Developing a shaft-hub assembly according to requirements with hubs made of co-continuous ceramic-metal composites

Duration of project: 3 yearsStart of project:15.02.2018End of project:14.02.2021

Aims

In many technical applications which place high demands on the materials in service, only high performance composites are suitable because of their low density, high hardness, excellent resistance to temperature and chemical & abrasive media. The future demands machine elements made of ceramic-metal composites with safe designs. The application of those composites in machinery requires suitable connectivity to adjacent components often in the form of shaft-hub connections for which an interference fit is the most suitable to avoid stress peaks and cause sudden failure. The aim of this project is to investigate the fail-related processes in terms of internal stresses and microstructure of joining partners in the interference fit shaft-hub connections to develop a safe and economical design recommendation. Furthermore, form-locking components will be considered, too. With the help of simulation models backed by corresponding experimental results, expensive and time-consuming tests can be avoided in the future.

Procedure

Some preliminary works have already been done by the IKTD and IMWF with their previous understanding of the hybrid interference fit assembly through various research projects and successful industrial implementation.



Fig 1: Micrograph (l.) of a ZrO2/NiCr-composite with 30 vol.-% ZrO2 (dark phase) and binary image (r.) with its skeleton lines of matricity model

For investigating the complex material behavior of co-continuous ceramic-metal composites, simulations on both micro- and macro-scale are necessary, taking into account the damage mechanisms of ceramic and metallic phase as well as interface damage. The matricity model is intended to use for obtaining effective material properties. Fig. 1 shows an example of a co-continuous ceramic-metal composite.

Initially, it is found that there is a stress peak in the hub edges of the shaft-hub assembly. So, if a correction is made to the hub edges, the stress can be homogenized throughout the shaft-hub interface, and thus, fracture can be avoided in the case the hub material is too brittle for joining it onto a steel shaft conventionally. The correction is calculated through finite element methods and is usually in the range of few microns. Note the absence of stress peaks at the hub edges after the homogenization in fig 2.



Fig 2: The stresses before and after homogenization of the shaft-hub interference fit. Results from Martin Blacha, IKTD (PhD-thesis, University of Stuttgart, 2009)

Work packages

The work program is divided into the following work packages:

- 1. Simulative development of the assembly
 - Dimensioning and structural simulation
 - Modelling the real micro-structure of the hub
- 2. Investigating the assembly during and after joining
 - Joining experiments and thermo-mechanical simulation
 - Modelling micro-mechanical damage and coupling micro-/macro-scale
- 3. Investigating the assembly during service
 - Quasi-static investigations and endurance trials
 - Materials testing and numerical simulation of hubs in service
- 4. Transferring knowledge to form-locking components
- 5. Preparing a design recommendation

The planned project involving the two institutes IKTD & IMWF only tests under torsional load, since it has the most practical relevance. Therefore, a complete interpretation cannot be given in advance. However, a design recommendation can be prepared.

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Partners

In this project, we work together with

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