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MODERN TECHNOLOGIES FOR FUTURE LIGHT HELICOPTERS

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Abstract

Several advanced helicopter subsystems are under development at MBB to improve effectivity and comfort and minimize life cycle costs of future helicopters.

Substantial improvements in rotor system technology are achieved by advanced blade airfoils and blade planforms as well as by bearingless rotor concepts with reduced weight, number of parts and increased component life.

Vibration levels are reduced by a new rotor isolation system, combined with a flat two stage main transmission.

The use of composite material for fuselage structures and cockpit solutions decrease weight and manufacturing costs.

New display systems enhance safety through reduced pilot workloads.

Incorporation of above mentioned subsystems in a light helicopter is shown.

1. Introduction

Advanced and improved subsystems are necessary for efficient, successful and competitive operation of future helicopters. At MBB several subsystems are under development with these general objectives:

- enhanced effectivity, i.e. useful load, flight envelope and range
- improved comfort, i.e. ergonomic design, reduction of vibration and noise levels
- reduced costs for production, operation, maintenance and service

The new systems are partially new and in part based on well proven BO105/BK117 technology, e.g. the use of composite material on a large scale and the evolvement of hingeless rotor technology into a bearingless rotor system.

Most important subjects of this developmental work are

- Rotor systems
- Composite airframe structure
- Cockpit layout
- Main transmission with suspension system

It is planned to use these new advancements to update the current fleet of MBB helicopters.

2. Rotor Systems

2.1 New Rotor Blade Airfoils

An airfoil research program is being conducted at MBB together with DFVLR with the targets of

- increased lift/drag ratios
- increase of Mach number dependent speed limits.

Due to the advanced airfoils DM-H3 and DM-H4, compressibility effects are shifted to higher Mach numbers. In addition, reductions in airfoil thickness and chord in the area of the blade tip serve to lower noise levels created by tip vortices and blade-vortex interactions. Noise emitted by stall phenomena is reduced by the more advantageous $C_{L_{max}}$-characteristics of the DM-H3/H4 airfoils.

Fig. 1 shows the comparison of the conventional baseline rotor with NACA 23012 airfoils and a developmental rotor with blades featuring DM-H3 and DM-H4 sections, a tapered planform, high non-linear twist, and an advanced tip shape. The results of wind tunnel testing of a scaled rotor demonstrated 10% less power demands for the developmental rotor. Flight tests with these new blades on the BO105 are scheduled for the end of this year.

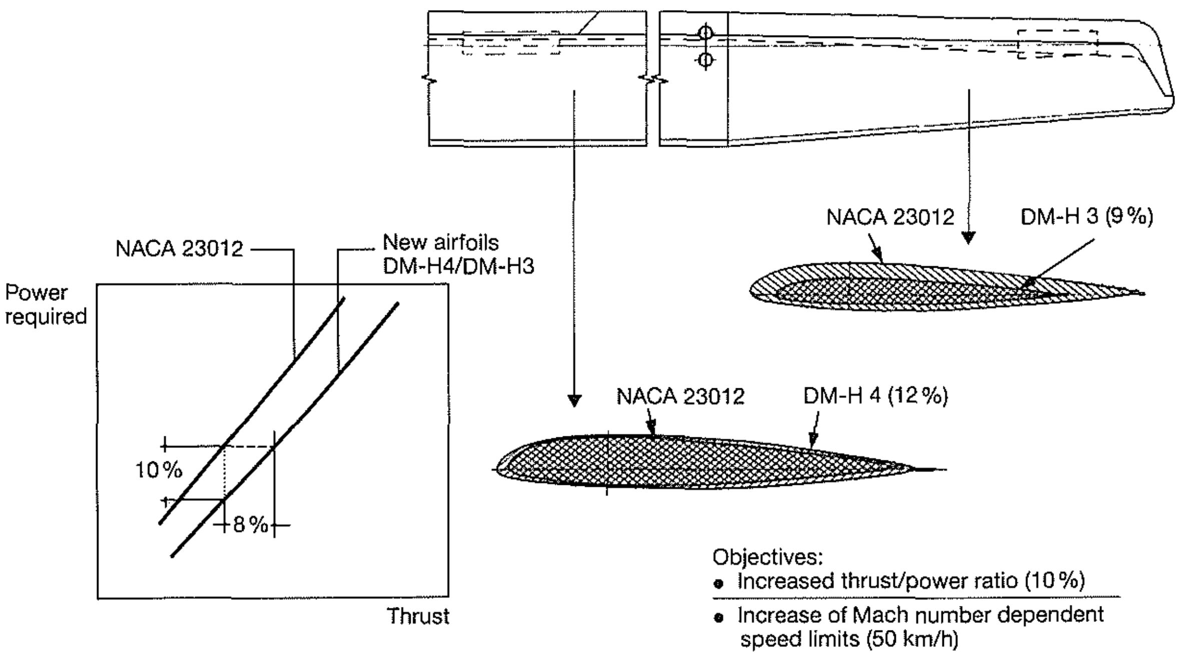


Fig. 1 High Performance Airfoils

2.2 Bearingless Main Rotor

The development of the hingeless rotor system for the BO105 with an elastic blade for flapping and lead lag motion resulted in a drastic simplification of the rotor hub. The consequent continuation of this simplification is a bearingless rotor system, in which the pitch change bearings are replaced by a flex beam element.

