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EUROCOPTER EC135 INITIAL FLIGHT TEST RESULTS

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Abstract

Based on the BO108 technology demonstrator, the EC135 was developed taking into account the requirements of a market survey. As a result of the merger of Aerospatiale's and MBB's helicopter divisions into EUROCOPTER, the best technology from both manufacturers has been made available for this helicopter. Two pre-production EC135 helicopters are used for development and certification flight test: S01, powered by Turbomeca Arrius 2B engines (designated EC135 B-1), and S02, powered by Pratt and Whitney PW206 B engines (designated EC135 D-1).

Testing of the first pre-production aircraft began in February 1994. After one week of ground checks, the EC135 S01 lifted off the same month for its first flight as planned. The second aircraft S02 had its first flight as scheduled in April 1994. Design freeze for the EC135 is expected this year following the company test campain which takes place in spring-summer 1994, followed by the certification test campaign. VFR day and night type certification for the EC135 with either engine type is scheduled for early 1996, and IFR certification is expected to follow one year later. First delivery will be in early 1996.

This paper will give a brief EC135 helicopter description as well as an overview on the entire test schedule and its present status. Furthermore it presents a survey on the first test results with respect to performance, handling qualities, vibration level, fenestron fan-in-fin tail rotor, engine tests and noise emission.

All information given in the following are of status 31 July 1994.

1. Helicopter Description

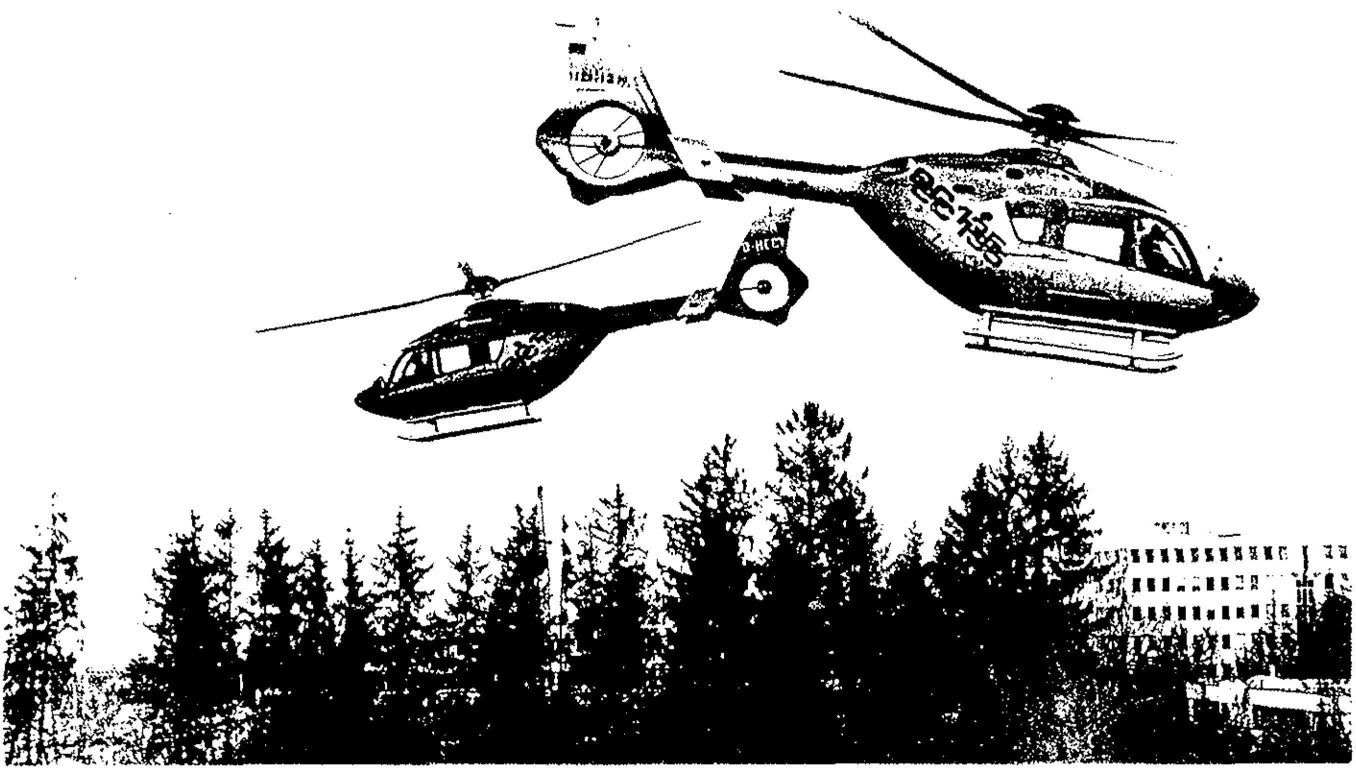

Fig. 1: EC135 B-1 and D-1 pre-production helicopter S01 and S02

The main objective of the EC135 conception was to make the helicopter more economical by simplifying maintenance procedures and reducing direct operating and life cycle costs whilst increasing performance at the same time. Most components and systems of the EC135 are designed for "on-condition" maintenance, reducing fixed TBOs. Extensive use of composites in the airframe

structure results in an increase in payload, flight duration and range - up to 800km on standard fuel (as compared to approximately 500km in most present production helicopters in this class). In addition, wear and corrosion have been minimized by using composites and fewer moving parts in the advanced Bearingless Main Rotor (BMR). By special customer request, the gearbox casing is made of aluminium to enhance corrosion resistance.

The design features of the EC135, a seven-seat, light twin multi-purpose helicopter, will play a major role in the international helicopter market. It was developed with special emphasis on environmental criteria. New technologies, including advanced main rotor and fenestron anti-torque system developments, significantly reduce noise emission of the EC135 as compared to present helicopter models. Newly-developed engines have lower specific fuel consumption and pollute less. EUROCOPTER has invested intensive research and development efforts in advancing helicopter technologies, paying special attention to customer requirements. Focal areas of engineering work were main rotor and tail section, dynamic systems, Anti-Resonance Isolation System (ARIS), composite structures, electrical and avionic systems, cockpit installations, ergonomics and engine integration.

Resulting from a series of customer consultations organized by EUROCOPTER under the working title of CHAT (Commercial Helicopter Advisory Team), major operator requirements with regard to this new-generation helicopter were incorporated during the design phase. Thus, a maximum of know-how and technologies were implemented in the EC135.

The EC135 has a maximum take-off weight of 2500kg to 2700kg and will be certified according to JAR Part 27 including the requirements for system separation and Cat. A operations. Furthermore it is designed to meet all current and new Transport Category Operating Rules such as ICAO, JAR Ops. 3 Class 1, IFR and FAR133 Non-Emergency Hoist Operations with reasonable payload.

