ROLLING ELEMENT BEARING TEST RIG DEVELOPMENT

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Abstract
The article describes a concept of bearing test rig intended for a simulation of induced dynamic loading to roller bearings. Tested bearing can be preloaded by static radial force and then harmonic axial or radial dynamic force can be applied. Tested bearing is inserted into a housing that allows its free motion in radial direction of static loading and a limited motion in the other directions. Thanks to housing fixture design a roller bearings with free axial play can be used, in order to isolate the effect of axial vibration on outer race. The article is provided with figures illustrating the concept.

Key words: *Bearing; Test rig; Design.*

INTRODUCTION

In order to fully understand the behaviour of, on first sight simple systems, such as rolling element bearings, it is necessary to conduct an extensive testing and data evaluation for defined load cases in controlled environment (Dynybyl, 2009). There are multiple levels, where behaviour of bearings can be studied. The lowest level testing focuses on general phenomena occurring in bearings and is mostly conducted in laboratories. Usually specialised test devices are used, e.g. spiral orbital tester test for the study of tribological problematics of rolling contact or pulsatory tensile test rig for study of structural properties of bearing materials. The other step is component level testing, where bearing is tested as assembled component. Most frequent tests on this level are fatigue life tests under static loading (Harris, 2006), where the time to bearing failure is of main interest under tested conditions. Among other investigated parameters, we can find a bearing drag torque or bearing critical speed. Highest level of testing is operational testing, where bearing is inserted into a real or simulation model of a real application and various parameters are observed. Such tests are usually very valuable, because can show a real response of bearing to simulated operational conditions in context of the simulation model. The drawback is a high cost of such tests.

MATERIALS AND METHODS

Described roller element bearing test rig will be used for a study of roller bearings under dynamic loading conditions. Tested bearing will be preloaded with radial static force. A dynamic force component will be applied either into same radial direction or into an axial direction to simulate challenging operational conditions. For a simulation, linear vibrators will induce a harmonic dynamic force.

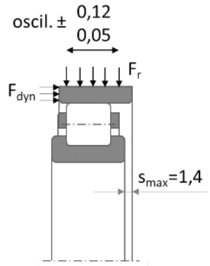

Fig 1. Studied roller bearing with free axial play of outer ring
and its predicted axial oscillation during dynamic loading.

Loading parameters are specified in next chapter. During testing, following values of bearing will be observed: Temperature of outer and inner ring, by surface acoustic waves generating and sensing device (SAW) a response to roller transition over observed region will be measured. (Brücker et. al.,A status of lubrication layer below the contact of most loaded elements will be estimated from measured signal and an orbiting speed of elements will be calculated too. Expected outputs from the tests are the record of temperature gradient between rings, the lubrication status identification for various operating conditions under pure static radial loading and with added dynamic components, either in radial or axial direction. In addition, the slide-to-roll ratio parameter of elements will be calculated with respect to loading character and a speed.

Requirements

Based on a brief test description a set of design and performance requirements for a test rig were defined. These were during design process multiple times revaluated to meet the low budget criterion and re-use in-house available resources and components.

<u>Tested bearing requirements</u>
Roller bearing with line contact (roller profile modification allowed)
Static radial load shall induce at least 2 GPa high contact pressure on inner ring. (Computed by KISSsoft)
Bearing shall have non-located outer ring – free axial play

<u>Selected bearing type: N306 (see Fig. 1)</u>
Bore diameter: 30 mm;
Outer diameter 71 mm;
Width: 19 mm
No of rollers: 12;
Axial play: max. 1,4 mm

<u>Static loading device requirements</u>
Loading device should provide loading force with magnitude 10 kN
Sensor of actual static radial force – range 10 kN
Connection of loading device with tested bearing shall eliminate undefined, off-axis loading
Loading force continuous control preferred

<u>Dynamic loading device requirements</u>
Loading device shall provide harmonic loading character
The frequency shall be at least 100 Hz
Dynamic force amplitude at least 90 N

<u>Drive requirements:</u>
AC motor, controlled by variable frequency drive (VFD),
Nominal speed 1500 rpm
Motor power 4 kW

RESULTS AND DISCUSSION

Defined requirements were in next step used as references for test stand concept development.

Mechanical Design Description

One of the main requirements for most of testing devices is a simple and fast change of the tested sample. On presented rig, see Fig 2 and Fig 3 with links, it was decided to place the tested bearing (1) on the end of the main shaft (2). The advantage is not only a good accessibility, but also the availability of free space for a direct axial loading of bearing, that would have been difficult to apply for different configurations.

