Hydrodynamic bearing analysis of a planetary gear in a geared turbofan

Dipl.-Ing. S. Popel, Dr.-Ing. V. Rombach, Univ.-Prof. Dr.-Ing. G. Jacobs

Institut für Maschinenelemente und Maschinengestaltung,
RWTH Aachen, Schinkelstr. 10, 52062 Aachen

popel@ime.rwth-aachen.de
Keywords: hydrodynamic, bearing, dimensioning

In the context of an aeronautical research program an efficiency-improved geared turbofan with reduced fuel consumption, pollutant emission as well as noise should be developed [1]. In geared turbofan concepts a speed reducer allows the turbine and fan shaft operating in an optimal range of speed. In this case the transmission is realized by a planetary gear with multiple planetary wheels, which are mounted by hydrodynamic journal bearings. As untypical high mechanical and thermal loads occur during the operation combined with a thin-walled construction, elastic deformation of the planet shaft and the surrounding structure need to be considered. Therefore conventional dimensioning tools, e.g. ALP3T, meet their limits. In this project AVL EXCITE PU v2010 is used to design the journal bearings.

Basic analyses of the journal bearing are carried out on only one planet and extracted from the planetary gear as well as the surrounding structure. A simplified simulation model is build, containing only the planetary wheel, the shaft and the journal bearing [2], see Figure 1.

Figure 1: Reducing the system to the multi-body-system

The planet and the shaft are modeled and meshed with ABAQUS. With increasing complexity, the level of detail is advanced. In the beginning the journal bearing is defined as a center-center-contact with rigid bodies and central force application ending with a surface-surface contact definition with flexible bodies. This approach permits a direct comparison of the computation results with conventional tools and illustrates the effect of elastic deformation on the EHD-contact.
Contemplating one single planet, the kinematics and external loads have to be computed and applied on it. In an additional calculation, the toothing forces are calculated for one tooth contact. In order to simplify the complex tooth meshing, the reaction forces are concentrated in one central point of each tooth, coupled via distributed couplings to the centre-nodes, see Figure 2. After defining the load for one node, the definition is shifted cyclically on the other teeth. As the EHD-Joint needs a parallel and equidistant FE-mesh, a membrane is created and tied on the inner diameter. With static dynamic reduction the planet is reduced to these nodes, so the number of degree of freedom is minimized. The shaft is mounted in its centre and is also reduced by the static dynamic reduction. In its final version the journal bearing is build by an EHD2-joint with a surface-surface contact (S-S) on the basis of the Greenwood/Tripp Asperity Contact Model and the Averaged Reynolds Equation. Parameters are assumed for the calculations until surface measurements of the prototype will provide the input for the simulation of the micro-contact with AVL MicroSlide. Temperature in the lubrication gap is calculated with the energy balance. The shear rate and temperature depended characteristics of the used oil is implemented by table defined oil properties, determined by an ultra shear viscometer.

![Figure 2: Assuring high model quality](image)

The results of the rigid model with a central load application match the results simulated with ALP3T. As the type of the planet is changed to elastic, the hydrodynamic pressure deforms the slide face of the planet, which results in an enlarged pressure area and a decrease of pressure maxima. When the toothing forces are applied on the teeth the radial components lead to an elastic ovalisation of the planet. This effect is counterproductive, because the diverging lubrication gap disturbs the pressure build-up. To reduce the deformation of the planet wheel and optimize the pressure build-up, an iteration loop with smaller bearing diameter is necessary. Maintaining the outer diameter constant increases the stiffness of the planet and decreases the stiffness of the shaft. This results in favourable pressure distribution with a greater gap height. As shown in Figure 2, an iterative process allows identifying critical points in the design and the successive optimization of the bearing.
Finally it can be mentioned that the planet wheels in this geared turbofan concept can be mounted on journal bearings in principle. The comparison of the simulation results of the simplified simulation model for:

- maximum oil film temperature,
- minimum gap height and
- maximum oil film pressure

with the permitted values for the bearing material and the minimum permissible lubricant film thickness shows the reliability of the bearing.

For future work the model should be extended by the remaining planets of the planetary gear. Toothing in this step will be illustrated with gear joints, whose stiffness are calculated. The journal bearings – except of one – should be characterized by NonL Joints, whose dynamic behavior is known from the previous step. In this step the elastic behavior of the environmental structure and its reaction to the load-carrying capacity of the bearing will be modelled.

2. This research was supported by C. Schweiger, AVL List GmbH, Graz