The development program is planned in 3 main steps (Fig. 2):

- Experimental system with flex beam blades on a BO105 hub with fixed blade attachment
- Prototype I rotor with a control tube around the flex beam bolted to the blade
- Prototype II with an integrated control tube

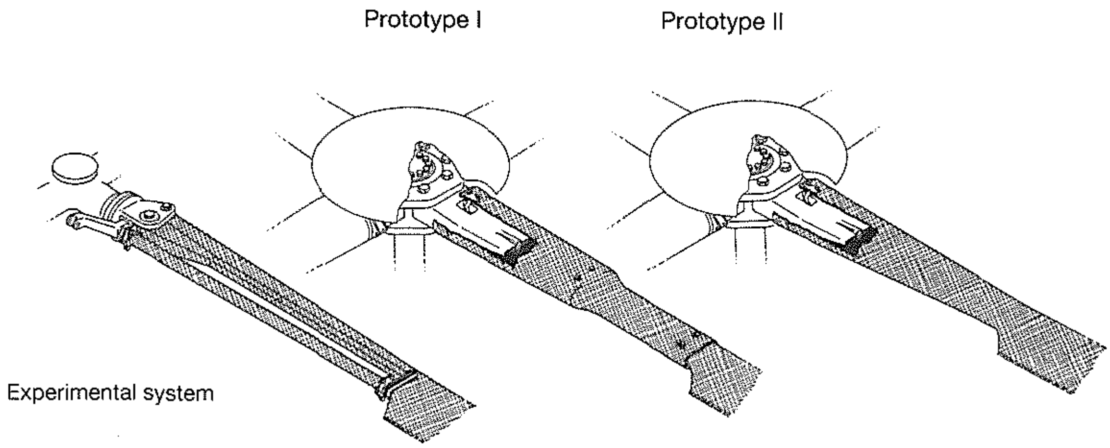


Fig. 2 Bearingless Main Rotor – Development Steps

Fig. 3 shows the experimental system during flight tests on BO105. The fibre composite blade with a T-shaped flex beam is attached to a BO105 rotor hub with a fixed inner sleeve. Pitch change movements are applied by a torque tube beside the flex beam.

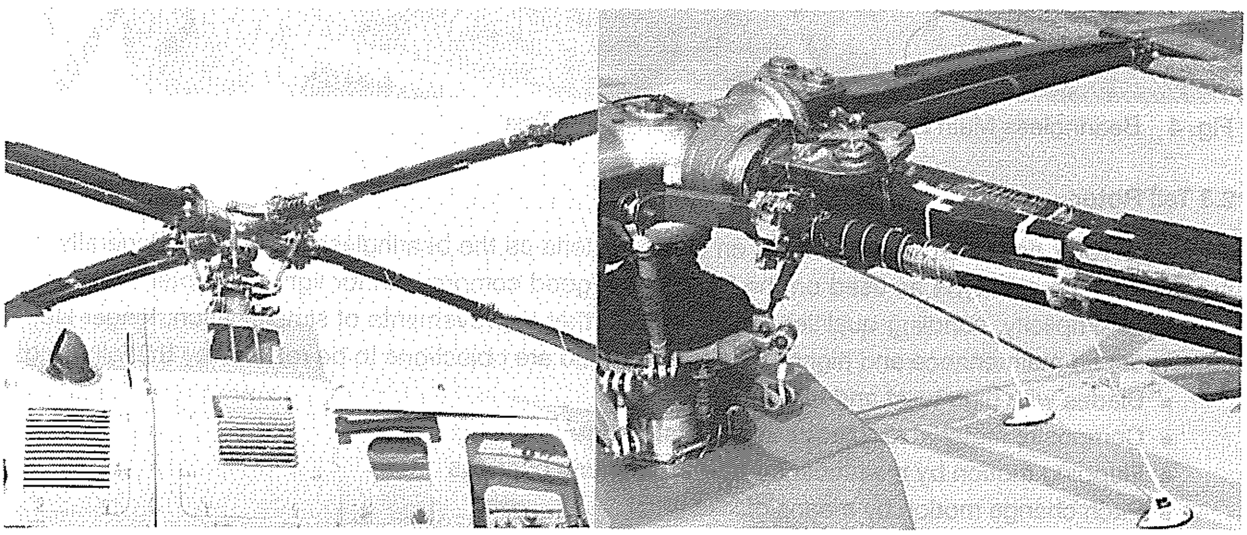


Fig. 3 Bearingless Main Rotor – Experimental System, Flight Test on BO105

Fundamental characteristics of bearingless main rotor systems have been studied in whirl tower and flight tests. The most important findings of these tests provide the inputs to the development of the MBB prototypes:

- Reduction of parasite drag by installation of a fairing around the flex beam. This "cuff" is also used to transfer the blade control motions
- Installation of lead lag dampers between that cuff and the blade root to avoid instabilities in flight and on the ground
- Optimization of stiffness and length of cuff and flex beam

Fig. 4 shows the prototype I during the whirl tower tests. Hub and rotor mast are of one piece to which the flex beams of the rotor blades are attached. The control tube is bolted to the blade. To facilitate inspection of the flex beam during flight tests the tube is made of 2 pieces. The flex beam has a symmetrical cruciform cross section. In a final version, the control tube can be an integral part of the blade bonded directly at the beginning of the airfoil section.

In comparison to the BO105 hub, a 20% weight reduction with 40% fewer parts can be achieved. Component tests have showed that the goal of unlimited life for all structural parts can be reached.

