ADVANCED HELICOPTER TRANSMISSION TECHNOLOGY FOR A 5 TON UTILITY HELICOPTER

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Abstract

The purpose is to design and develop a power transmission system meeting the requirements for advanced helicopters of the 21st century

The dynamic system ,of the main rotor drive, designed as an Integrated Dynamic System (IDS) includes the advantages of new technology and leads to advanced performance capability as well as multipurpose aircraft capability owing to the compact modular construction.

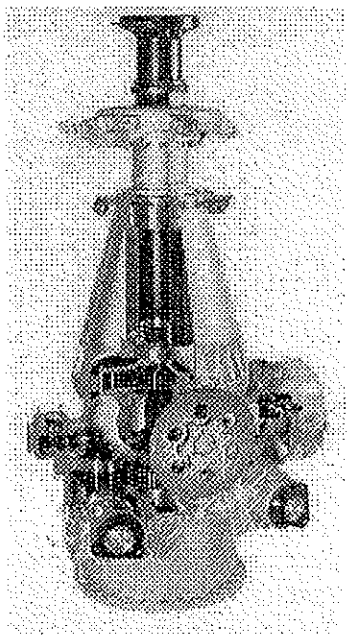
The application of advanced technology for the structural design combined with well-balanced use of new material-technologies makes to exceed the requirements for economic efficiency and reliability with practical no compromising in essential overall performance.

Comparison

The comparison of conventional main transmission and Integrated Dynamic System shows the advantages of the innovative IDS system and demonstrates the range of potential improvements for a future architecture of helicopter main transmission.

Conventional Design

- blade pitch actuation device exposed to environment
- control struds exposed to environment
- pitch control of rotorblades outside the gearbox
- grease lubrication under environmental condition with separate sealing
- rotorshaft as mast-configuration with disadvantageous distance of bearing bases
- reduced available space under gearbox due to disadvantagious distance between rotor center and gearbox deck

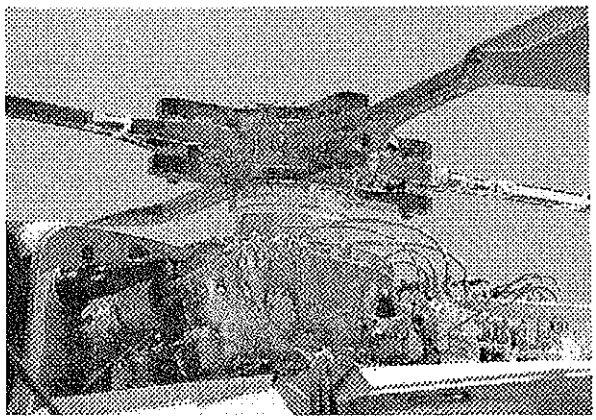


Picture 1: BO105 Transmission

Integrated Dynamic System

- blade pitch actuation device situated inside the gearbox

- control rods situated inside the Gearbox
- pitch control of rotorblades inside the gearbox
- controlled oil lubrication under clean condition
- Gear Schematic concepted for Low Height
- More space provided for passenger and cargo compartment due to short distance between rotor center and gearbox deck
- Rotorshaft is not necessary; Connection between Gear and Rotor Head with extremely Low Height



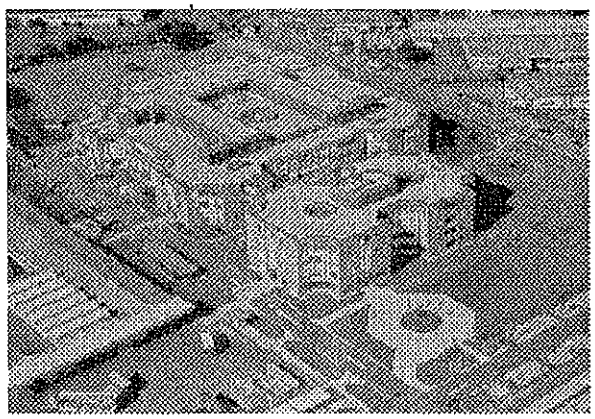
Picture 2: ALH Transmission

Background

Experience was gained in areas which are essential for future helicopter design in tight contact with the ZF Friedrichshafen AG owned research and development centre.