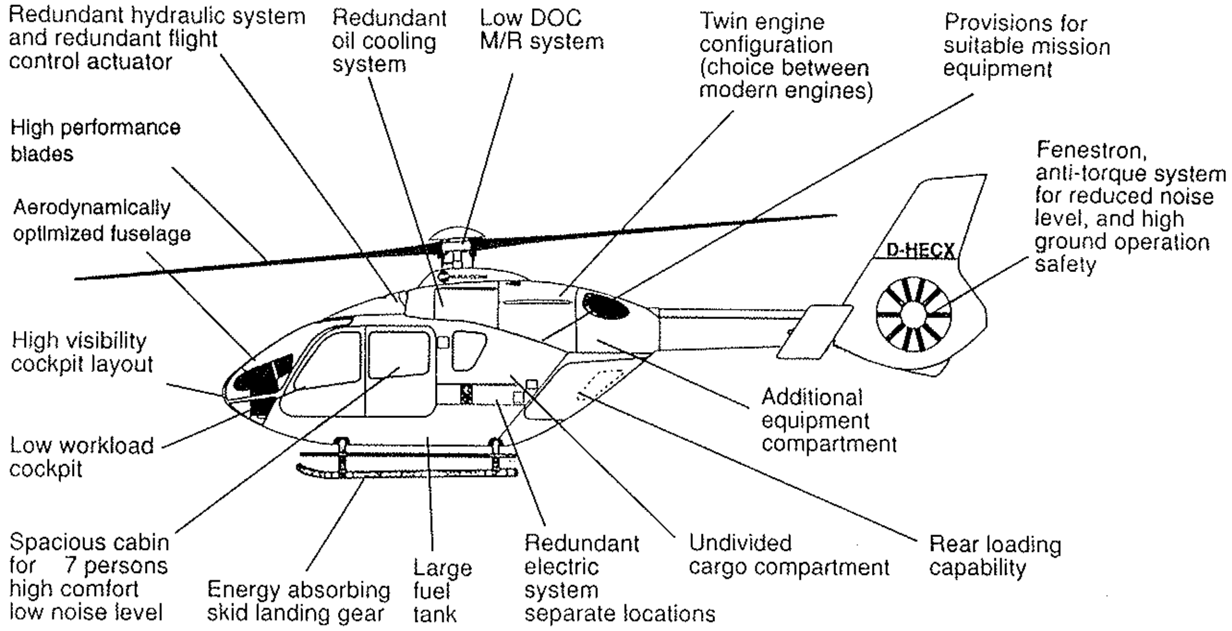

Fig. 2: Basic design features

The essential technology features of the EC135 are as follows:

The BMR main rotor system does not have a rotor head in the traditional sense. It consists of four aerodynamically optimised composite rotor blades with an integrated glass-fibre-composite flexbeam and control cuff, and a rotor shaft with blade attachment flange, which is a one-piece forging. Hub elements used in conventional systems such as centrifugal force transmission elements, bearings, bearing sleeves, etc. were eliminated and replaced by the elastic properties of the flexbeam. By design, the BMR has no flap, lag or pitch hinges. Their functions are executed by stiffness tuning in the flexbeam. The EC135's BMR is thus the most mechanically simple and maintainable rotor possible.

The airframe structure has been developed to feature a high percentage of Kevlar/carbon fibre sandwich components and is aerodynamically optimised. The application of composite materials facilitates in reducing mass as well as the number of components susceptible to corrosion.

The electric power supply system of the EC135 is designed according to JAR Part 27 Cat. A, including IFR capability. It is decentralised and has redundant power distribution.

The cockpit was developed on the basis of modern design criteria and ergonomic aspects. Instrumentation (airborne control and actuation) as well as the radio/navigation system are designed to meet future requirements. In addition to modern, conventional radio/navigation systems, and a display for engine control and fuel management, an EFIS 40 Piloting Display is being used. Further display technologies are under consideration.

The new main transmission is a joint development of EUROCOPTER and ZAHNRADFABRIK FRIEDRICHSHAFEN. Its compact external dimensions and flat construction allow a compact design of the drive system, minimising the front surface and drag. On account of the flat drive system installation, the EC135's cabin is unusually spacious despite its compact external dimensions.

The advanced dual hydraulic system of extremely compact design was developed in cooperation with FEINMECHANISCHE WERKE MAINZ and is fitted to the front side of the gearbox. The hydraulic unit incorporates redundancy in all control axes. Modules may be added for augmented flight control tasks.

In summary, the main objective in the EC135 conception was to combine increased performance with affordability and to achieve the best environmental compatibility, using the best technology.

Designed for multi-role operational missions, the EC135 is suitable for executive transport, emergency medical services, police and law enforcement duties, offshore operations, and cargo transportation flights.

Several presentations have been given with regard to development of main systems /1,2/, technologies used /3/, fenestron fan-in-fin tail rotor /4/, configuration of the EC135 /5/ and test results of its predecessor - the BO108 helicopter /6/. Initial test results of the two EC135 pre-production helicopter S01 and S02 will be given in the following sections.

2. Test Schedule and Status

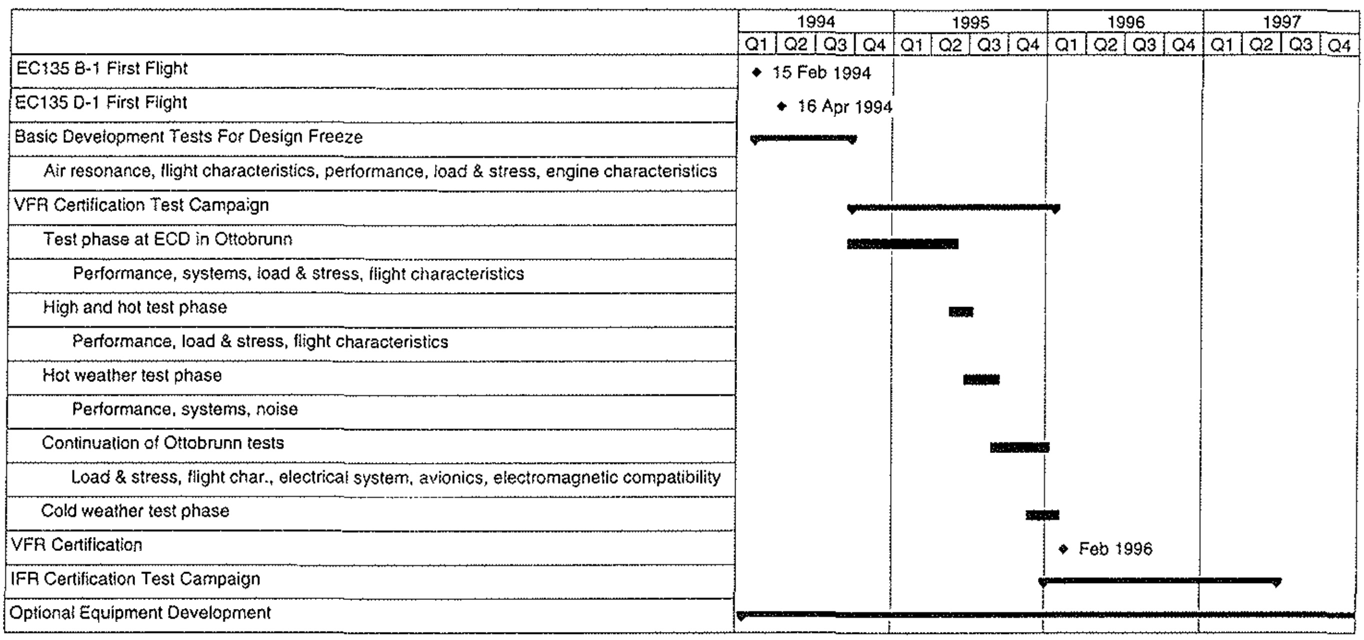

Fig. 3: EC135 test schedule and program milestones

After two short years of development the EC135 lifted off for its maiden flight on 15 February 1994. First operational milestones such as flight at VH, VNE, VD, in high altitude and flight under high g-load condition were reached during early tests. The first months of testing were dedicated to evaluate mainly ground and air resonance, performance, flight characteristics, load and stress and engine characteristics. All results are used for refining the EC135 configuration.