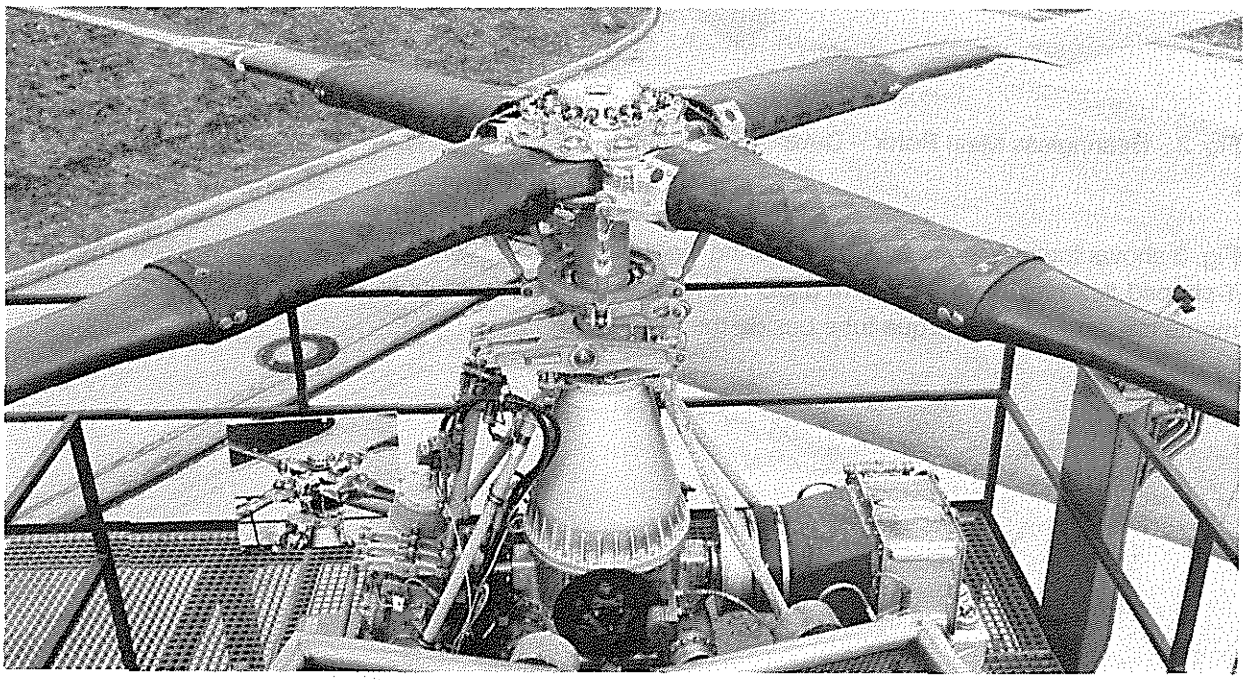


Fig. 4 Bearingless Main Rotor Prototype I – Whirl Tower Test

2.3 Tail Rotor

A new tail rotor has been studied based on similar criteria as the bearingless main rotor. Generally, a two bladed see-saw type as used on the BO105 is a good compromise for light helicopter tailrotors regarding simplicity, handling qualities, noise, etc. Further improvements of simplification, longer life time, reduced maintenance and higher thrust/power ratio are objections to be realized by the following:

- Blades with high twist and tapered planform
- Composite material for blades and hub structure
- Flapping motion by maintenance-free elastomeric bearings
- Pitch change motion by means of
  - composite flex beams or
  - elastomeric bearings

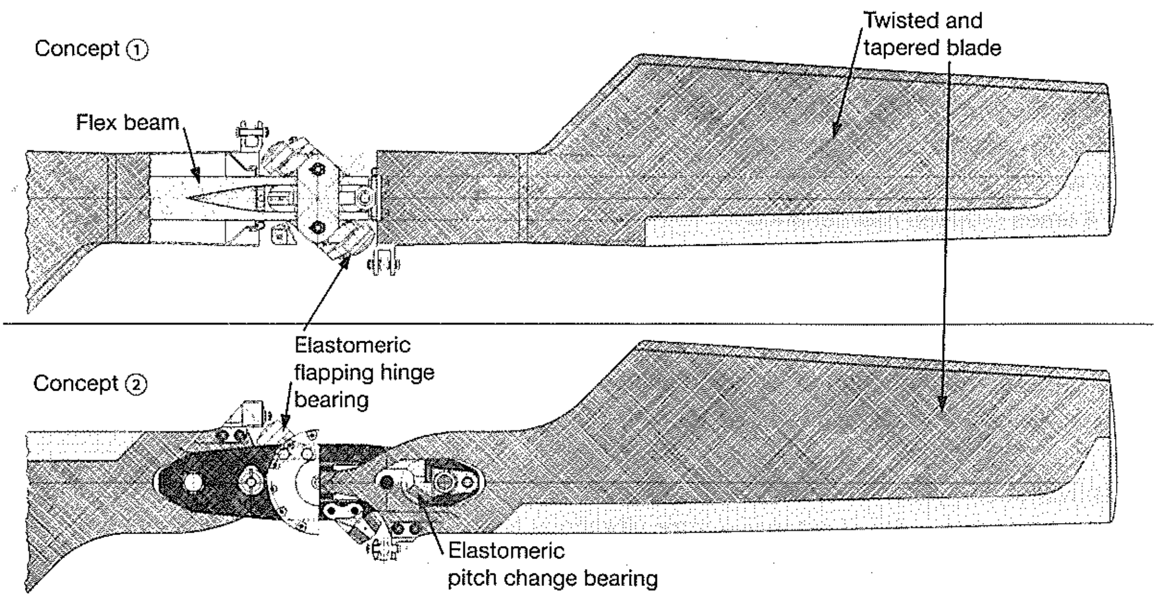


Fig. 5 New Tail Rotor Concepts

Fig. 5 shows two tail rotor types both with tapered blades and elastomeric flapping hinge bearings.

