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CONTROL SYSTEM FOR SLOW RUNNING BEARINGS

Summary. The subject of this paper is the design of a control system for slow running bearings including a strength analysis and load capacity measurement. The intention here is to apply the results to the manufacturing operation of chain conveyors in paint shops.

Keywords: slow running bearing; diagnostics of bearing; vibrodiagnostics; paint shop.

1. INTRODUCTION

The design of a control system for slow running bearings is highly desirable across a wide range of industrial sectors. Especially for transport, technologies are necessary to identify damaged bearings before production failure and large economic losses occur.

Chain conveyors are used in the bodywork painting process, with chain wheels mounted on the shaft, which is in turn mounted on two roller bearings. Shaft speed is relatively slow in terms of rpm. There is no doubt that the reliability of this construction has a major influence on the volume of production, especially since the paint shop is the bottleneck of the whole production process of cars.

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The diagnostics of high-speed bearings are based on vibration measurement, which has been reliably used for many years. For the diagnostics of slow running bearings, there is no appropriate physical method able to identify the bearing damage.

2. USED METHODS

The design of a control system for slow running roller bearings is based on the analysis of the current state. The basis is to determine a load under all manufacturing conditions and the force of the chain in the most exposed position. With knowledge of the manufacturing operation force of the chain, it is possible to calculate the load of shaft and roller bearings. The results may be used for FEM analysis, calculation stresses and deformations in each part of the current state as the basis of a design solution.

The design solution for a system of diagnostics for slow running roller bearings can be based on the principle of rolling resistance or vibration measurement. However, effective vibration detection depends on a sufficient level of measured acceleration, which cannot be achieved in slow rotational movements. This means, for the current state, dismounting the chain and then measuring the rolling resistance, or increasing the rpm by external power and measuring the vibration.

Pursuant to the demand for reliable chain conveyors and mounting for shafts and chain wheels, we designed a system consisting of two pairs of roller bearings: shaft and frame. These are connected to each other by the so-called reference part, which is a freely rotatable part. This solution allows us to identify the bearing damage with the two methods. The first method is dependent on changes in rolling resistance during the forced rotation of reference part. The other method uses vibration measurement by increasing the rpm with properly connected external power. This innovative solution is protected by patent.

A kinematic link between the shaft and reference part allows for the distribution of the dynamic load between the shaft and frame bearings, which is convenient for manufacturing operational matters. Based on this kinematic link, the shaft and reference part are in forced rotation. Due to the kinematic link of the shaft, reference part and frame, the design solution leads to the integration of a planetary mechanism with spur or bevel cogwheels. This solution is protected by patent as well.

After the strength analysis of the designed solution, the prototype was made with the intention to experimentally measure deformation using the nominal and maximum load value. The fatigue test has already been prepared.

2. DESCRIPTION OF CURRENT STATE

The current state of the shaft mounting of the conveyor chain wheel is made up of two spherical roller bearings mounted to the frame by bearing units. The chain wheel is connected to the free end of the shaft and separated by the frame’s front plate, which is connected to the frame of the paint shop production line.