In addition to the main work-packages *transmission* and *blade control system* which will be highlighted, efforts were made in most of the related tasks as they are:

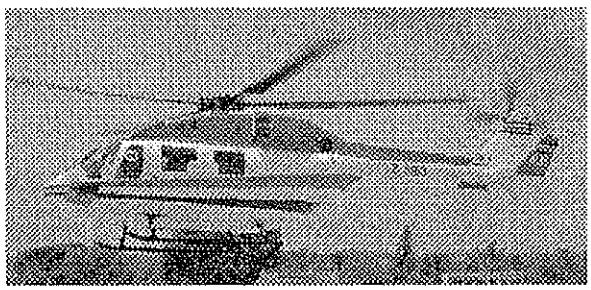
- gear materials
- gear geometry
- lubrication
- health and usage monitoring system
- advanced materials composite and metal foam
- noise reduction



Picture 3: ZF Friedrichshafen AG R&D-Centre

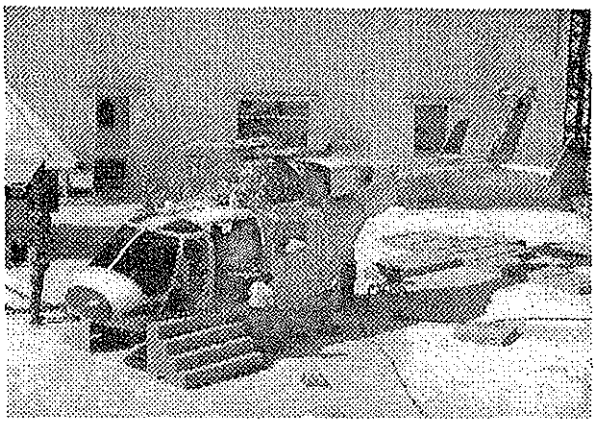
Transmission

A helicopter main transmission development for a 5 ton class helicopter was conducted by Hindustan Aeronautics Ltd.., India together with ZF Luftfahrttechnik GmbH under contract for the Advanced Light Helicopter (ALH).



Picture 4: ALH in flight

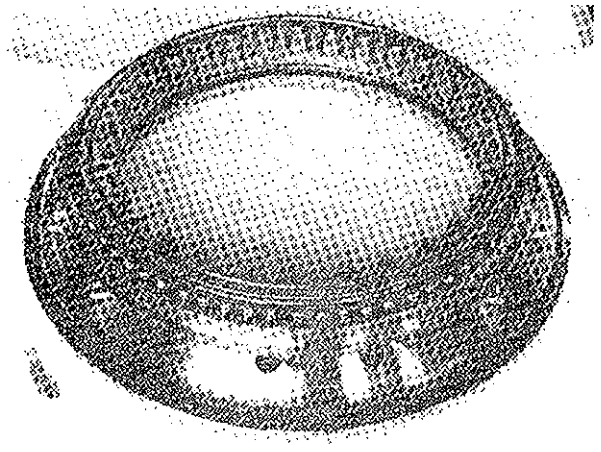
Substantial weight and cost reductions were achieved by the use of a two-stage concept together with the integration of the swash-plate and blade pitch actuation system inside the gearbox. Both features have been supported by advanced analytical optimisation methods and by testing on a full size Ground Test Vehicle.



Picture 5: Ground Test Vehicle ALH

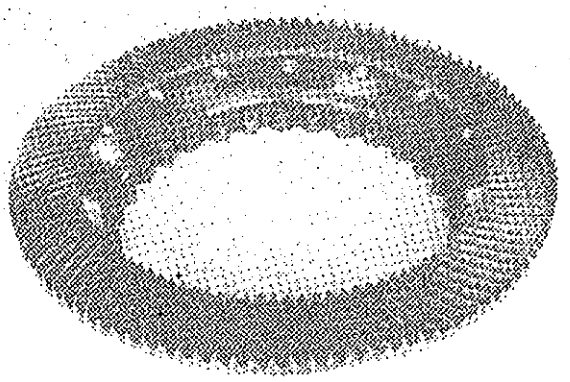
A wide range of strength and performance tests in conjunction with to comprehensive analytical investigations were carried out in addidion.