Concept 1 features a pair of blades with an integrated flat flex beam in between. The glass fibre rovings of the flex beam also form the blade spar. In the center the flex beam is split and spaced for installation of a snubber bearing for each blade and for attachment at the hub. A composite cuff is bonded to the blade for transfer of control movements.

Concept 2 consists of two single composite blades and a composite hub. The blades are attached to the hub by means of a cylindrical non-lubricated bearing and a conical elastomeric bearing. The elastomeric bearing is installed in an opening of the blade root. Fabricated hardware of concept 2 is shown at figure 6.

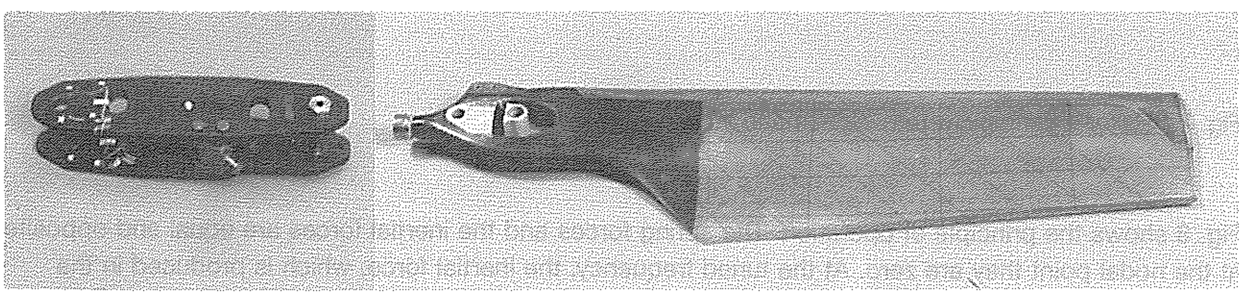


Fig. 6 New Tail Rotor Hardware

The benefits of the composite type BO105 tail rotor include:

- 11 % reduction of power at maximum thrust
- 5 to 6 times longer life of flapping hinge bearings
- Infinite life of structural components
- 10 % weight reduction
- 2 to 4 times reduced maintenance

3. Antivibration System

In future helicopters, the reduction of vibration level will be an essential aspect for improvement of comfort for passengers and pilots as well as for safe installation of highly sensitive instruments.

A passive antivibration system is under development called ARIS (Anti-Resonance Isolation System), *which can prevent the transfer of extensive rotor vibrations to the fuselage. Isolator elements are* incorporated in the gearbox suspension to the fuselage (Fig. 7). They are a combination of a force generator and an isolator spring.

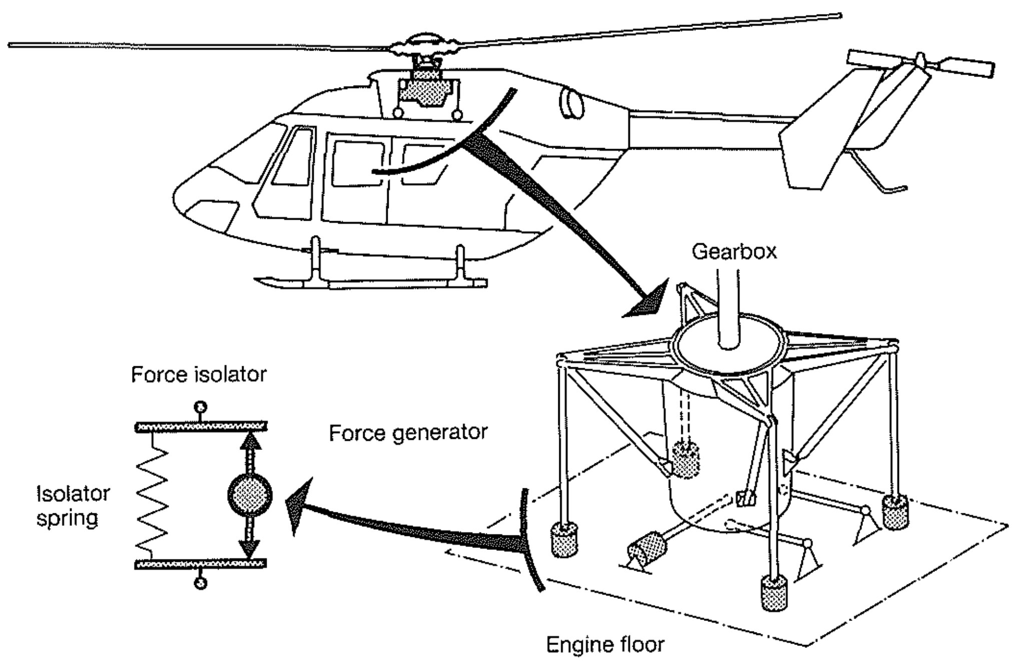


Fig. 7 Rotor Isolation System. Schematic View

Fig. 8 shows the principle of operation. The spring forces and the inertial forces are equal and opposite; at the nodal point they are zero. At the tuned frequency, the inertial force, which is produced in the force generator by relative movements between the rotor transmission unit and the fuselage, cancels the spring force. Thus, a nearly perfect isolation can be obtained.

