Bild 1: . Das Hauptrotorgetriebe ist ein zentrales Element des Antriebsstrangs

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Take off with KISSsoft

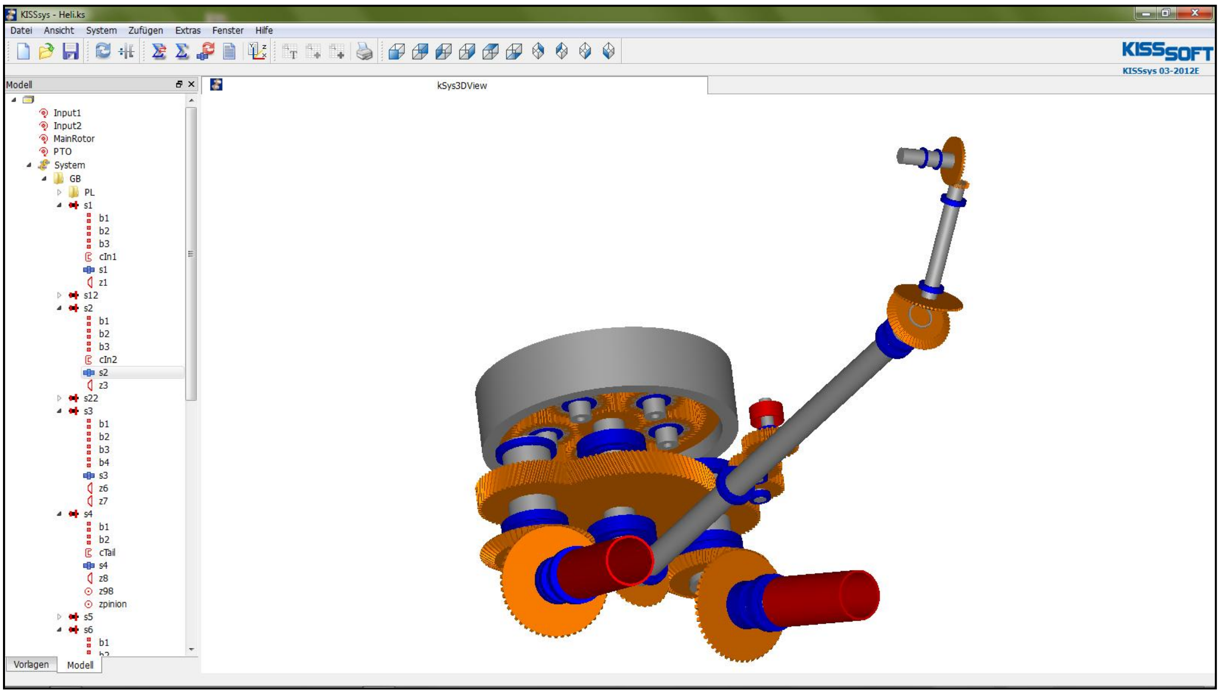
During the development a of a new lightweight helicopter, the first gearbox concepts have been developed very early in the development process using gear design software. Based on the concepts developed there, the most suitable candidate was selected and optimised in detail. The relevant targets were a low mass, a simple structure and high strength. KISSsoft and KISSsys was used during this development process.

The new lightweight helicopter developed by Marenco Swisshelicopter AG uses a turbine to drive the main and rear rotor. The main and rear gearbox are the central elements of the drivetrain and they both need to accommodate an angle of 90deg between input and output side. The first concepts were studied very early in the design process even then using KISSsoft. For the subsequent optimisation, KISSsys, the system module for KISSsoft, was used.

Gearbox structure

The helicopter main transmission transmits the power from the turbine to the main rotor. Three stages are used. The first stage is a spiral bevel gear stage with 90deg shaft angle. This bevel stage is followed by two planetary stages. The bevel pinion speed is directly controlled by the turbine speed.

The speed of the main rotor is quite low in comparison to the turbine speed, a relatively large ratio inside the gearbox of apporximately 1:16 is required. Furthermore, several PTO (power take off) units are attached to the gearbox to drive e.g. the climate control unit or hydraulic pumps. For the lubrication of the gearbox, an internal lubrication system was design using an oil pump. All bearings and gear meshes are pressure lubricated and reservoirs to keep the gearbox running in an emergency are foreseen.