One additional feature to contribute to the design goals is a high contact ratio spiral bevel gear for the collector stage.



Picture 6: Rotor Mast Bearing

One experience gained during this development was that a two stage bevel gear system is an attractive alternative to conventional planetary designs for helicopter main transmissions. Spiral bevel gear systems offer lower weight and less parts but have normally not been used because of lack of experience with obtaining proper load distributions on the tooth surfaces during all operating conditions.

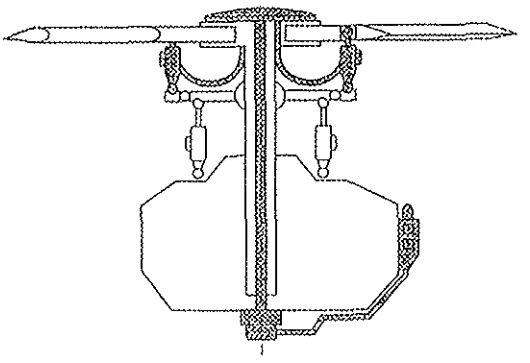


Picture 7: Collector Gear

Blade Control System

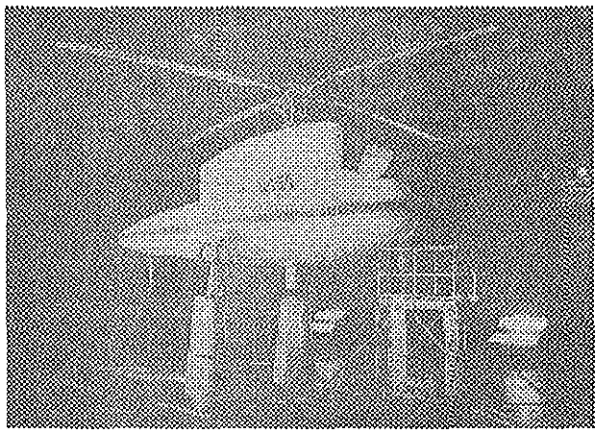
A second field of experience is the successful layout, design and testing of Higher Harmonic Control (HHC) system which was tested at NASA Aimes Research Centre and Individual Blade Control (IBC) systems.

One servo-hydraulic actuator for each rotor blade allows to overlay the traditional cyclic pitch control with higher harmonic inputs. The actuators are installed between swash-plate and pitch horn of each rotor blade replacing the control ·rods. The hydraulic and electrical power is guided through the rotor shaft and distributed in the rotorhead to the consumers. The control inputs are generated by a data management system derived out of actual conditions as manoeuvre, vibrations and noise.



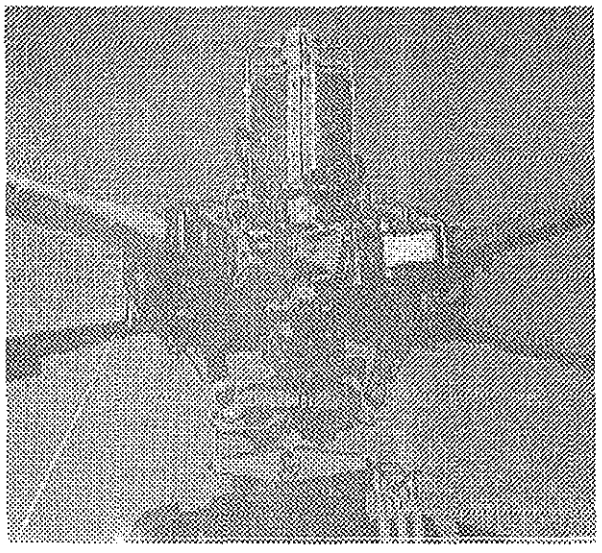
Picture 7: Scheme of IBC-System

The IBC performance tests have shown significant reductions of the total rotor power consumption. Further improvements seem to be possible with higher control authorities.



Picture 8: NASA-Aimes Research Centre

The analysis of the rotor aerodynamics has shown that especially the effects of high mach-number contribute to the profile power losses. The investigation shows clearly that the use of IBC in combination with variable rotor speed seems to be promising for future improvements.



