Hydrodynamic Bearing Analysis of a Planetary Gear in a Geared Turbofan

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Outline

- Introduction
  - Motivation / Geared turbofan concept
  - Specifications / Problems
- Approach
  - Reliability / Dimensioning tools
  - Modeling technique
- Results
- Summary and Conclusion
Introduction
Motivation / Geared turbofan concept

Aeronautical research program

Project goals:
- Reduced fuel consumption
- Reduced pollutant emission
- Reduced noise

Strategy:
- Developing an efficiency-improved geared turbofan

Geared turbofan

Characteristics*:
- The fan is driven through a reduction gearbox
- No direct connection to the rest of the engine
- It allows the turbine and fan shaft operating in an optimal range of speed

Task for the Institute of Machine Elements and Machine Design:
- The hydrodynamic journal bearings, on which the planetary wheels are mounted, have to be designed

* C. Riegler, C. Bichlmaier, THE GEARED TURBOFAN TECHNOLOGY

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Introduction
Specifications / Problems

Some specifications:
- Mounting of the gear wheels on hydrodynamic bearings
- Planetary Gear with a fixed carrier
- Rotational speed up to ~10,000 rpm

Project goals:
- Verification of operation
- Displacement of planetary gearwheel for high tooth accuracy
- Optimum of bearing dimensioning regarding reliability and efficiency

Problems:
- **High Load** at **high circumferential speed** and **high temperature**
- Elastic deformation of the surrounding structure
- Little know-how for dimensioning at these conditions available
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Reliability of bearing design:
- Durability of the bearing material ↔ Pressure Distribution
- Temperature safety ↔ Temperature Distribution
- Protection against wear ↔ Minimum oil film thickness

Dimensioning tools:
- DIN 31652, VDI 2204
- ALP3T
- AVL EXCITE PU v2010

No elastic deformation considered!
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Stepwise approach:
- Basic analyses of the journal bearing extracted from the surrounding structure
  - Verification of functioning under optimal conditions
  - Short calculating time
  - Rigid bodies ↔ flexible bodies
  - Central force application ↔ force application at teeth
- Enlargement of the system with ambient structure

Source: Pratt & Whitney
Elements:

- B-Pin, ROTX, AXBE
- Planetary wheel
- Wheel shaft
- ElastoHydroDynamic bearing

- Constant rotation is given by B-Pin with rotational (ROTX) joint to planetary wheel
- Additional axial (AXBE) joint adjust numerical inaccuracies
Elements:

- B-Pin, ROTX, AXBE
- Planetary wheel
- Wheel shaft
- ElastoHydroDynamic bearing

- Gearwheel with linear hexahedra (C3D8I) and 9x36 Nodes Membrane (M3D4) in the inner contour
- Gear forces are applied to reference points in the middle of the tooth with distributed couplings across tooth width
Elements:

- B-Pin, ROTX, AXBE
- Planetary wheel
- Wheel shaft
- ElastoHydroDynamic bearing

- Shaft is modeled – due to the complex geometry – with linear tetrahedra (C3D4) and a bush with linear hexahedra (C3D8I), tied on the inner structure
- Shaft is restraint at one central node
- Combined static dynamic reduction decreases the number of degree of freedom (DOF) from 2,000,000 to 700
- 10 Eigenmodes show appropriate accuracy
Elements:

- B-Pin, ROTX, AXBE
- Planetary wheel
- Wheel shaft
- ElastoHydroDynamic bearing

Planetary wheel and shaft are coupled via EHD2 joint
- Definition of surface profile and viscosity of the used oil

Approach
Modeling technique
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Results
Rigid bodies ↔ flexible bodies

Force application in center of planetary wheel:
- Rigid bodies vs. flexible bodies

- Results of rigid bodies match the results of ALP3T
- Enlargement of pressure area and decrease of pressure maxima with flexible bodies

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Flexible bodies:

- Central force application vs. force application on tooth-center

- Meshing forces out of FE-Stirnradkette (STIRAK)
- Application on Tooth-center
- No axial forces due to double helical gearwheel

- Tooothing forces lead to an elastic ovalisation of the planetary wheel
- Pressure build-up is disturbed by a diverging gap
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Approach
Central force application ↔ force application on teeth

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Source: WZL
Approach
Iterative optimization process

 reduc inner diameter increases stiffness of planet and results in greater gap height
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Summary and Conclusion

- Results of pressure distribution, temperature distribution and minimal oil film thickness are essential for bearing design.
- Elastic deformation of planetary gearwheel and carrier shaft has a great effect of the hydrodynamic pressure distribution and has to be considered.
- **Flexible EHD2 contact is necessary for adequate simulation of the planetary wheel bearing.**

- Results show that bearing diameter has to be reduced to gain higher stiffness of the planetary wheel.
- Fine tuning via contourisation of the bush surface.
- **Several loops to achieve optimum geometry necessary.**

- Next step is the enlargement of the system with ambient structure and the remaining planets.
Thank you for your attention!

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Citation