Example of a twin turbine helicopter model in KISSsys.

The mechanism used to control the rotor had had to be considered in the design of the gearbox. Depending on the level of integration of the control, this has more or less influence on the design of the gearbox. In the current project the control system is higly integrated into the gearbox, the control is inside the rotor shaft and hence inside the gearbox. Accordingly, sufficient amount of space was required inside the central parts of the gearbox.

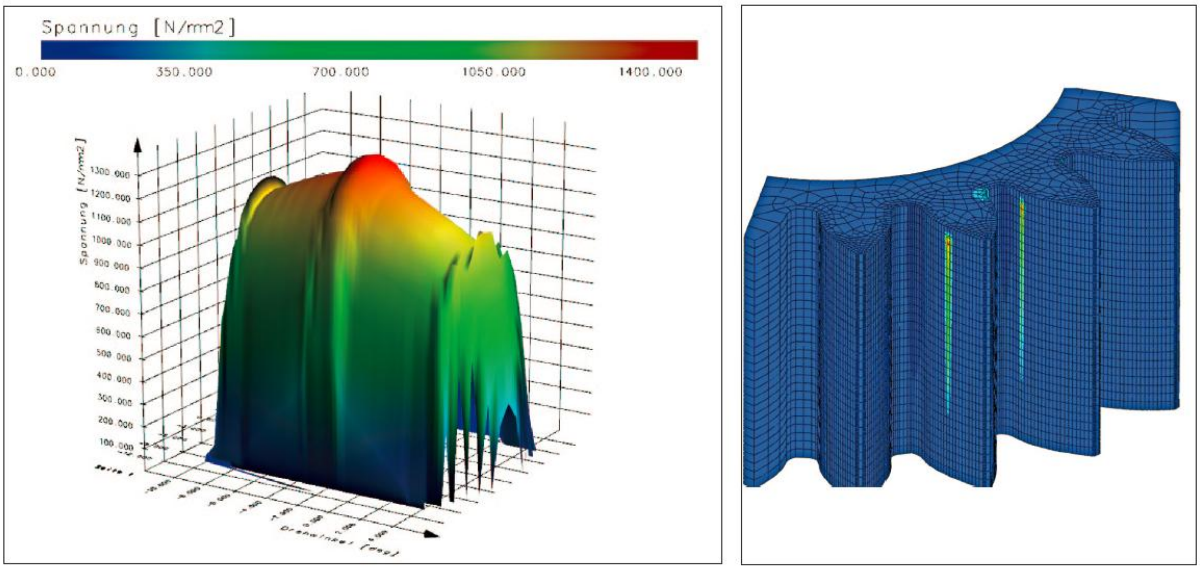
In order to be able to look at the gearbox as a system, a KISSsys model was set up. The advantage being that all calculations are done in one single file and unified environment. Also, any changes are immediately updated on the whole system and revisions are more simple to follow.

Gear design process

The three gear stages were designed using KISSsoft fine sizing function giving optimised gear macro geometry. The functions in KISSsoft allowed for a very fast and targeted gear design and countless variants were studied in order to find the design with the highest power density. In particular, flank safety factors were studies as a function of different modules and number of teeth while observing tight constraints on the centre distance and design space.

An even load distribution among the planetary power trains was one of the major challenges in this design. Only if the load is evenly distributed among the planets will the gearbox achieve its required power density. For this, different variants were compared using KISSsys. It was soon found out that a flexible element between the first and second planetary stage was a suitable solution, see below.

In flight, the loads on the rotor are transmitted to the cell of the aircraft through the gearbox housing. Using FEM calculations and KISSsys simultaneously, a design of the housing meeting structural requirements, mass requirements and requirements for the gear and bearing design was found in a timely manner.