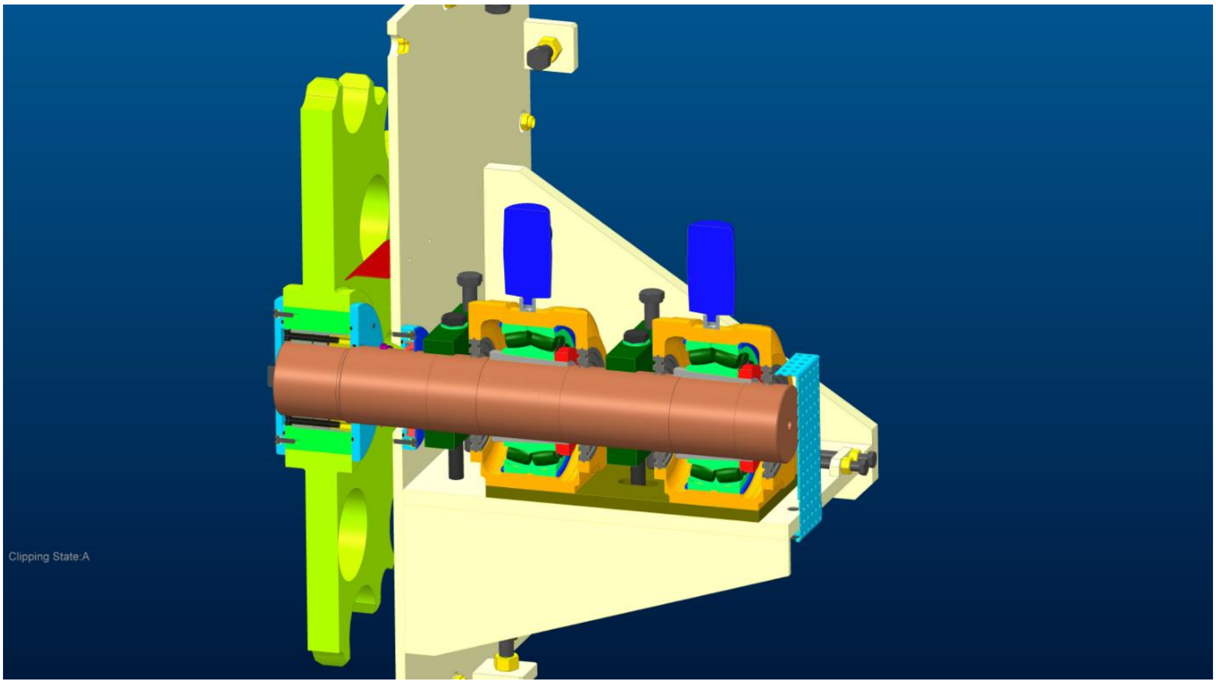

Fig. 1. Current state of the shaft mounting of the chain wheel

The advantage of the current shaft mounting of the conveyor chain wheel is its relative simplicity. Significant disadvantage is complicated by the dismounting and changing of the bearings. As a result, the bearings are subjected to vibrodiagnostics using the latest technologies. Low-frequency vibration sensors are used for the identification of damaged bearings. The difficulty relates to the insufficient intensity in the vibrations of slow running bearings, whose value merges with the vibrational background of the paint shop production line. The reliability of the identification of damaged bearings is insufficient.

3. DESIGN SOLUTION FOR THE DIAGNOSTIC SYSTEM

The reliable design of a control system for slow running bearings can be based on the identification of changes in the rolling resistance of the bearings or their vibrations in the case of sufficient rpm. Both these methods are difficult to be realized during the manufacturing operation. A change in rolling resistance can only be identified with increased power load, which is usually too late. The sufficient rpm value of the bearing can only occur if the standard, low-speed operation is off.

The design solution for a control system for slow running bearings, which is the topic of this paper, comes from the idea that, if one ring of the roller bearing is forced into a low speed, the second ring of the roller bearing is freely rotatable. This diagnostic solution allows for the identification in the change in the rolling resistance of the shaft bearing or a sufficient rpm increase in its freely rotatable ring, which enables the damage to the bearings to be determined using known vibrodiagnostics methods. The freely rotatable ring of the shaft bearing is rotatably mounted to the frame using the frame bearing. The reference part is mounted between the shaft and the frame bearing (Figure 2).

