14th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2010, Mediterranean Cruise, 11-18 September 2010

ROLLING ELEMENT BEARING VIBRATION – GENERATION AND SIGNIFICANCE

Radoslav Tomović
University of Montenegro, Faculty of Mechanical Engineering
Džordža Vašingtona bb, Podgorica
Montenegro

ABSTRACT
Rolling bearings are one of the most important noise and vibration generator into mechanical constructions. Therefore, it is very important to have knowledge of the rolling element bearings influence on the level of noise and vibration in this systems. This paper deals with a basic forms for generation of vibration and noise of rolling element bearing and suggestions of vibration analysis significance of rolling element bearing for increase mechanical construction quality.
Keywords: Rolling Element Bearing, Vibrations, Noise

1. INTRODUCTION

Requirements for noise and vibration reduction at contemporary mechanical industry products are more and more uttered. Accomplishment of these requirements is triggered from one side by more and more claimed and refined market, and from the other side by string of positive lows and regulations, which lately are presetting increasing standards with respect of permitted level of noise and vibrations generated by these products. One of main noise and vibrations generator at mechanical constructions are built in rolling bearings. In the matter of rolling bearings terms noise and vibrations often describe similar and connected phenomenon. Noise heard by machines works is result of vibrations generated by rolling bearings. Noise respectively vibrations, as physics phenomenon, are determining with relation to two dimensions: amplitude and frequency. Amplitude is characteristic of vibration's signal intensity, while frequency is vibration iterating speed in time unit.
This paper deals with an analysis of basic causes of noise and vibration generation of rolling element bearing and points out significance of vibration and noise on correct working conditions of mechanical systems.

2. MECHANISMS FOR GENERATION OF VIBRATIONS IN ROLLING ELEMENT BEARINGS

Reasons for generation of disturbance forces that cause vibratory movement and affect the dynamic behaviour of rigid rotor in rolling bearings, in general can be classified into four categories:

- specific construction and operating profile of rolling element bearing (structural vibrations),
- micro and macro geometry errors of bearing elements (vibrations with technological origin),
- damage of bearing elements (vibrations due to damage of bearings elements),
- negative environmental impact (vibration due to the environmental effects).

The first sort of distraction forces generation is a direct consequence of discrete structures of rolling element bearings, which causes that the mutual position of elements and distribution of bearing load is cyclically changed during operation. Generation of oscillations is a direct consequence of specific functional principle and design of bearings and cannot be avoided, even in ideally manufactured rolling element bearings. These vibrations are also known as structural vibrations.

In other three cases, disturbance forces occur due to various geometric imperfections of working surfaces, originated in manufacturing and assembly phase i.e. before the exploitation phase or in exploitation phase by wearing of working surfaces or negative influence of environment. As the vibration generation is a consequence of imperfection in manufacturing and exploitation, they often can be reduced and even missed.

Bearing construction has influence on the vibration generation in all noted cases. However, only in the first case the specific bearing construction directly causes vibrations, while in other cases the vibrations are caused by technological errors and damage of bearing elements as well as the disturbance forces generated in bearing vicinity.

2.1. Structural vibrations

In principle rotor oscillations, caused by specific construction of roller element bearings, arise in two ways:

- because of influence of internal radial clearance and discrete structure of rolling element bearings,
- because of periodical changes in stiffness of rolling element bearings due to contact deformations.

First cause of vibration in rolling element bearings is consequence of discrete structure and kinematics of rolling element bearings. Namely, load distribution from inner to outer bearing race occurs across definite number of discrete, cage separated rolling elements, whose angular position, in relation to direction of outside load, is constantly changing during bearing operation. This simple change in rolling elements position causes the constant change of internal and outer race mutual position, which occurs periodically with the cage rotation. Accordingly, axis of internal race, in relation to outside, is constantly oscillating during the bearing operation. Internal radial clearance, which is planned in bearings to avoid negative influence of errors in micro and macro geometry, temperature dilatation and deformations occurred during installation and caused by external load, is the basic reason of these oscillations.