Certification tests will follow design freeze and last until beginning of 1996, comprising of tests at EUROCOPTER DEUTSCHLAND's home test center near Munich, in high mountain area, during hot weather and cold weather conditions. VFR type certification is expected for early 1996 with aircraft deliveries to follow suit. Most optional equipments requested by potential first customers will be available for the first production helicopters. IFR-certified EC135 are scheduled to be on the market in 1997.

The center of gravity and flight envelope explored to date are shown in figures 4 and 5:

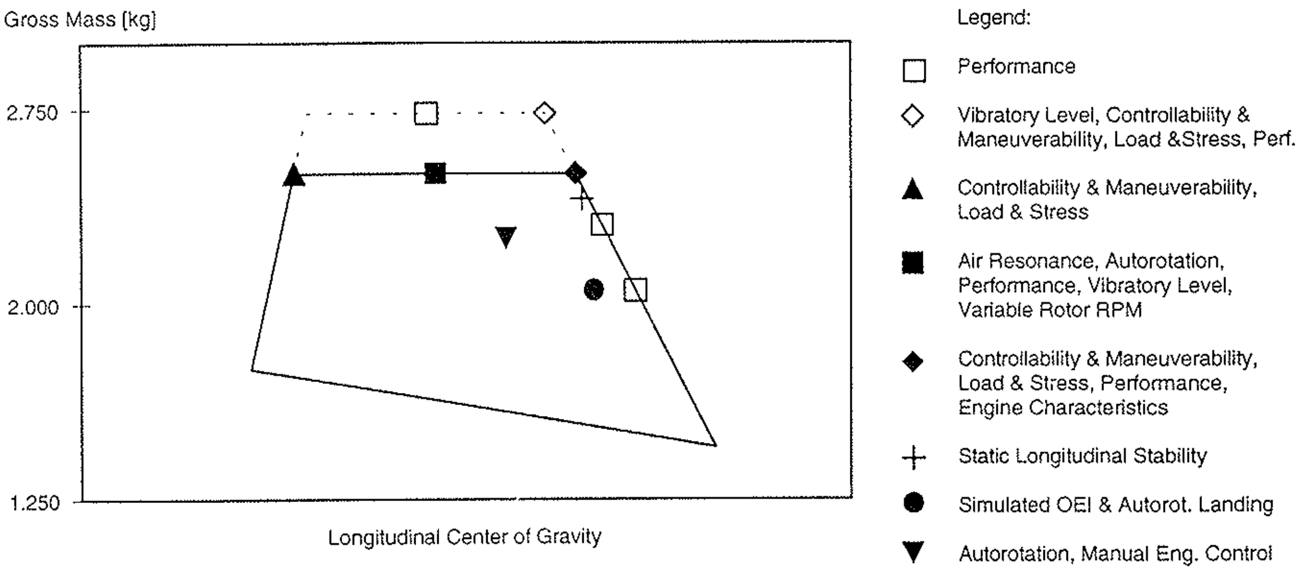

Fig. 4: Center of gravity - overview of tests performed

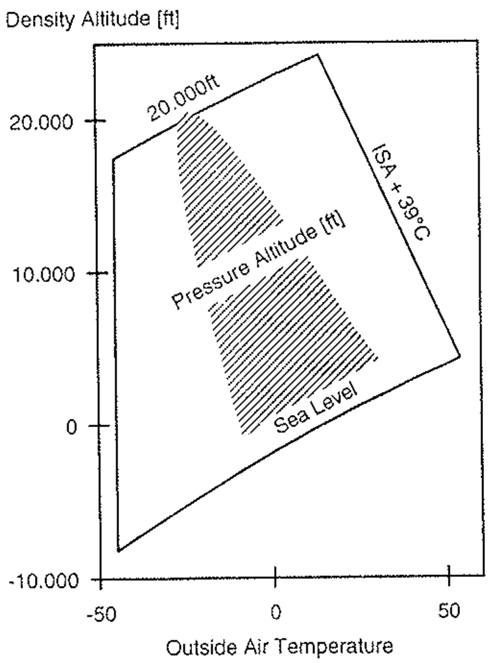

Fig. 5: Flight envelope - tested area

Test flights have been conducted within the shaded area of figure 5. Test time comprising of ground and flight hours can be seen in figures 6,7:

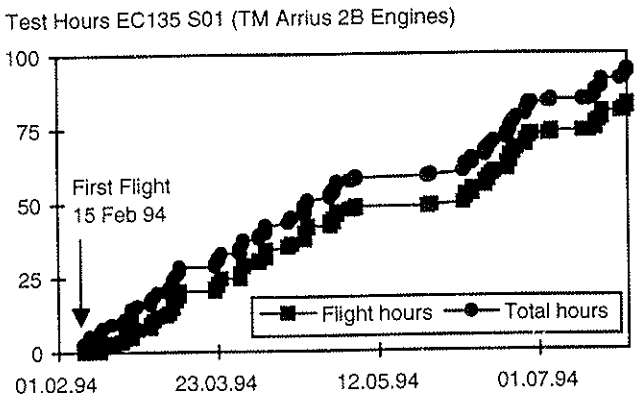

Fig. 6: Test hours EC135 S01

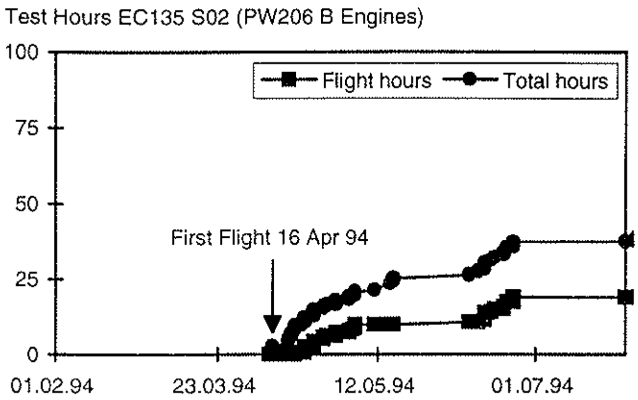

Fig. 7: Test hours EC135 S02

3. Performances

Helicopter steady state performance was checked at various flight conditions. Measured power requirement and theoretical calculations agree and promise high reliability of performance predictions (see ref. /5/) and specified performance. Hover measurements were taken in Ottobrunn at different ambient temperatures and in mountain region at altitudes up to 9200ft in order to cover most of the hover polar. Figures 8, 9 illustrate the accuracy of power calculations:

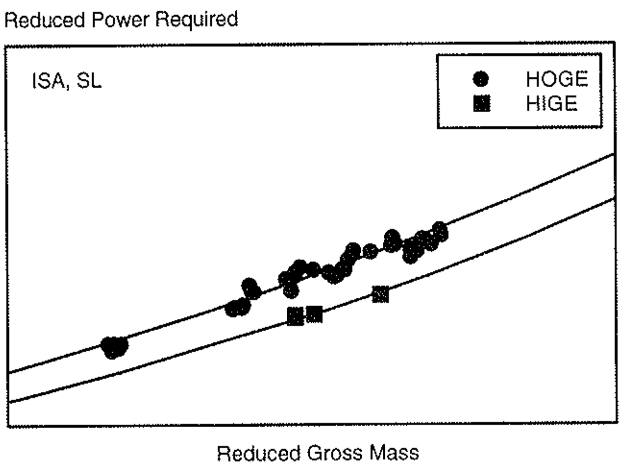

Fig. 8: Hover polar IGE, OGE

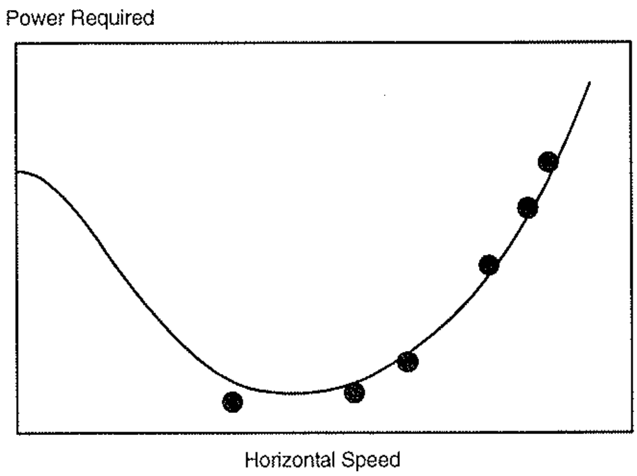

Fig. 9: Level flight power requirement

4. Handling Qualities

The general flight characteristics of the EC135 are judged as smooth. As characteristic for hingeless rotor systems the maneuverability is excellent. Sufficient control reserves are available in all axes during turns, climb, autorotation, and flight at VNE and at VD.

4.1 Pitch Attitude in Level Flight

An optimum pitch attitude in level flight is one of the criteria to judge upon a comfortable flight. As shown in figure 10 the cabin floor attitude remains about the horizontal position. This was achieved by tilting the rotor shaft 5° forward, minimising airframe drag and reducing rotor stiffness.

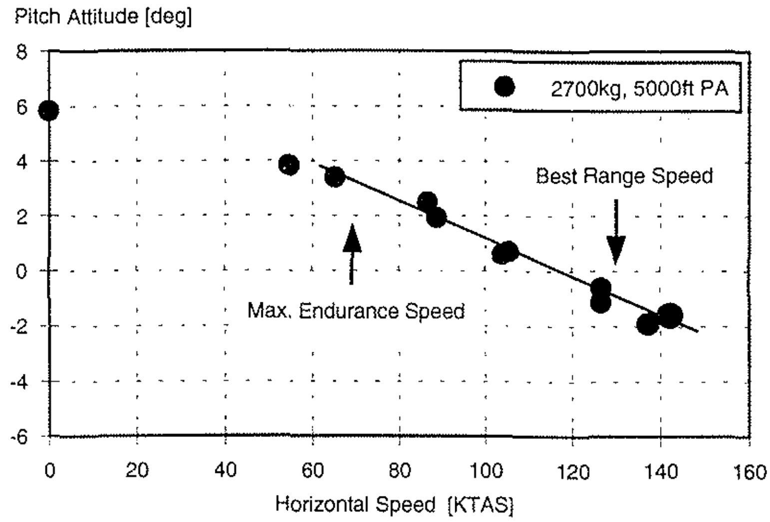

Fig. 10: Pitch attitude in level flight

4.2 Static Longitudinal Stability

JAR/FAR require a positive slope for longitudinal stick position vs speed up to 1.1 VH. Airfoil design parameters such as low pitching moments and high Mach tuck boundaries, but also increased torsional blade stiffness were applied in the rotor design to improve static stability up to high advancing blade tip Mach numbers. A more detailed description of the design parameters and the development of the DM-H-airfoils may be found in reference /7/.