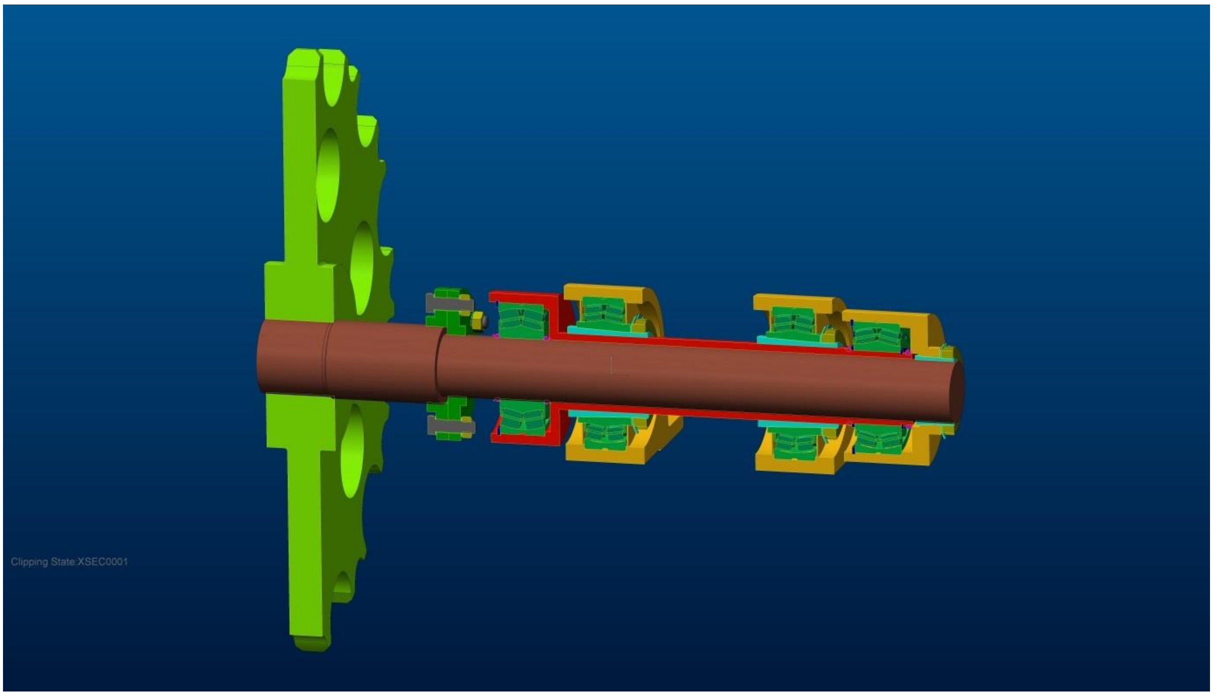

Fig. 2. Drafted solution of the chain wheel shaft mounting

Changing the bearings is quite a difficult operation and, because of that, the shaft is divided between the chain wheel and the bearing. This design allows us to repair or change the bearing outside of the paint shop production line.

This solution provides a number of design variants, one of which is chosen as optimal and analysed.

4. STRENGTH ANALYSIS

Strength analysis is an important element of every design solution.

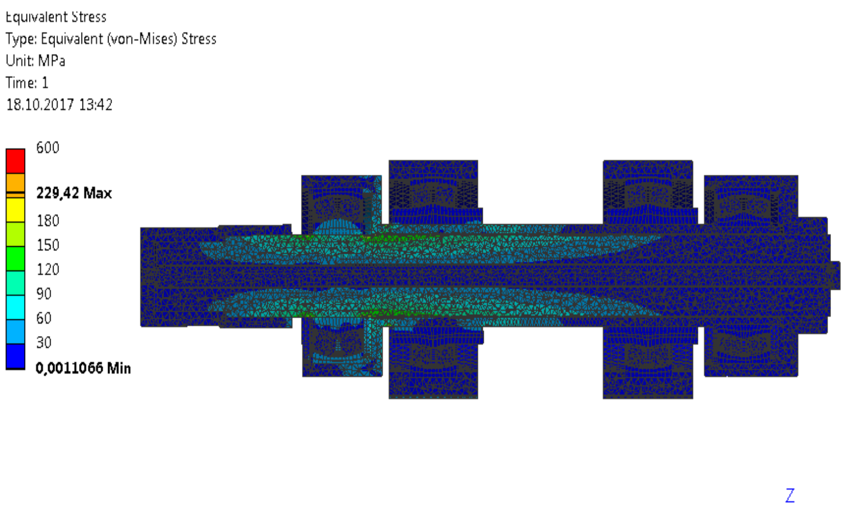

Fig. 3. Equivalent stress (von Mises test) of the designed solution

With this shaft mounting solution, strength analysis is mainly focused on stress and deformation calculations. In all cases, Ansys software for FEM analysis was used.

