NOVEL LIGHTWEIGHT SOLUTIONS FOR HIGHLY LOADED POWER TRANSMISSION COMPONENTS

WERNER HUFENBACH, OLAF HELMS, DANIEL WOHLFAHRT, THOMAS RITSCHEL

Technische Universität Dresden, Institut für Leichtbau und Kunststofftechnik
01062 Dresden, Germany

BURKHARD IFFLAND

ZF Luftfahrttechnik GmbH, Flugplatzstraße, 34379 Calden, Germany

SUMMARY

In the field of helicopter power trains (Fig. 1) the use of carbon fiber composite materials enables remarkable weight reductions and a variety of functional advantages. In this paper the design of lightweight power train components is described by means of two different gearbox components. For a bevel gearbox housing a novel double-shell design is applied in which the inner shell takes over the structural function while the outer shell serves as an oil containment and cooling. For a maintenance lid a remarkable noise insulation is achieved by the use of a sandwich built-up with a foam core. Furthermore the lid has to take over a structural function since it features a highly loaded mounting point for a strut component. Both composite components are accomplished with a load adapted design which is proved by runs on different test rigs.

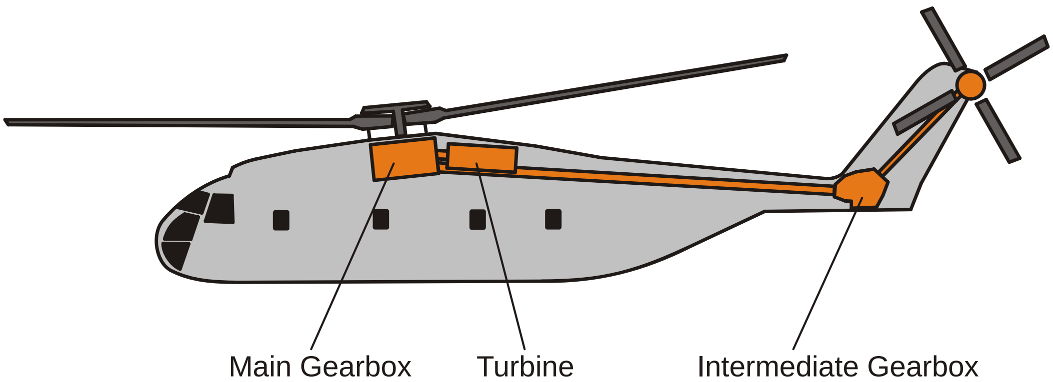

Fig. 1 **Allocation of drive train components inside a helicopter**

1. INTRODUCTION

Foremost the aerospace industry was revolutionized by means of the introduction of fiber composite materials and appropriate production processes. This development came step by step: At first large plate and shell structures like floor panels and vertical rear fins were selected to comprise composite materials. Herewith significant weight savings can be achieved and the geometries fit well to available fiber fabrics and manufacturing processes. Because of ongoing competitive pressure within the aviation industry now a more complex range of highly loaded aircraft components is focused for the implementation of novel fiber composite designs to achieve further weight reductions. In this category of products for example landing gears, hydraulic actuators and power train components can be classified.

In the field of helicopter power trains carbon fiber composite materials gain more and more attention. Reasons for this trend are not only remarkable weight saving potentials but also better damping behavior and fatigue strength compared to metal designs. To achieve considerable benefits with fiber composite solutions, aspects like structural function, adapted joining technologies, thermal balance and manufacturing concepts must be mutually adjusted. In this paper the design of such composite components is explained by means of a helicopter intermediate bevel gearbox and a maintenance lid.

2. COMPOSITE GEARBOX HOUSINGS

In the field of helicopter design novel fiber composite solutions are demanded for the highly loaded power trains. As these systems amount to a large proportion of the total weight, such lightweight design activities are particularly worthwhile. Furthermore fiber composite materials provide higher fatigue strength and corrosion resistance than most metal alloys, so maintenance intervals can probably be extended. Another target is the noise reduction, which should be achieved by means of the superior damping behavior of composites and sandwich structures. But not all power train components are suitable for the application of composite materials. Where stable functional surfaces and high thermal conductivity are needed, sophisticated metal parts are preferred. In the area of helicopter power trains for example gear box housings are muchly appropriate for composite designs, as they feature shell structures which are suitable for load adapted textile reinforcements. Such shell structures are found in the gear box for the main rotor drive and in secondary gear boxes like they are needed for the tail rotor drive (Fig. 1). In the following the design of an intermediate gearbox housing is examined more precisely.