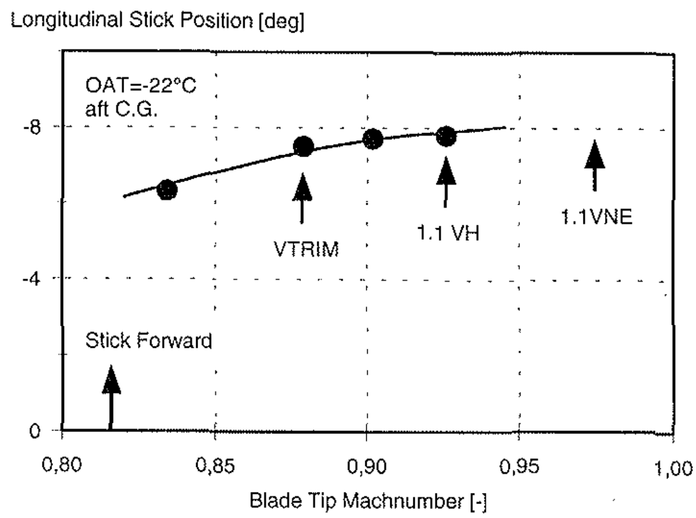

Fig. 11: Static longitudinal stability in horizontal flight

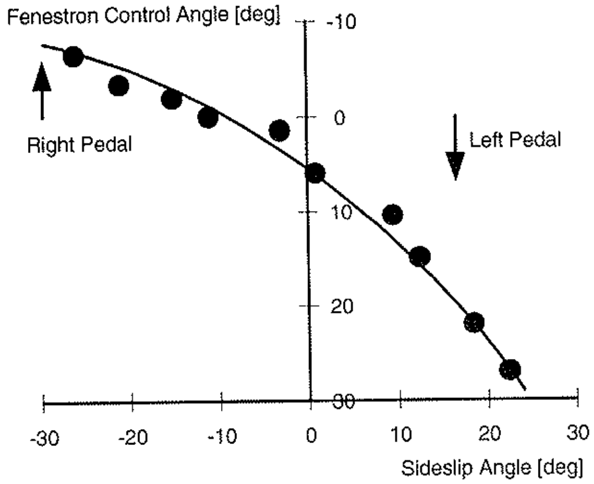

Fig. 12: Directional stability in horizontal flight

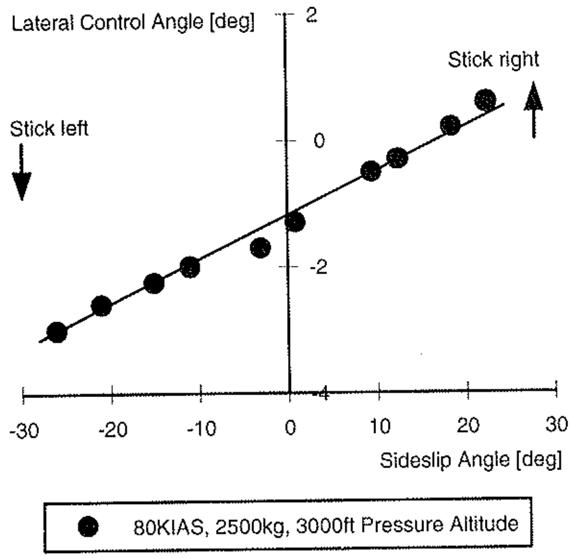

Fig. 13: Dihedral effect in horizontal flight

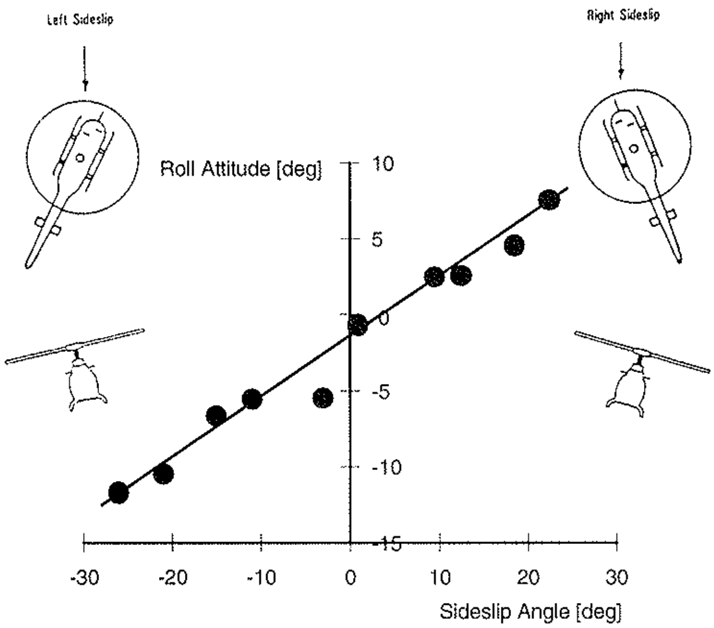

Fig. 14: Sideforce characteristics in horizontal flight

4.3 Static Lateral-Directional Stability and Sideforce Characteristics

The aircraft must have positive directional stability. The amount of pedal position required to hold a sideslip angle indicates the directional stability, and certification regulations require the demonstration of directional stability for sideslip angles up ±10° from trim. A helicopter has positive directional stability, if left pedal deflection is required for right sideslip (nose left, wind coming from the right) and vice versa. Figure 12 shows the result at 2500kg gross weight in an altitude of 3000ft.

Besides the change in pedal position during steady sideslips, the change in lateral cyclic control position and roll attitude influences pilot opinion. The dihedral effect is both positive and stable if the stick has to be moved to the right when flying in a right sideslip. Positive and is desirable for VFR-certified aircraft (IFR certification regulations demand positive dihedral), and protects against the unwanted effect of a divergent spiral dive. The positive dihedral of the EC135 is shown in figure 13.

The change in roll attitude, or bank angle, to hold a given sideslip is an indication of the sideforce characteristics of the helicopter. Positive sideforce characteristics help the pilot make coordinated turns. The positive sideforce characteristics of the EC135 are here shown using data taken during the same horizontal flight conditions as for demonstration of lateral-directional stability. See figure 14.

4.4 Flight under Load Factor

An nz-v envelope was tested as shown in figure 15. Horizontal flight speeds up to 150kts true airspeed and maximum flight speeds of 175kts true airspeed in dive were flown at 2500kg gross weight. Banked turns up to 2.3g normal load factor were achieved. The handling qualities assessment concluded that turns were easy to stabilize without degradation in flying qualities.