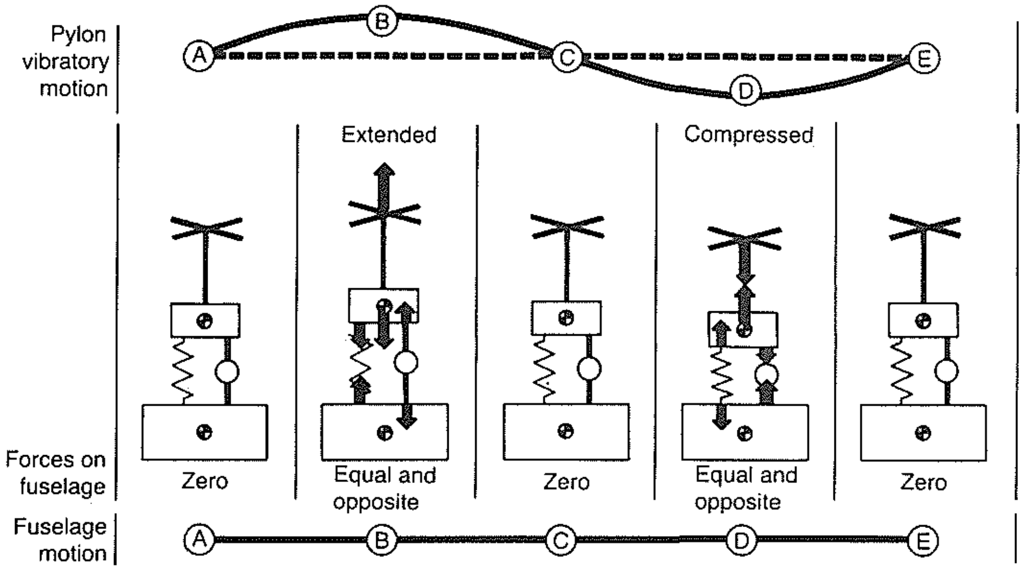


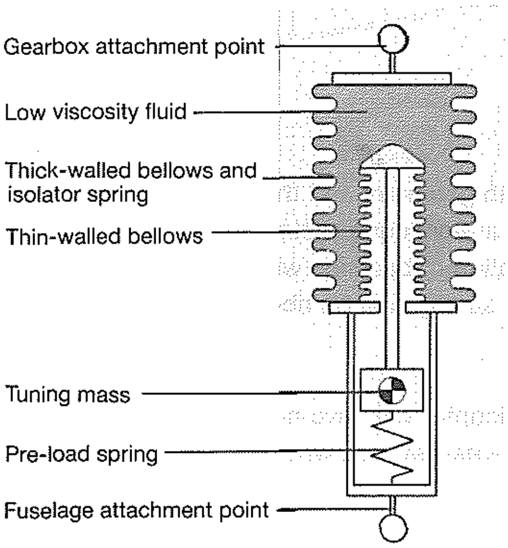
Fig. 8 Principle of ARIS Operation

Two different types of isolator elements have been developed, both using a parallel connection of a spring and a pendulum:

- a mechanical element with a composite ring-type spring and a mechanically driven pendulum
- a hydraulic element with two metal bellows filled with low viscosity fluid, a pendulum affecting hydraulic metering, and an additional coil spring

Fig. 9 shows the hydraulic isolation element. The bellows serve not only for sealing the fluid volume but also as an isolator spring. The pendulum weight is fastened to the free end of the inner bellow. The additional coil spring statically pressurizes the fluid in the bellow system to guarantee that the pendulum mass continuously follows the stroke of the outer bellow.

The excellent efficiency of the ARIS has been demonstrated during flight tests on the BK117. Measured acceleration at 4/REV on pilots seat and in the rear cabin has been below 0.1 g in forward flight and below 0.15 g in a flare condition.



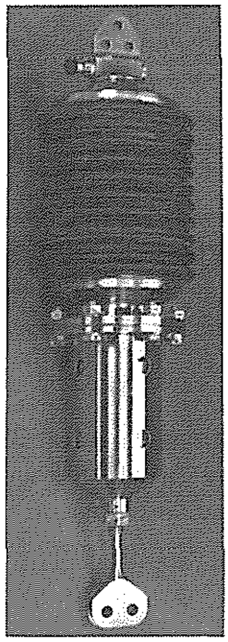


Fig. 9 Hydraulic Isolator Element

4. Transmission

In modern transmission technology, some fundamental aspects have been proven and will be applied at a new main gearbox design for a light helicopter:

- the use of high reduction ratios in each stage in order to reduce number of stages and thus number of gears and other parts, especially in the main power train. The effects are lower costs and better reliability.
- a reduced number of connections with splines, couplings, flanges, etc, which results also in a fewer number of parts
- a reduced number of fits especially those with high tolerances
- the integration of roller bearing races in the shafts in order to save parts, reduce weight, avoid fretting corrosion and simplify mounting procedures
- the minimization of housing parts

The new main gearbox is designed for a two-engine installation (Fig. 10). It consists of two stages: a bevel gear entrance stage and a spur gear collector stage. The tail rotor shaft is driven by the collector stage; the accessories by the intermediate shafts.

The rotor mast bearing installation at the upper and lower sides of the housing allow for a very flat gearbox design with the benefit of additional usable room in the cabin.