The intermediate bevel gearbox is part of the power train for the tail rotor and has the function to deflect the drive shaft axis. This gearbox contains two shafts each with a bevel gearwheel and two ball bearings whereas the gear shafts are arranged in flange components which comprise metallic material (Fig. 2). The box between these two flange components is designated for the application of a novel composite lightweight design.

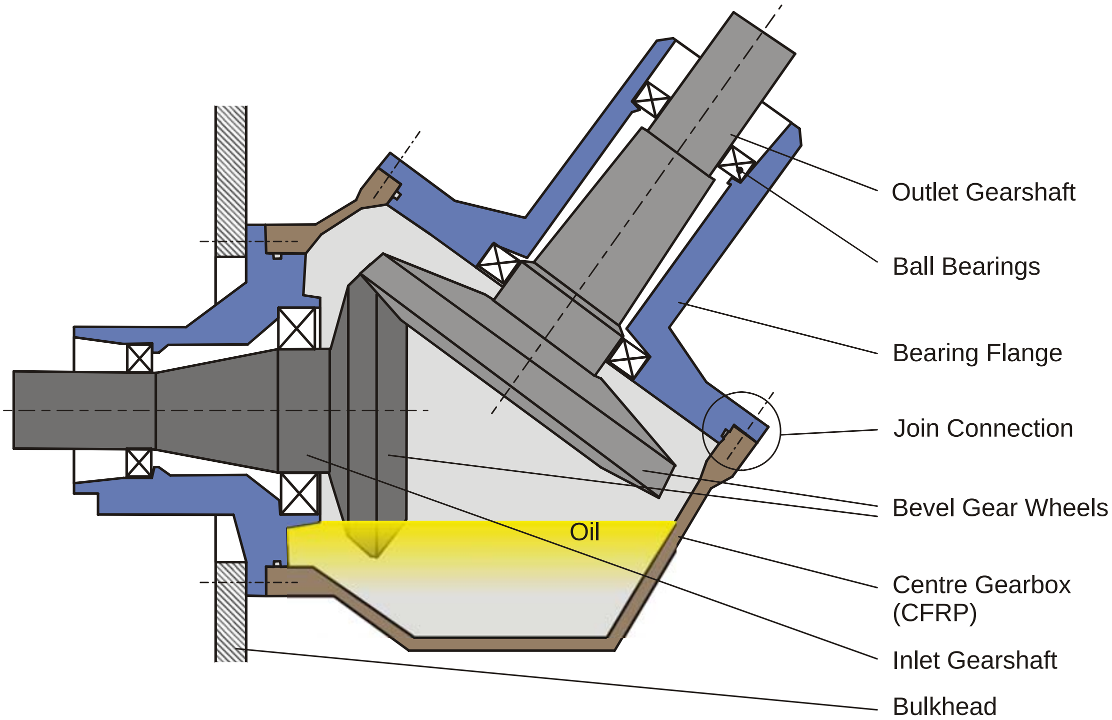

Fig. 2 **Principle design of the intermediate gearbox**

3. DESIGN OF A COMPOSITE GEARBOX HOUSING

Within the design process for the center gearbox housing which comprises carbon fiber reinforced plastics (CFRP) several subtasks had to be solved:

- A high grade of lightweight design should be achieved.
- A stiff connection for the load transmission between the two bearing flanges must be assured.
- A strong join connection between center gearbox and the flanges has to be ascertained.
- Heat flow from the oil to the surrounding air should be enabled.
- The center gearbox must contain a sufficient amount of gear oil.
- A device for the collection of spray oil and for the oil distribution to the bearings has to be integrated.

These requirements lead to some conflicts of objectives. For example a stiff connection from flange to flange is contradictory to a big oil volume. Another problem is that the carbon fiber reinforced polymers have only low thermal conductivity in the direction of wall thickness, whereby the heat transfer from the oil to the air must be assured by another way. These problems were solved by a novel double-shell design with an inner shell for the load transmission and an outer shell which acts as an oil containment. The inner shell has a bigger wall thickness and provides a very short, direct and thus a very stiff connection between the bearing flanges (Fig. 3). As the inner shell features some openings to the outer shell, an oil exchange is enabled. The outer shell comprises CFRP as well, but some areas are cut out and are replaced by aluminum cooling plates with ribs.

