DESIGN AND CONSTRUCTION OF A ROTOR TEST BENCH FOR TESTING SENSORS

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1. Introduction

The actual temperatures for the bearing and the rotating parts of a motor are important for a proper monitoring. For a temperature measuring sensor system in a motor only a very limited space is available. The high requirements are provided by a telemetric system. For the temperature measurement sensors at characteristic positions of the rotor system have to be mounted and a transmitter and receiver module has to be added. A suitable rotation test bench has been developed to perform long time tests in a temperature range from -40°C to 220°C. High rotation speeds up to 18000 rpm have to be maintained so that very good balancing is required and the testing time of the sensor has to be between 8 and 250 hours.

For the temperature measurements on rotating objects a telemetric system is used which is combined with a wireless equipment. The passive sensor can be applied to high temperatures up to 400 °C, high rotation speeds and difficult accessibility. For the application of such a system e.g. in the automotive industry a detailed test schedule has to be performed and the present rotation test bench is developed.

2. Development procedure

The design of the test bench consists of a frame, a rotating shaft on two bearings, a driving motor and a housing for the high temperature chamber. The high temperature chamber is made of a material with good isolation property and the mechanical requirements are fulfilled by a composite of ceramic, steel and plastics. The surface of the temperature chamber is as small as possible to keep the necessary heating power small. Within this high temperature heating chamber a special designed rotor is placed on the shaft. On the rotor the electronic equipment of the sensor with the transmitter module has to be mounted. The frame is constructed of standardized parts so that it is cheap and modular, see [1] and [2].

As the performance of tests on the real motors is not possible, the properties of the rotating shaft of the test bench have to be similar to represent the actual motor. Specially the position and radius of the sensor has to be kept close to the original application. A high temperature load at the rotor position and the heat conduction of the steel shaft results in high temperatures at the bearings, which have been placed outside of the insulated heating chamber. Among different possible shaft designs like using ceramic parts a hollow shaft has been applied. Based on a Finite-element-calculation for various shaft geometries, materials and thermal boundary conditions the dimension of the shaft has been derived iteratively. On the left end a temperature of 250 °C is defined for the different shaft configurations. The result of the temperature distribution in the shaft and the hollow shaft with different surface heat conduction conditions is shown in Fig. 1. The shaft configuration with the lowest possible temperatures at the position of the bearings has been chosen.

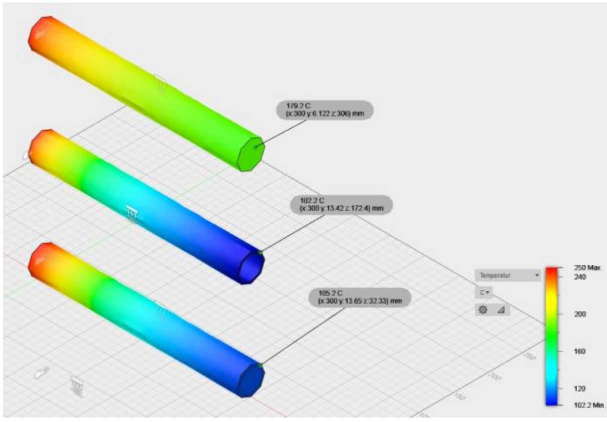

Fig. 1. Temperature distribution of three different configurations of the shaft.

3. Rotor test bench and measurements

The resulting rotor test bench is shown in Fig. 2 with the isolated heating chamber. At the position of the bearings an accelerometer can be seen, which is used for the balancing process. The rotor has been placed within the heating chamber and has been design in order to provide a proper mounting position for the sensor and the electronic equipment.

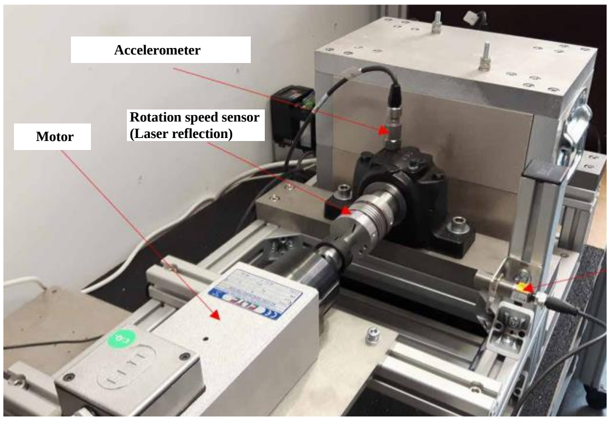

Fig. 2. Rotation test bench with the shaft, heating chamber, motor, bearings and sensors.

The dimensions of the elements and parts of the test bench have been calculated for the improved shaft with respect to the allowable stresses and temperatures, for the motor with respect to the moment of inertia, the power and the resonance case and for the bearings with respect to static and dynamic load, see [3], [4] and [5].

In the preparation step first the sensor equipment has been tested and then it was attached onto the rotor. The position of the equipment at the rotor as well as the bearings had to be mounted very carefully in order to prevent vibrations due to high eccentricity. The signals of the accelerometer and the laser sensor have been read by a NI-card to an industrial PC and the further processing was done using Matlab and toolboxes.

For the used high rotation speed a careful balancing is necessary, see [6]. The center of gravity is usually not at the axis of rotation as the tested sensor has been mounted. A static and dynamic balancing procedure has to be performed at different rotation speeds by balancing at operating conditions presented in [7]. In Fig. 3 reference measured signals are shown for the vertical acceleration of both bearings and the signal of the optic rotation sensor. Measurements have been performed with and without added mass. Based on the evaluation of the computed power cross spectra involving the phase shift of the different configurations the position of an additional mass for an improved balance state has been determined. The procedure of balancing has been carried out at different rotation speeds and it is similar to that described in [7].

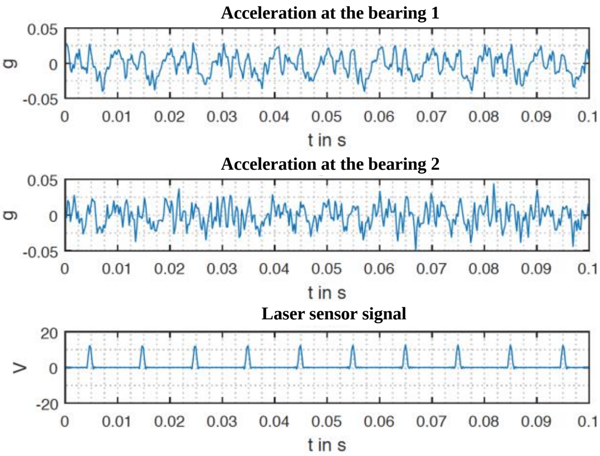

Fig. 3. Measured signals for the vertical acceleration at the bearings and the laser rotation sensor.

4. Conclusions

A rotor test bench has been designed and constructed for the testing of a sensor equipment at rotation speeds of 18000 rpm and at temperatures of -70 °C to 280 °C for up to 2,5 hours. With the improved balanced rotor also the vibrations and the emitted acoustic noise have been reduced. The measurement system detects the vibrations of the bearings so that also wear and faults can be monitored. The sensor tests have been performed successfully.

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