17 000 ft in ISA conditions. Autorotation entry from 160 kt was checked. Gross weights of 2900 kg with maximum center of gravity variations have been flown.

8. Conclusions

After having completed the BK 117 helicopter development phase, the main characteristics of this aircraft can now be summarized as follows:

Careful aerodynamic and dynamic design work, under integration of proven BO 105 components resulted in a successful development product.

Dominant handling quality features stem from the hingeless rotor system, providing strong and invariant control response characteristics. Further improvements in flying qualities have been achieved by effective empennage surfaces. The soft-inplane rotor also shows high inherent stability of the ground- and air resonance modes.

Aerodynamic refinement worked out during wind tunnel and flight testing was highly successful in providing performance improvements and in completely eliminating turbulent flow-induced vibrations.

Through careful components layout and system integration low load levels have been achieved, indicating unlimited fatigue life of critical components. The design objective of low vibrations has been met by an optimized rotor blade design; further substantial vibration reductions are achieved by the use of blade pendulum absorbers or by the application of a rotor isolation system.

The outstanding flight characteristics and the excellent performance capabilities will certainly contribute to making the MBB/KHI BK 117 a successful new helicopter.

9. References

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