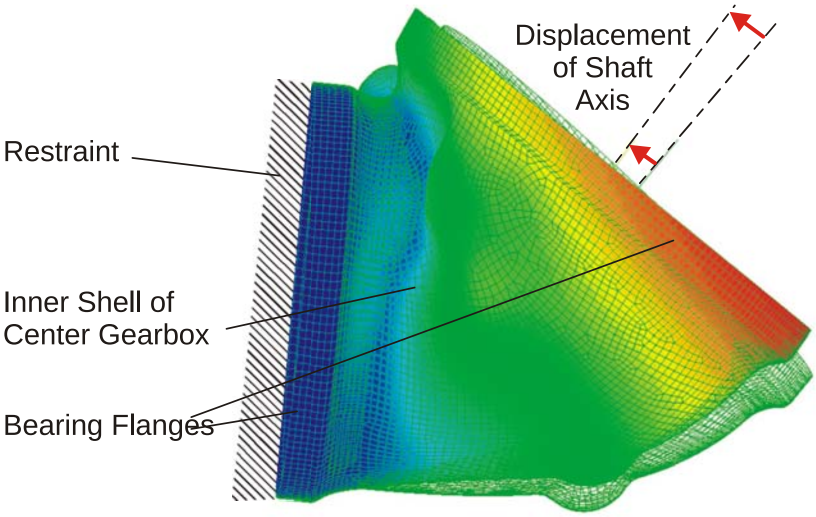

Fig. 3 **FE-Simulation of the component stiffness**

An ambitious task was the design of the flange connection between the CFRP center housing and the metal flanges (Fig. 4). The design space has not been large enough to fit out the center gearbox with classic assembly flanges and through borings (regard dimension d). A solution was found with the use of a special bolt connection principle, which is well proven for the mounting of wind turbine rotor blades. To enable the installation of this bolt connection, the wall thickness of the housing is considerably increased in the joining zone.

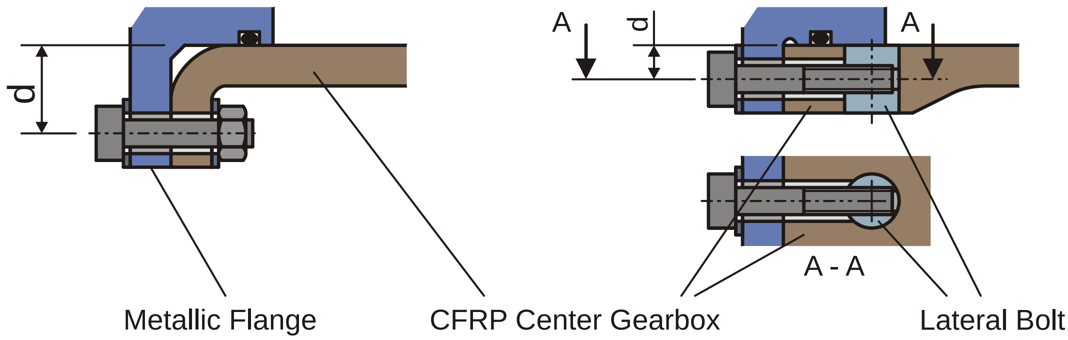

Fig. 4 **Conceptual design of the join connection between metallic flanges and CFRP center gearbox: Classic flange connection (left) and bolt connection with lateral bolts (right)**

4. PROTOTYPING AND TESTING

The design results had to be verified by means of prototype manufacturing and execution of tests on a helicopter power train test rig. Form tools were designed and built for the inner and outer shell structures as well as for an oil collection device. The manufacturing of the carbon fiber composite components was carried out via autoclave process by use of woven fabric prepregs. Afterwards the functional surfaces were milled, the shell structures were bonded and the metallic elements were assembled (Fig. 5). During the test runs the novel bevel gearbox housing showed a very good performance. The structural and functional demands like stiffness, oil circulation and thermal balance have been verified.