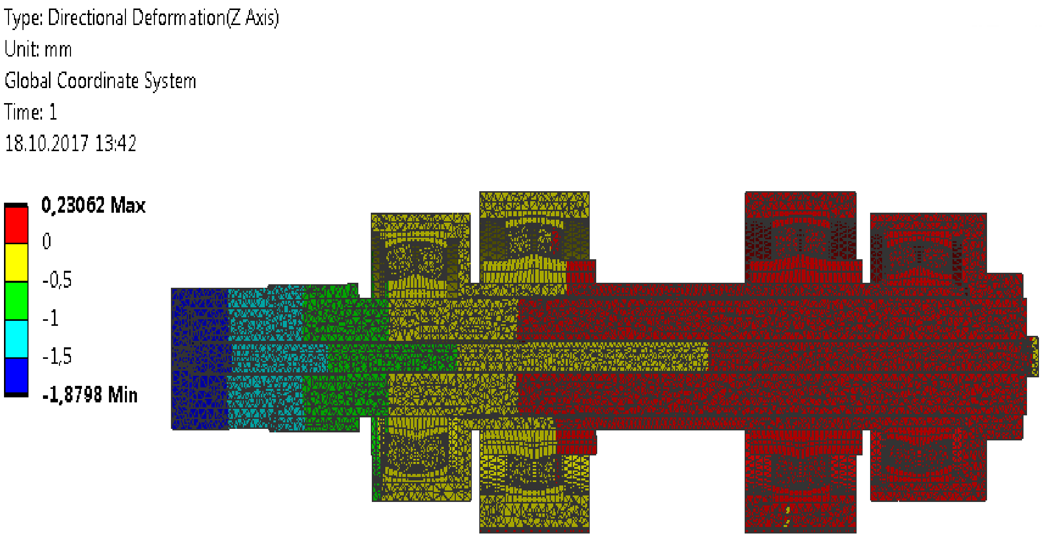

Fig. 4. Deformation in the z-axis direction of the designed solution

5. DAMAGE IDENTIFICATION SYSTEM

The identification of the damaged shaft or frame bearing can be made based on the change in rolling resistance. For this purpose, the kinematic and moment link in the shaft, reference part and frame, consisting of a planetary gear with simple planets and bevel cogwheels, was designed. The shaft cogwheel with the main axis of rotation is tightly connected to the shaft. The frame cogwheel with the main axis of rotation is connected to the frame by an adjustable frictional moment. The link between these cogwheels is made by satellites mounted on the pins of the reference part.

The motion of the reference part is determined by a kinematic and moment link of the planetary gear. If the rolling resistance of the shaft bearing increases beyond the load capacity limit, the frictional moment between the frame cogwheel and frame is exceeded. The frame cogwheel then starts to rotate in the same shaft direction.

If the rolling resistance of the frame bearing increases beyond the load capacity limit, the frictional moment between the frame cogwheel and the frame is exceeded. The frame cogwheel then starts to rotate in the countershaft direction.

Both rotations of the frame cogwheel against the frame can be easily identified by a connected sensor (Figure 5).

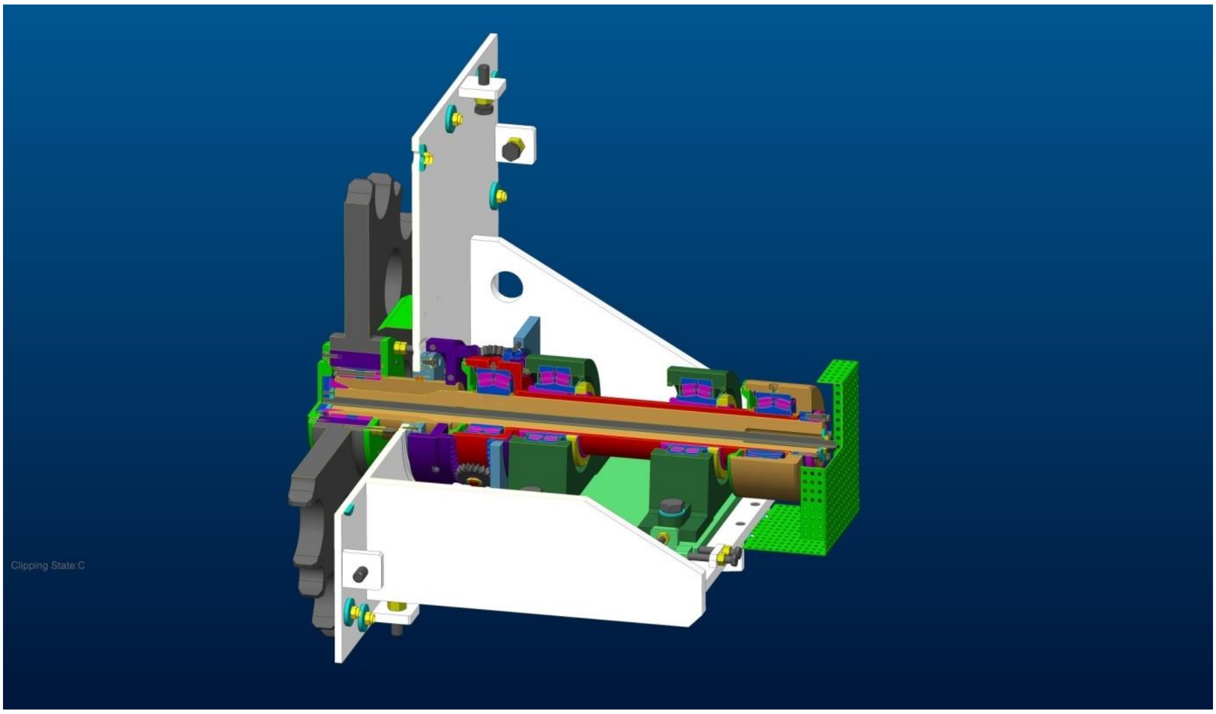

Fig. 5. Designed solution of shaft mounting of chain wheel

5. CONCLUSION

The paper is focused on the actual issue of the diagnostics of slow running roller bearings. The designed solution uses a reference part between the shaft and the frame bearing. A change in rolling resistance, which leads to bearing damage, can be identified using the reference part. This can be realized during the manufacturing operation. The designed diagnostic system consists of a planetary gear with bevel cogwheels. Considering this is an original solution, two patent applications have been filed, one of which has been granted.

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