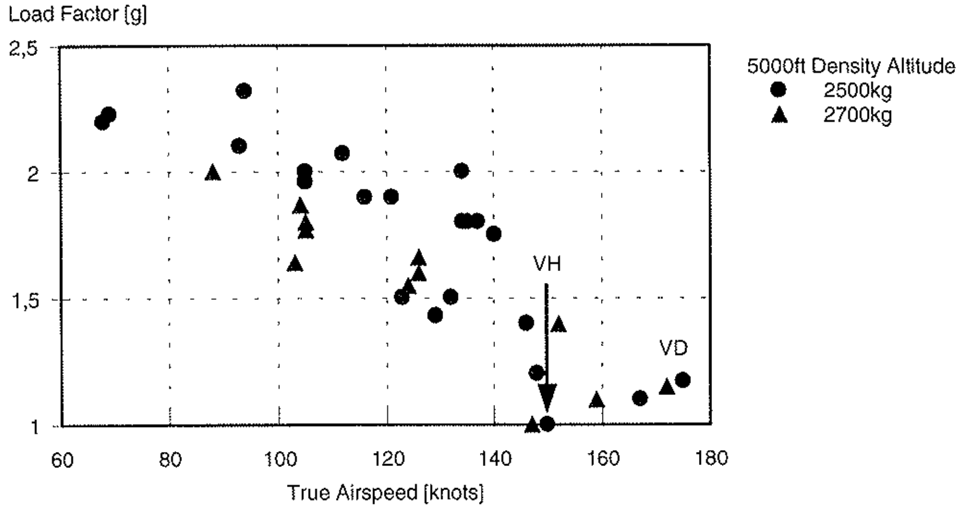

Fig. 15: Normal load factor in forward flight

4.5 Eliminating Tail Shake

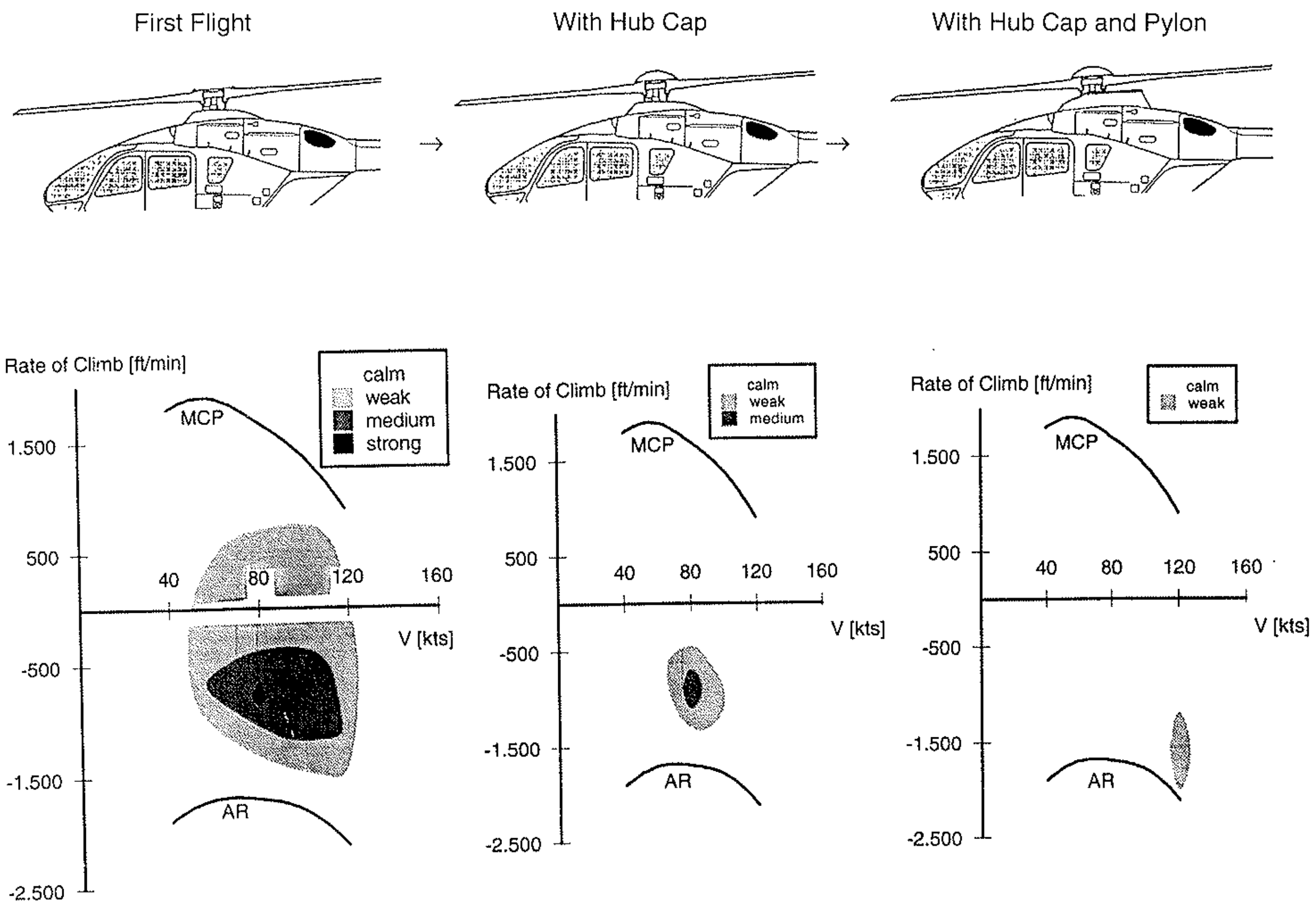

Fig. 16: Tail shake occurence within the flight envelope

Tail shake was identified as an aerodynamic excitation of the lateral fuselage bending mode resulting in an unpleasant vibration centred on 1/rev frequency. This "buffeting" was caused by wakes shedding from the main rotor head and cowlings striking the empennage. Tail shake is a phenomenon present on most helicopters, however, its intensity varies.

During the first flight of EC135 the crew reported unacceptable tail shake, its intensity dependent on airspeed and climb/descent rate, see figure 16 left picture. Due to the company's experience with tail shake during the BK117's early hours, a hub cap had been prepared in advance which proved to help in reducing tail shake intensity and occurence in the flight envelope.

However, the minimisation of this effect was not quite acceptable as can be seen from the shaded areas in the centre picture of figure 16. In order to further improve the tail shake behaviour, wind tunnel tests were conducted to find the best solution. The task was to reduce flow unsteadiness of the wake hitting the empennage as well as to achieve flow deflection, i.e. bringing a more homogeneous airflow to the fin and fenestron area. Optimum results were obtained by mounting a pylon on the cowling. This measure was then tested in flight. The tail shake was eliminated except for a small area in descent flight around 120KIAS, of intensity comparable to occasional light air disturbance.

5. Vibration Level

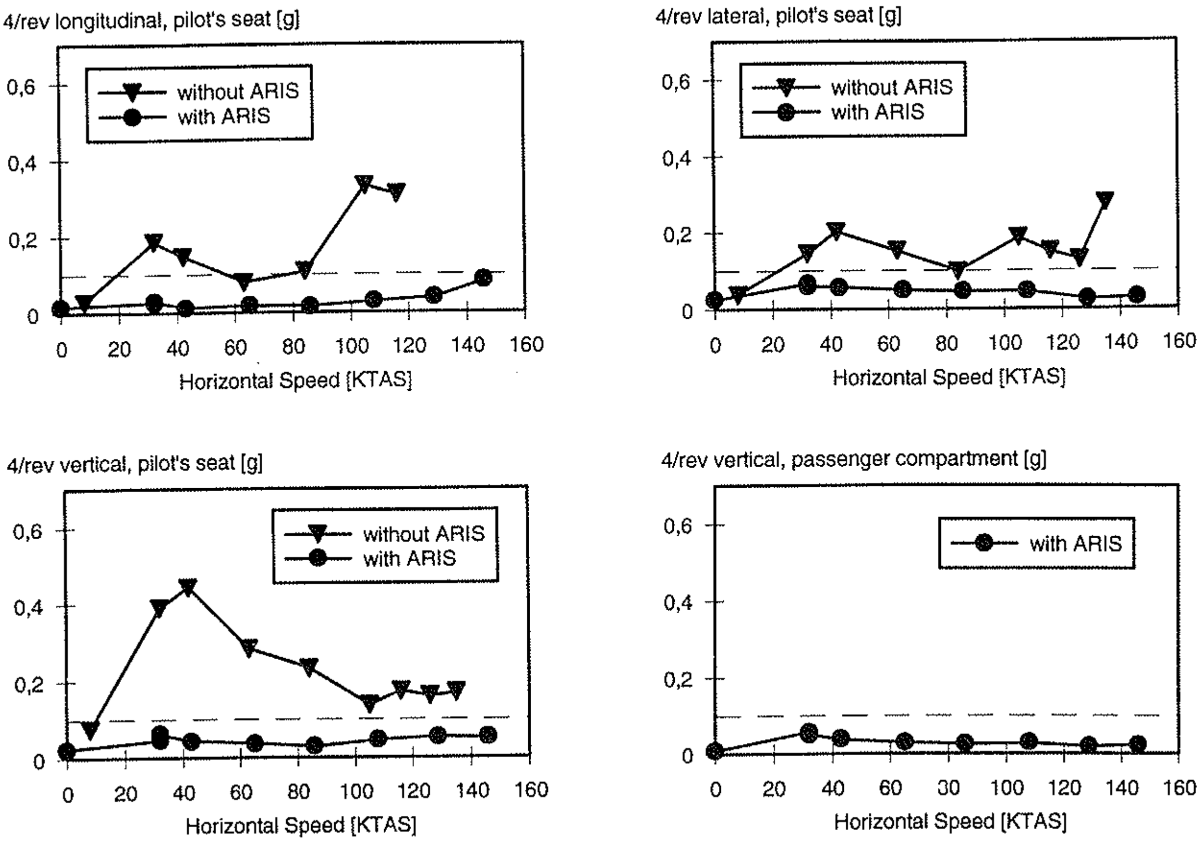

Fig. 17: Vibration level in horizontal flight at pilot's seat and in passenger compartment

One feature for the dynamic optimisation of the EC135 is the EUROCOPTER DEUTSCHLAND developed Anti-Resonance Isolation System (ARIS), mounted between the gear box and the helicopter upper deck, in order to isolate vibrations coming from the rotor. Aircraft S01 was equipped with ARIS from its first flight on while aircraft S02 flew the first hours without this system in order to identify the efficiency of the ARIS. The longitudinal, lateral and vertical accelerations are shown as a function of horizontal speed in figure 17. Measurements confirm the crew reporting a comfortably low vibration level over the whole flight range with the ARIS installed, and measurements taken in the passenger compartment indicate an even lower vibration level at cruise speed. Furthermore, and in comparison to BO105 and BK117, the vibrations are significantly reduced during transition from hover

to forward flight and vice versa. With the ARIS installed the vibration level as shown in figure 17 is well below an acceleration of 0.1g, which is deemed to be an upper comfort tolerance level, especially for the more sensitive up-and-down vibration.