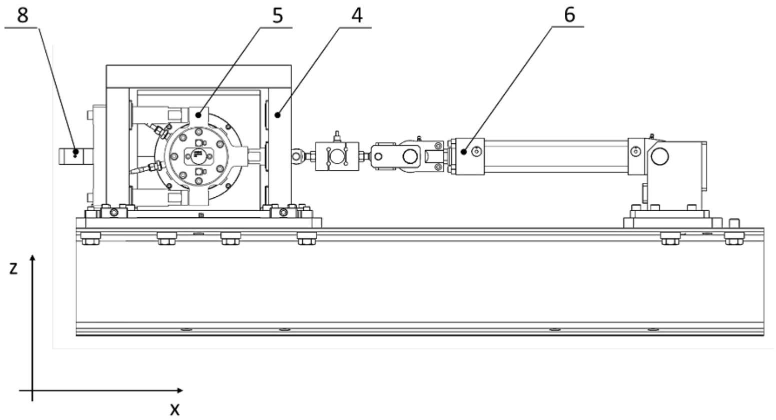

Fig. 2 Test rig front view with highlighted tested bearing housing

The dynamic loading would cause an excitation of all components of the test rig, therefore, two bearings that support center shaft are a heavy-duty tapered roller bearings in a stiff back-to-back configuration (3). The preload will be applied during the assemblage. Housings where both support bearings are located consist of rigid massive steel blocks, so high dynamic stability of structure is assured.

For the study of applied dynamic loading, a roller bearing with non-locating outer ring was selected (1). The location of outer ring must be assured by design of rig. According to a Fig 3, in the front section of the test rig, there is apparent a closed frame structure (4) equipped by bushings. These serve as guiding surfaces for three rods that provide a location of tested bearing housing (5). The guides allow housing free positioning in the direction (x) of applied force by hydraulic actuator (6). The motions in the other directions (y, z) are restricted and can be partly controlled by the selection of fits of the bushings and guiding rods. Estimated motion amplitude is based on fitting and manufacturing tolerance between 0,05 - 0,1 mm.

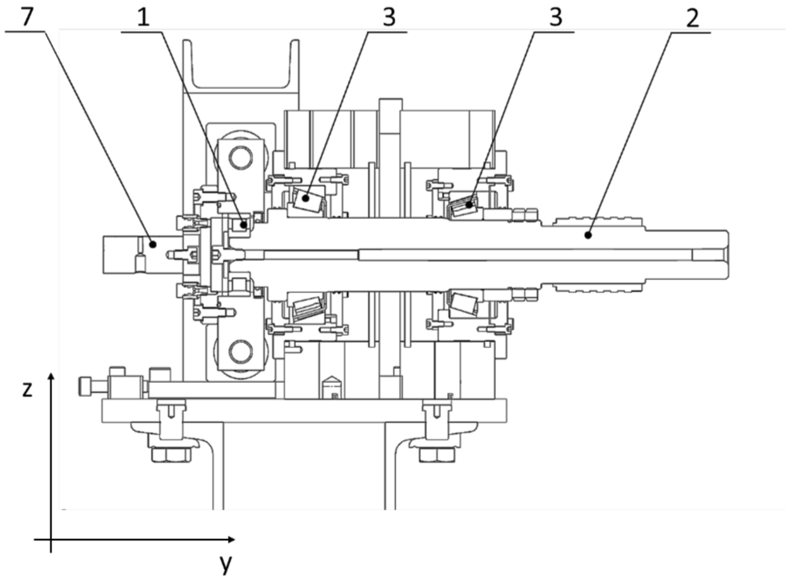

Fig. 3 Test rig concept section

The housing for tested bearing is at the front face closed by cover with prepared attachment points for dynamic loading exciter (7), also there are located input and output fittings for oil lubrication. The other side of housing has built in a rod sealing preventing the leakage of lubricant from chamber with bearing.

A radial surface of the housing is drilled with threaded thru holes that could be used for a direct attachment of sensors to outer ring of bearing. Dynamic exciter for a radial direction (8) has an attachment point on the lever that connects guiding rods.

Loading Apparatus

Static loading
Static loading mechanism consist of a hydraulic actuator, force gauge and two spherical joints. The system is designed to provide loading force with a magnitude up to 10 kN. The applied force is sensed in a force gauge and during test cycle is maintained at a preset value. Spherical joints are used to avoid any unrequested off axis loading that would induce an additional loading both tested bearing and force gauge.

Dynamic loading
To meet a requirement for a relative high frequency loading the option of pneumatic linear vibrator K15 was selected. Parameters of vibrator are summarized in a Tab. 1. Tests will be designed to use only one vibrator at a time. Attachment points are prepared according to Fig. 2 on the lever that connects guiding rods and Fig. 3 on the front cover of tested bearing housing. The attachment is by a screw.

Tab. 1 Parameters of pneumatic linear vibrator

Operating pressure [bar]	Frequency [Hz]	Peak force [N]
2	75	28
4	93	59
6	110	83

CONCLUSION

A bearing experimental test rig was introduced in this paper. It is intended for testing of roller bearings under an oscillatory dynamic loading. Tested bearing is attached to the end of the center shaft. An innovative tested bearing housing was introduced, allowing its free motion (limited only by inserted bearing radial clearance) in an axis of loading and constrained in the other directions. Test rig is equipped by a static radial loading mechanism, which can induce a force up to 10 kN that is equivalent to 2 GPa of contact pressure on inner ring of tested bearing. Pneumatic linear vibrator with excitation frequency up to 100 Hz will be used for dynamic loading of bearings. It can be attached either to the bearing housing front cover in order to induce axial vibrations or to the lever that connects guiding rods to induce radial vibrations. Test rig will be equipped by sensor based on excitation and sensing of surface acoustic waves allowing detection of lubrication state during operation (Brückner et.al, 2015). Currently test rig design concept is in patent approval process (Patent application No. 2017-270, 2017)

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