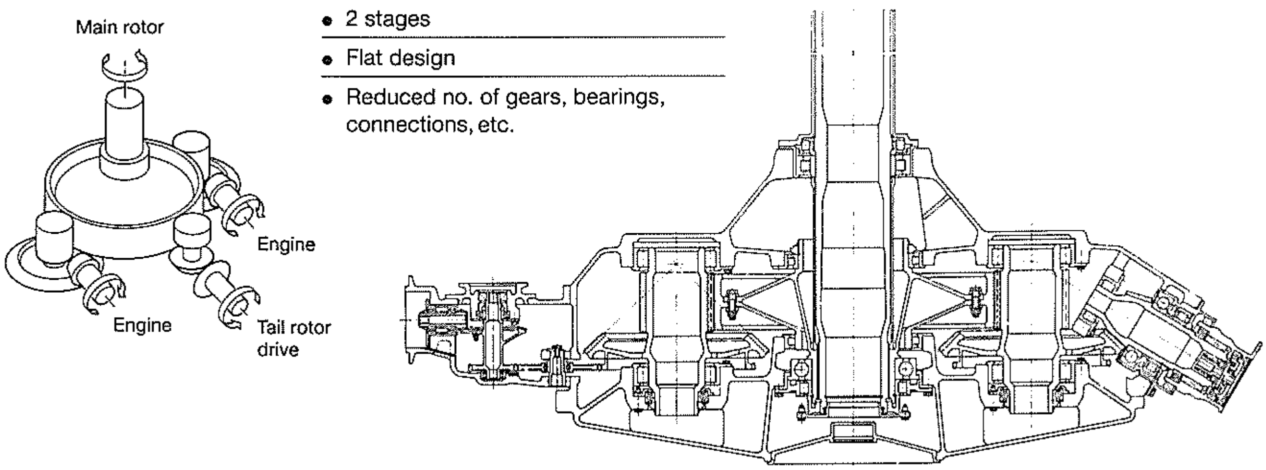


Fig. 10 Main Gearbox

By means of short load paths, optimized tooth geometry and the use of titanium, e.g. for the spur gear carrier, weight will be reduced. Integration of a monitoring system, dimensioning of shafts, gears and housings for high or unlimited life and installation of bearings with more than 3000 hours MTBR will improve maintainability and reliability. Weight savings will be about 12 % compared to the BO105 transmission.

The new dynamic system for MBB's light helicopter will have no TBO-limits. For all subsystems the defined goal is a MTBR of 3000 hours for the weakest part, where a monitoring system will be used.

5. Airframe Structure

Extensive studies on composite airframe structures have been conducted with regard to design to cost principles and weight reduction objectives. Carbon fibre composites or hybrid structures of carbon fibre and aramid fibre composites have proven favorable for primary structures while aramid fibre composites are preferred for secondary structures.

Most important advantages of composite structures are:

- a significant reduction of parts per kg structure especially in the area of joints, where the major aspect for cost savings is realized
- the tailoring of stiffness by use of different fibre material and layers in accordance with technical requirements
- the manufacturing in a fixture which guarantees exact size and shape of frames, door and window openings facilitating correct fit and good interchangeability of doors and windows and the tailoring of structural members to specific needs.
- With the ability to manufacture spherical shells, the airframe can be designed for optimized aerodynamics

Fig. 11 shows as an example a composite fuselage which is under development for the BK117. The complete cockpit section is fabricated of aramid fibre composite shells. Front doors, passenger doors, rear doors are also planned to be aramid fibre composites. Lateral shells and lower structure are of carbon/aramid hybrid composite structure. The engine deck (hot section) will be manufactured in titanium sheet metal. The complete fuselage design compared with the previous model, offers a weight reduction of 20%.

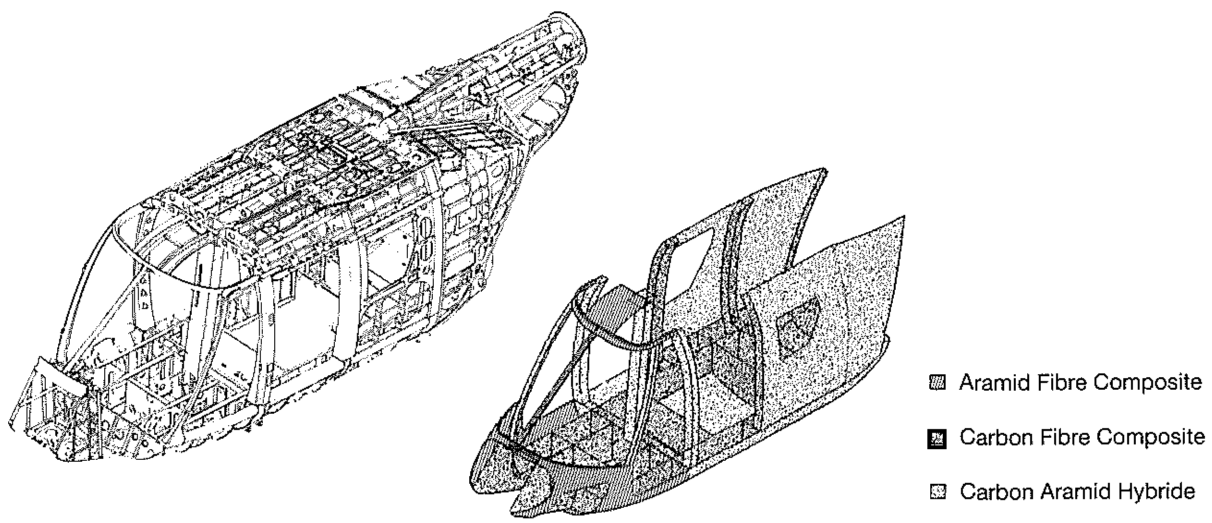


Fig. 11 Comparison of Conventional and Composite Airframes

6. Cockpit Design

In numerous evaluation meetings where engineers, pilots, marketing personnel, commercial artists and operators were in attendance, the features of a modern comfortable and ergonomical optimized cockpit were defined.