6. Fenestron Fan-in-Fin Tail Rotor

The shrouded tail fan of the "Fenestron" type has been developed by EUROCOPTER FRANCE. This system was selected in order to increase operating safety on the ground and flight safety with respect to foreign object damage. The EC135's "Fenestron" features an advanced configuration with improved aerodynamics, reduced noise emission, increased life cycle and reduced operating costs. Since the fenestron operates at high RPM a low vibration level contributes to flight comfort.

High yaw maneuverability and control response have been demonstrated in flight. In left sideward flight the vortex ring state is delayed to about 35kts, which in comparison to a helicopter of this weight class (15kts range) with conventional tail rotor is an improvement, i.e. small pedal inputs and forces support the pilot in fulfilling his duty with excellent handling qualities for the expected operational requirements.

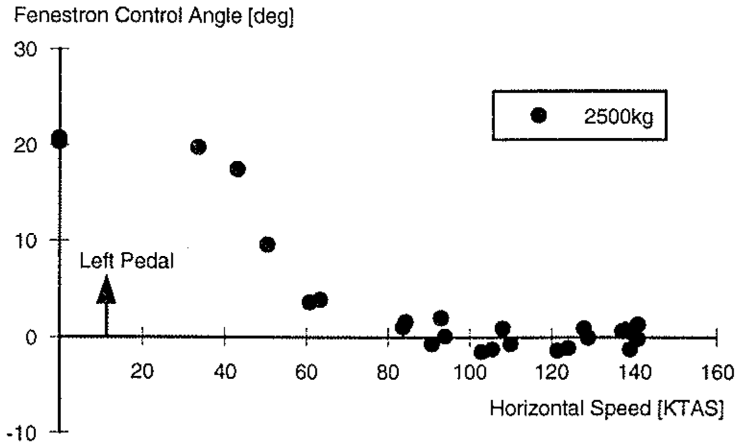

Fig. 18: Fenestron control angle in horizontal flight

In cruise very low loads on the fan itself and low control loads are required due to the entire design of the tail with endplates, side-fin and fan housing. These parts provide the required anti-torque force in cruise, thus minimum fenestron control angle (figure 18), pedal force and low power consumption are required.

7. Engine Tests

The EC135 is the world's first helicopter to be simultaneously certified with two engine types — the Turbomeca Arrius 2B, and the Pratt&Whitney PW206B — to better meet customer requirements. The main features of both engines and their installation are:

- Full Authority Digital Engine Control (FADEC) with:
  a. Optimized fuel flow scheduling during starting, governing, accelerating and decelerating, with added minimum fuel flow protection to prevent unrequested engine shutdown,
  b. Variable Nro governing speed for reduced noise at low altitude and best controllability and performance at high altitude,
  c. One Engine Inoperative (OEI) training limits for safer pilot training, and
  d. Automatic torque matching and isochrounous (integral) Nro governing (PW206B only)
- Integral burst protection for engine rotor blades,
- Suction-lift fuel supply, and
- 15% specific fuel consumption reduction in comparison with the BO105 helicopter.

The following tests have been completed during the design freeze phase:

- Powerplant/rotor drive torsional stability,
- Engine characteristics (N2/Nr governing, Accel/decel, power limiting, control modes, autorotation recovery)
- Engine and Engine Electronic Control (EEC) failures testing.

The Arrius 2B has proportional N2 governing with collective and pedal anticipation. The PW206B has additionally a primary asynchronous mode with automatic torque match, made possible by torque and N2 information sharing between the two EECs.

Torsional stability tests were performed in single and twin engine mode and all powers, using the STIMULI computer system for control inputs. The equipment is used for making precise types of inputs, including frequency sweeps, in any control axis. No torsional instabilities were found. This test is routinely performed after EEC software modifications.

Engine acceleration and deceleration tests (transient droop) included collective and pedal inputs, and in-flight transient manoeuvres. The results showed that the engines respond quickly to power change demands, with only minimal Nr variation. Ground tests were used to fine-tune the EEC s/w chiefly because of time saved and excellent tests repeatability for comparison purpose. Figure 19 shows the single-engine response to a rapid collective input to MCP OEI to be excellent. Figure 20 is an example of data presentation used to compare various s/w for collective inputs. The over-anticipation was not observed during flight; the reason being that the collective load maps (static) are optimized for flight conditions. Due to the expanded capabilities of FADEC, several parameters had to be considered in the evaluation and characterization of transients:

- Nr: minimum, overshoot, and steady-state values,
- N2: autorotation and recoupling values, and
- Torque: overshoots, splits, dynamic response shape

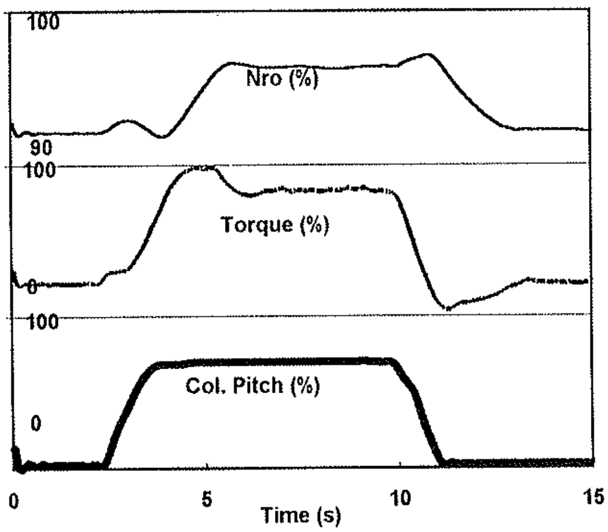

Fig. 19: Engine response to a collective input

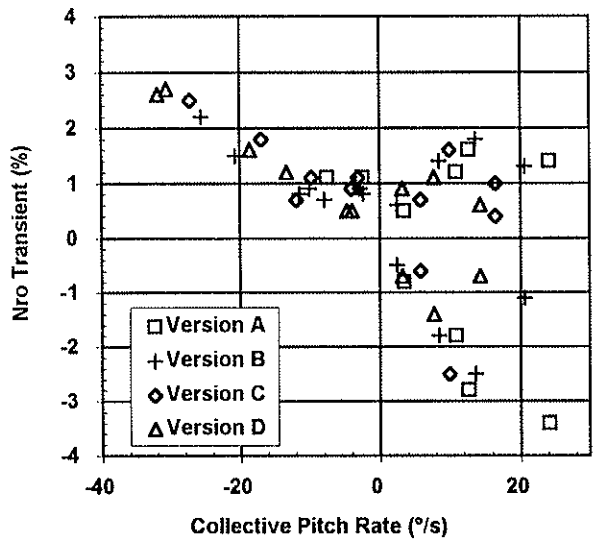

Fig. 20: Nr transient droop vs collective input rate

Engine manual fuel control tests were performed to ascertain the pilot's capability to operate the helicopter safely in all manoeuvres, from T/O to landing, by using the Twist Grips (TG) located on the collective. The following factors were assessed:

- Pilot workload
- Nr variation
- TG characteristics (breakout force, friction, freeplay, fuel flow linearity, TG sensitivity and angular range)

A large number of manoeuvres were performed under normal operating conditions, with moderate workload, without exceeding rotor limits. Figure 21 illustrates an approach and transition to hover flight. Suggested improvements to the TG were the reduction of the friction and sensitivity.

Finally, autorotation recovery tests and EEC failure modes tests were conducted and concluded a successful initial phase.