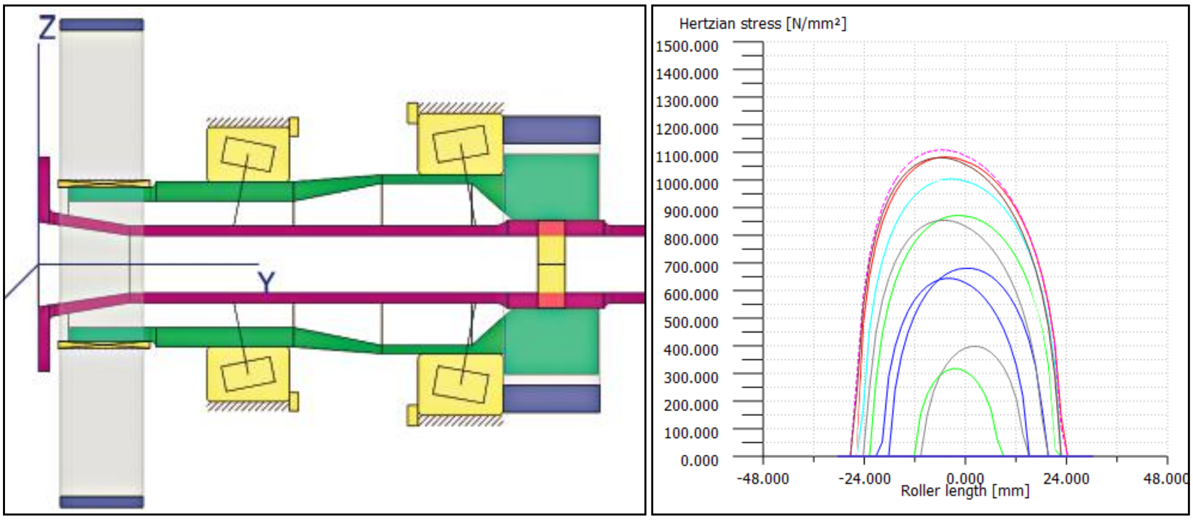


Left: LTCA in KISSsoft, showing contact stress distribution in gear mesh.

Rigth: Unfavourable contact before optimisation

Bearing design

The bearings were selected based on the results generated using the KISSsoft coaxial shaft modeller. Different bearing types were compared in terms of resulting shaft deformation, size, mass and lifetime. Advanced calculation methods along ISO/TS16281 were used to consider the inner geometry of the bearing on the deformation. Also, the bearing operating clearance for different temperature conditions was calculated, a most critical design aspect. The bearings, their position and the shaft stiffness was optimised such that the bearing load distribution / the stresses along the rollers were fairly uniform. This further allowed to reduce the bearing size.



Left: Coaxial shaft system allowing for shaft stress and detailed bearing rating.

Rigth: Stresses along bearing rollers in steady flight mode

Also, the effect of the thermal expansion of the shaft and the housing on the bearing life was considered, allowing for a detailed design of the bearing arrangement and defining the requirements for pretension in assembly.

Then, the shaft geoemtry was optimised such that low stress levels resulted. For this, the integrated strength calculation algorithm in KISSsoft was used, reducing the number of time consuming FEM calculations required.

Gearbox optimisation

In order to compensate the housing deformations, topological gear modifications were applied. The effect of these modifications can easily be analysed in the loaded tooth contact analysis module in KISSsoft (LTCA). Results were compared to a contact analysis using FEM and the results were found to be similar but of course the FEM calculations were much more time consuming.

Obviously, in the course of such a project, the requirements and design constraint keep changing. Using KISSsys, these changing influences could be assessed very quickly. Very helpful in this regard is the possibility to import CAD data into KISSsys for a detailed collision check.

Summary

Using a standardised gear design tool like KISSsoft and KISSsoft during the whole gearbox development process proved to be the right approach. To be able to quickly visualize and to calculate the effect of changing parameters virtually instantaneous increased the efficiency of the design process. Also, different variants of the gearbox could be compared, leading to an improved strength to weight ratio. In particular in the design of aircrafts, the comparison of many variants in terms of mass is a must, KISSsoft and KISSsys support this requirement. The first gearbox was developed and built within one year and will be tested on a bespoke test rig in 2013.