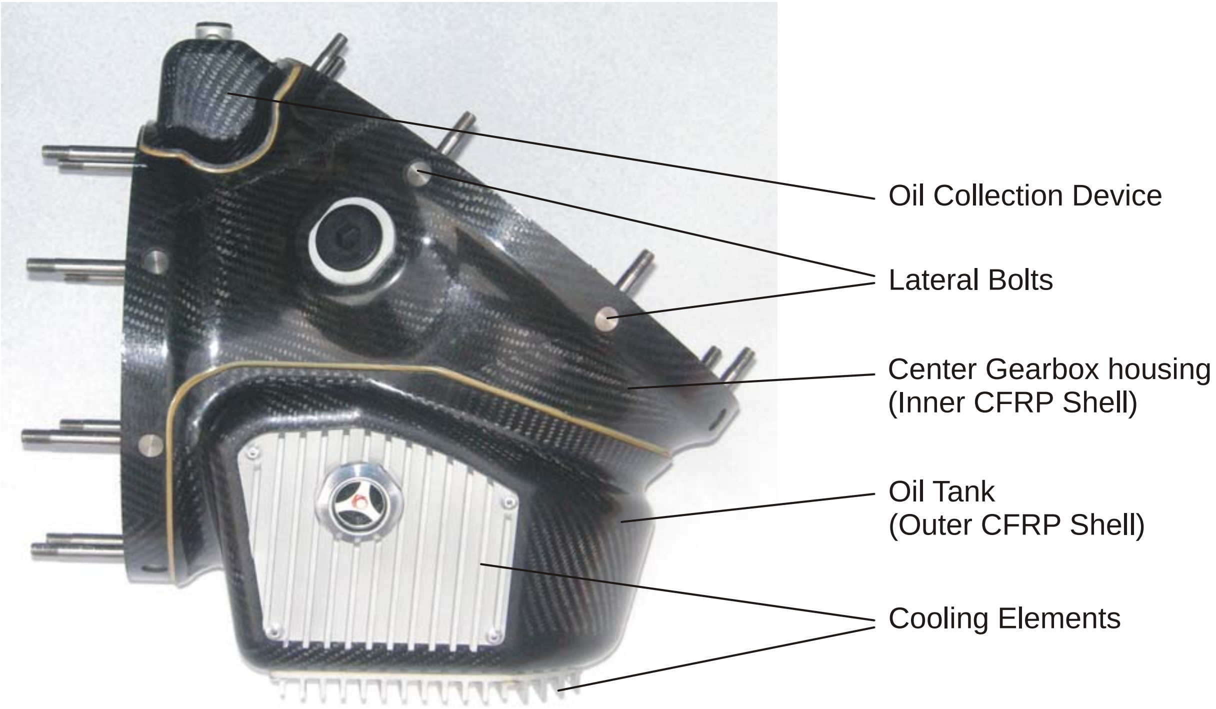

Fig. 5 **Center gearbox housing prototype**

5. COMPOSITE LID FOR A MAINTENANCE OPENING

In the scope of helicopter drive trains carbon fiber composite constructions do not only allow significant weight reductions but also an efficient noise insulation since fiber composites provide a higher damping value compared to most metallic construction materials. In the bottom area of the main gearbox noise insulation efforts are especially worthwhile as the distance to the passengers hearing is rather short. The easiest way to improve the vibro acoustic behavior of a metallic gearbox housing is to replace the metallic maintenance lids for novel composite lids. To identify the most suitable composite design for the lids, some fundamental investigations and simulations were accomplished first [1]. In the following this research results were considered for the design of lid prototypes. The best noise insulation was achieved by use of a sandwich built-up with a structural foam core. However one of the regarded lids features some mounting points for a rod with structural function and for a measurement system. Thus in the mounting zones the foam was replaced by a stiffer and stronger filling material to achieve a sufficient support for the designated screw and bolt connections. The prototype lids were manufactured via resin transfer molding (RTM) technique inside a closed mold. Subsequently the sealing gaps, the mounting holes and the outer contours were milled to the final shape (Fig. 6).

Fig. 6 **Lightweight and acoustically optimized maintenance lid structure featuring a sandwich built-up**

As the bolt connection for the structural rod has to endure higher dynamic loads, the strength of this mounting zone had to be proved on a test rig. However with the specified load level and the number of load cycles a failure could not be achieved.

ACKNOWLEDGMENT

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