Picture 9: HHC on BO105 Gearbox

Ambition

Consequently to the experiences made so far on transmission- and actuation systems individually the next step is to merge both systems, the two stage high-ratio gearbox with its flat architecture providing central space, and the actuating system which could advantageously be situated in the gained central space area. Both systems are supporting each other by means of most overall space saving architecture within a helicopter main transmission.

As the gearbox will be constructed as a 2-stage system with input stage and collector stage combining the power of the engines, the collector gear is directly attached to the rotor hub and carried together with the hub by the rotor bearing.

The Pitch Control System with the Swash Plate is placed inside the Gearbox in the Centre Area of the Collector Gear

An Individual Blade Control System with additional Control Authority beyond the Primary Control can be installed without having additional Aerodynamic Disturbtions at the Rotor Centre

Investigations

The basic investigations for the merge of two stage bevel gear transmission and advanced blade pitch actuation system was divided into two blocks

- definition of the gear train arrangement
- definition of blade pitch actuation system

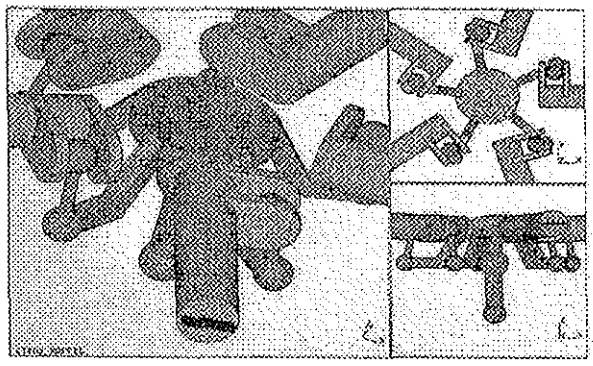
with following high-priority objectives:

- minimum weight
- minimum volume
- highest reliability

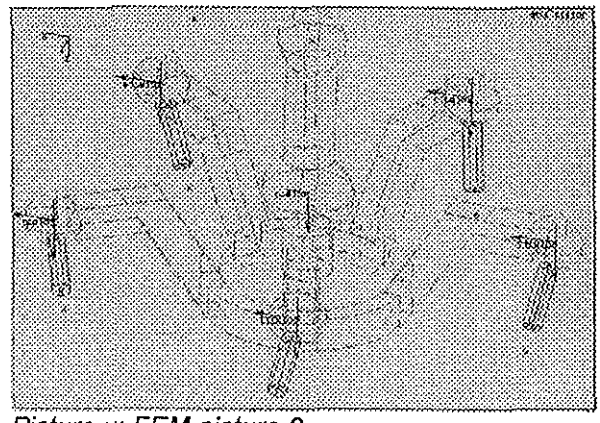
- minimum number of parts by aiming maximum communality
- balanced load distribution
- balanced lifetime
- ecological improvements in all aspects

Different gear train and blade pitch actuation system arrangements were discussed and were studied to compare the needs and benefits of the different configurations. To validate the studies excessive calculations were conducted to an extend which is unusual in an early design phase but necessary whenever new fields of research are conquered and comparison bases must be developed.

One of the examples for calculations is a very detailed cinematic analysis to verify distortions under realistic operating conditions which is an absolutely requirement for more detailed integration studies; the risk to follow the wrong track is too high, to handle this complex problem just with estimates.



Picture x: FEM picture a



Picture x: FEM picture 2

Summarize

The results of investigations and design studies made so far and taking into account the background of experience gained with isolated projects require the further evolution step. This means to combine these elements which are validated in sense of function and reliability to an extend that we are sure that the combination offers further improvements for the Future Helicopter Transmission Concept of next generation.

The development has to take also under consideration the aspects of low weight, low cost and reliability resulting in increased economic and ecologic efficiency by

- new materials
- advanced gear geometry
- aerodynamic improvement
- efficient lubrication and cooling
- monitoring systems

the synthesis of a flat gear train architecture, an integrated dynamic system and an individual blade control designed to be

the one link between engine and rotor blades

is today already more than a vision.