Subsequently a cockpit and cabin mock-up as shown at Figure 12 has been fabricated for optimization of crew and passenger compartment.

The ergonomical/anthropotechnical design features are:

- optimal seat comfort and position
- ergonomical flight controls
- extra-large and glitter-reduced windscreens
- effective ventilation and heating system
- noise absorbing inboard fairings
- deposit cases for maps and handbooks
- sun shutters (integrated in cabin interior)

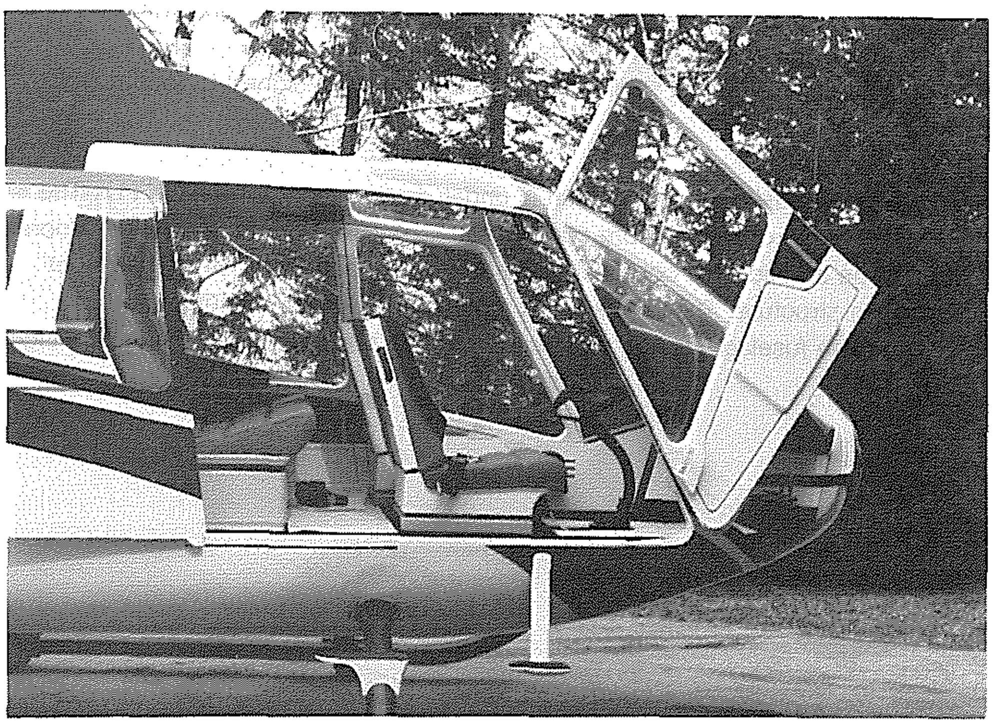


Fig. 12 Cockpit Design Mock-up

One of the important aspects in modern cockpit design is the available display technology of multi-function displays capable of projecting vast amounts of information in various formats.

Fig. 13 shows a conventional "dual pilot IFR" panel with LCD-display for engine and transmission data and the preliminary design of a CRT-display panel with back-up attitude indicator and barometric altimeter. A weight and price comparison of these two concepts show higher weight and about double the cost for the CRT-display panel, assuming today's available technology. Although a significant reduction of costs can be expected after 1990, taking into account the economics of civil operations, a cockpit layout only based on CRT-display technology is not recommended today.

The application of displays is, therefore, planned in two steps:

- conventional Com-Nav Systems plus LCD-display for engine and transmission data in 1990
- CRT-/LCD-displays beginning after 1995.

This means that a LCD-display for transmission and engine data will be used as a first step in the direction of the new generation MBB cockpits. 30 % space and weight reduction can be expected compared to the conventional instrument installation.