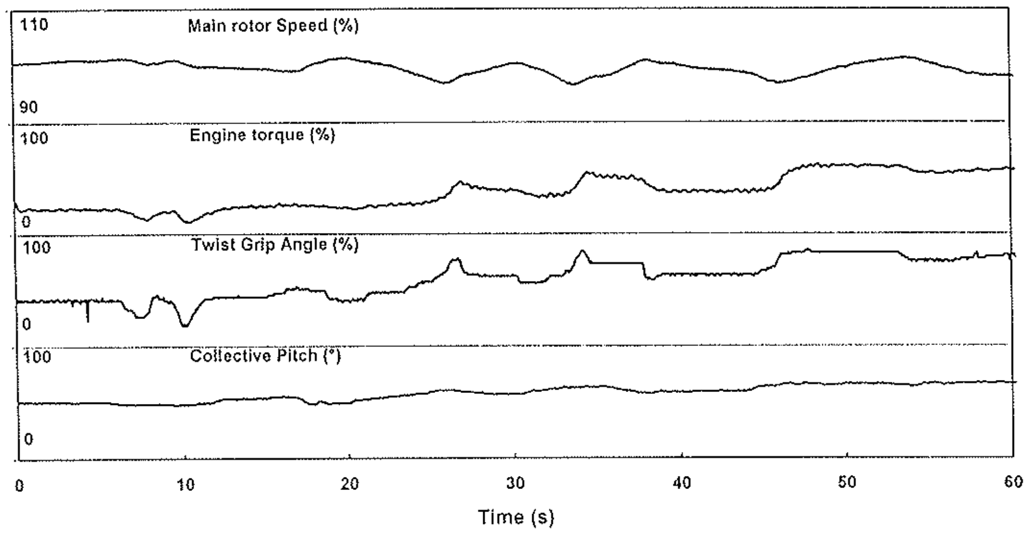

Fig. 21: Approach and Transition to Hover

8. Noise Emission

Verious design measures were taken to achieve the overall target of -6dB below current ICAO Annex 16 limits. These measures include:

- a reduced main rotor tip speed of 211m/s (at 100% rotor RPM), and corresponding fenestron tip speed of 187m/s.
- main rotor blades with 3rd generation DM-H3 (outboard) and DM-H4 (inboard) airfoil sections and advanced parabolic tip geometry.
- asymmetric fenestron blade spacing (for frequency modulation) and increased distance between blades and stator/driving shaft (thus avoiding any "whistling" noise).
- an aerodynamically clean fuselage which requires less thrust for a given speed which leads to lower power required.
- low drag rotor hub which gives reduced hub wake interference.

Environmental aspects, noise, rotor blade loading and controllability are all improved by varying the rotor RPM with altitude. This concept has been validated on the BK117 C-1 variable rotor speed system. In the EC135 the FADEC controls the power turbine output shaft as function of density, see figure 22 for the EC135 rotor RPM vs density altitude.

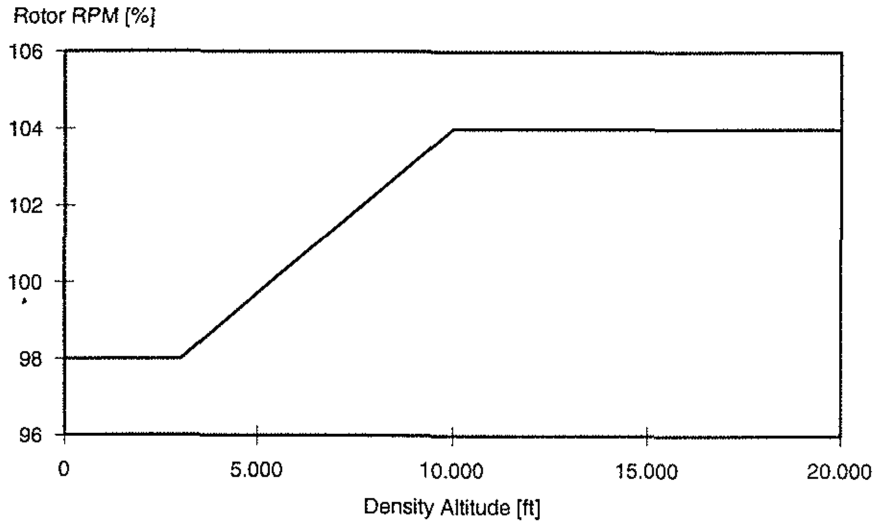

Fig. 22: FADEC controlled variable rotor speed

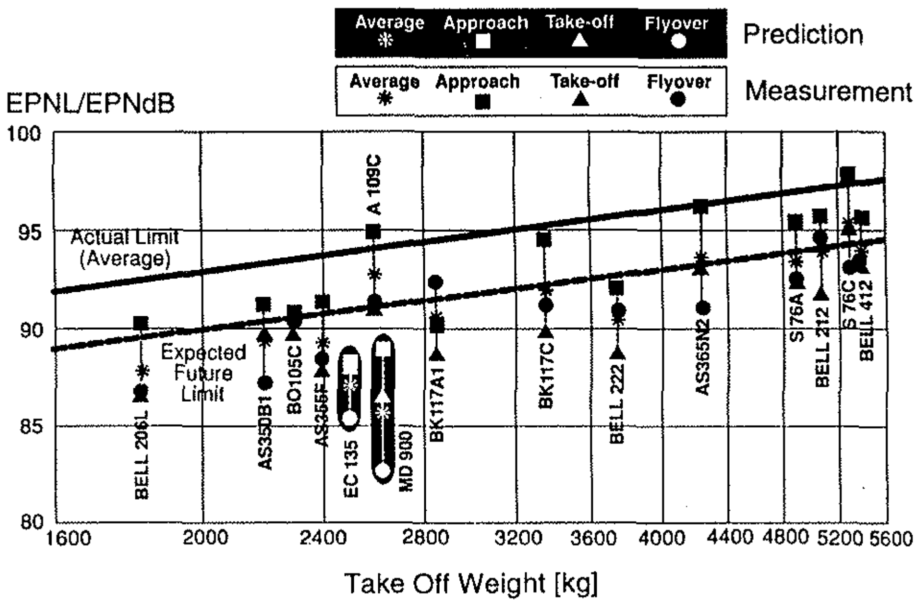

Fig. 23: External noise comparison

The current ICAO limit as function of take off mass is shown in figure 23. External noise measurements were taken with the EC135 predecessor, the BO108, both helicopters having similar main rotor systems. First test results with the EC135 confirm predictions with a margin of -7dB to ICAO limits in flyover, thus verifying the design target low noise helicopter.

A low interior noise level will be achieved with minimum weight constraints. The EC135 is with expected 91dBA or even less in standard configuration well below existing helicopters in its weight class.

9. Conclusion

In conclusion the EC135 test results confirm the design targets:

Measured performances are as predicted, flight characteristics with the completely hingeless and bearingless main rotor show good handling qualities. The dynamic layout of the helicopter with its anti-resonance isolation system allows for a smooth ride at low vibration level. The fenestron fan-in-fin directional control concept proved to be the best choice for the EC135 and contributes to high safety. The overall noise emission is low. Alltogether with modern engines, the EC135 promises to rank high on the market.

The EC135 test course is on schedule and all certification activities will be finished as planned in February 1996.

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