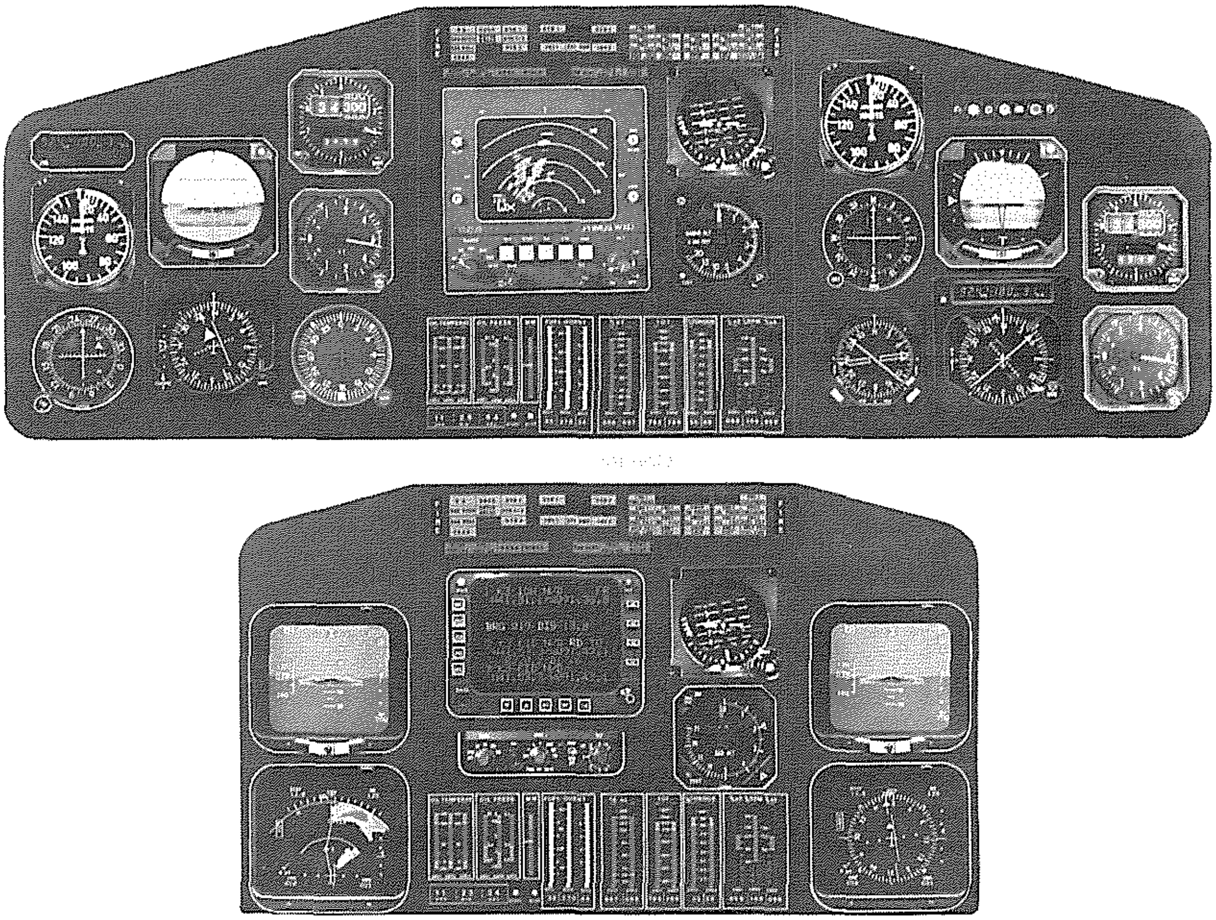


Fig. 13 Instrument Panel Comparison of Conventional/LCD and CRT/LCD-Displays

7. Light Helicopter with Advanced Technology

It is planned to incorporate the previously presented systems into the MBB helicopters in progressive steps. After finalizing the various technology programs some of these systems will be used directly for the BO105 family, others will be modified and adapted, especially those which have been developed for the BK117.

Obviously, part of the existing helicopter design will be modified with the integration of the new system. Changes in the outer helicopter contour to reduce aerodynamic drag, and internal changes to provide more pilot headroom and greater width for the passenger seating are in discussion.

Allison 250-C20R engines and alternatively the Turbomeca TM 319 and the Pratt and Whitney PW 205 are candidate power plants for these advanced helicopters.

Fig. 14 summarizes the areas, targeted for improvements.

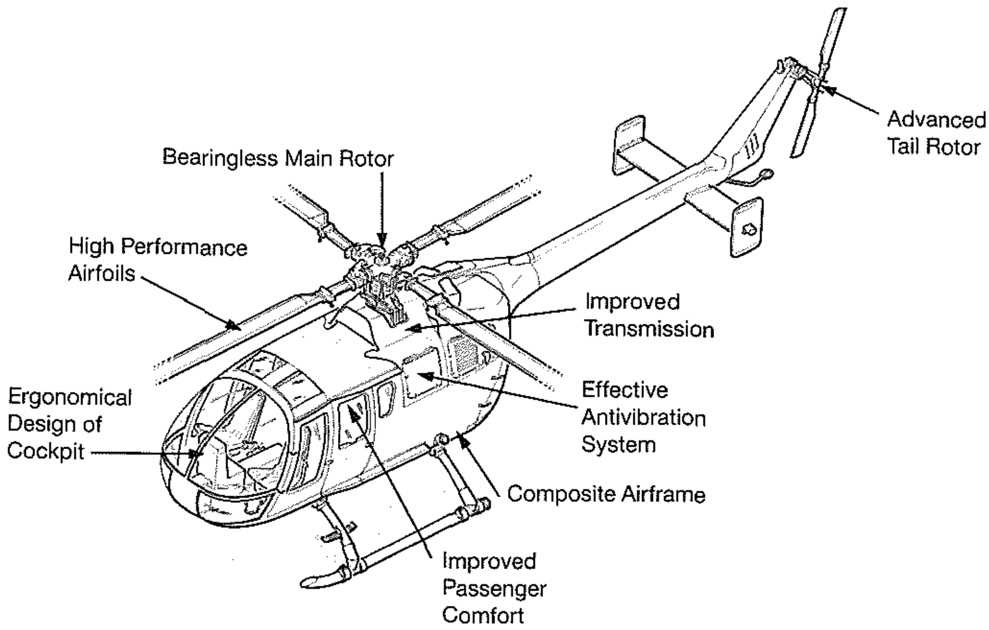


Fig. 14 Target Areas for Improved Systems

8. Conclusion

The program status of these new technology subsystems vary from first article fabrication to extensive flight tests. The results to present are very promising and encourage their utilization.

Vast experience in light-twin helicopter operations will be used to integrate these improvements provided by high technology into the MBB helicopter family. These improved light helicopters will feature more comfort, 10 % less weight, 10 % increased performance and significantly reduced life cycle costs.

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