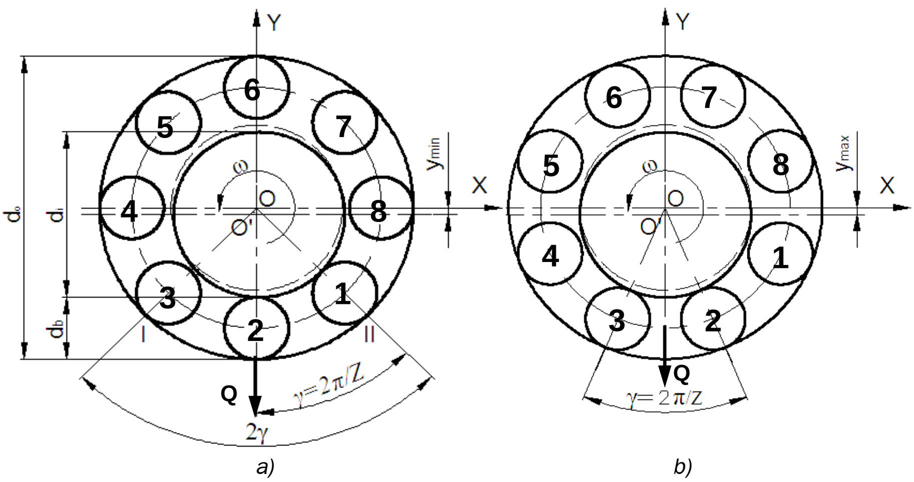

Figure 1. Relative movement of bearing races due to different sets of position of rolling elements

Figure 1. shows rolling element bearing with eight rolling elements in two different positions. In the Figure 1.a) load is transferred trough rolling elements 1, 2 and 3, while the rolling element number 2 is exactly on the direction of external radial load. In the Figure1.b) rolling elements 1, 2, 3 and 4 participate in the transfer of external load and are symmetrically distributed in relation to the direction of external radial load.

From the image it is obvious that the radial distance between the bearing races is different. Position in the Figure 1. a) has the minimum radial distance between the bearing races. By rotation of rolling elements set, together with the separator, the radial distance between the races is increased until the set of rolling bodies doesn't come to symmetrical position in relation to the direction of external load, which is shown in the Figure 1.b). In this case, the radial distance between the bearing races is largest. By further rotation of the elements set, they will be returned to their original position, when the rolling element designated as number 3 is in the direction of external radial load. Therefore, these changes of relative distance between the races of bearings occur periodically with the rotation of rolling elements set and separator and the frequency of vibration will be equal to the frequency of rotating separator multiplied with total number of rolling elements in the bearing. This frequency is known as a specific frequency of outer bearing race (f_o). This frequency represents the speed with which rolling elements come over a fixed point on the outer race of bearing [1]. Specific frequency of outer bearing race is a very important feature for diagnosis of the rolling element bearing working state. During the analysis of vibration, a specific vibration frequency of rolling bearing is used during the vibration spectre analysis for the detection of damage locations and various irregularities on bearing elements.

2.2. Vibrations with technological origin

Due to the irregularities in the grinding and honing process, the contacting surfaces of the balls and the guiding rings always deviate from their perfect shape. A typical imperfection caused by these production processes is waviness (Figure 2.). Waviness consists of global sinusoidally shaped imperfections on the outer surface of the components. Nowadays, the amplitudes of waviness in small deep groove ball bearings is of the order of nanometers. In spite of that, waviness still produces significant vibrations in the entire audible range. Besides waviness, other imperfections that are addressed in the present work are ball diameter variations and cage run-out.

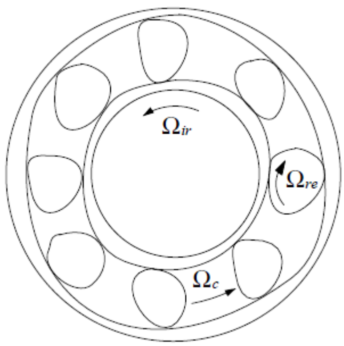

Figure 2. Waviness excitation in a ball bearing

3. INFLUENCE OF ROLLING ELEMENT BEARING VIBRATION ON CORRECT WORKING CONDITION OF MECHANICAL SYSTEMS

The need for investigation of the impact of rolling element bearing to noise and vibration generation in machinery generally can be classified into four categories:

The first category includes all those applications of rolling element bearings, where the bearings due to their specific design and specific operating profile produce very uncomfortable vibration and noise. This is especially noticeable in consumer goods, such as the various household's devices or office equipment, where sound or vibration produced by these devices can be tremendously irritating. Noise is also a major problem in the heating and air conditioning systems, where the vibrations of motor or fan bearings can be transferred and boosted trough air lines and ventilation canals. Application of bearings in transportation machines, also request the quiet operation. This category encompasses devices such as are drive systems of elevators, which with too much vibration and noise can cause panic by passengers. Vibrations and sounds are often interpretative when the system speeds up or slows down, i.e. when the system passes through the resonant region. Knowing the frequency of vibrations produced by bearings, can contribute to alleviate these problems, or avoid them completely.

The second categories encompass the machines, which to function properly, must have very high operating characteristics and positional accuracy. Such are for example, a variety of machining devices, rolling mills for sheet metal, paper and chemical films, etc. Computer disks are one of the examples, where the constant operating bearing precision is required, which are within the range of

0.25 to 0.5 μm [1]. Grinders shaft often have to meet very high requirements in terms of geometric accuracy and surface roughness of elements, with derogations much less than 1 μm. Vibrations can significantly contribute to the deviations in terms of geometric accuracy and surface roughness, and may lead to impacts that could cause permanent metallurgical damage to elements of hardened steel.
The third category includes those cases where the working accuracy is not so important as working availability, reliability and security of machines. Machines that are in this category often produce and transmit great power, have large rotary components and operate at large speed. These are compressors, pumps, turbines and the like. Disturbance forces arising as a consequence of dynamic instability of these systems may represent a significant burden for the construction, while those loads can be easy overlooked in the design phase. Therefore, the dynamic characteristics of rotating system in those machines are analyzed in all phases of design, while different techniques and vibration analysis of rotor dynamics are used. Knowledge of dynamic behaviour and disturbance forces generated by rolling bearings, allows more efficient modelling of rotating system dynamic response.
The fourth category encompasses applications where, based on measuring and analysis of rolling element bearings dynamic behaviour, significant conclusions about the operating accuracy can be made as well as the system as a whole, as well as its parts. Causes of disturbance in dynamic behaviour may occur in assembly phase and during operation, caused by damage of structural elements or changes in process parameters, such as changes in pressure, fluid turbulence and the like. Analysis of dynamic behaviour can give significant information about the quality of installation, maintenance and reparations of machine elements, as well as the quality of the process. These data can be the first indicators for undertaking the maintenance activities or as a signal for repair or exchange of machines parts in the coming period. Disclosure of the rolling element bearings gradual deterioration by analysis of its dynamic behaviour is used for quite a bit and has become much cheaper and more reliable recently. Rolling element bearings transmit load between rotating elements and housing and inevitably contribute to transfer of disturbance forces which cause different dynamic behaviour of the overall machine system. For these reasons, the mechanical vibrations should be measured in the vicinity of the bearings, because in those places the overall state of machine is best reflected. In general, it is considered that almost all the irregularities are first shown on the machine bearings. As such, rolling bearing dynamic behaviour is one of the most important and most relevant indicators of the general mechanical system operation state. Knowledge of rolling element bearings dynamic behaviour is a necessary precondition for a valid analysis of the overall state system operating accuracy.

4. CONCLUSION

Rolling bearings are one of the main noise and vibrations generator at mechanical constructions. Reasons for generation noise and vibrations in rolling bearings in general can be classified into four categories: specific construction and operating profile of rolling element bearing (structural vibrations), vibrations with technological origin, damage of bearing elements, negative environmental impact. The need for investigation of the impact of rolling element bearing to noise and vibration generation in machinery generally can be classified into four categories: reduction noise and vibration, increase precision of rotation, investigation of rotating system dynamic behaviour, condition monitoring and diagnosis of mechanical systems.

5. REFERENCES

[1] Harris T.A., Kotzalas M.N.: Rolling Bearing Analysis, Taylor & Francis Group, SAD, 2007.
[2] R. Tomović, "Mathematical model of dynamic behavior of rigid rotor inside the rolling element bearing", TMT 2009, Hammamet, Tunisia, 16-21 October 2009.
[3] R. Tomović, "Značaj redovnog nadzora stanja radne ispravnosti kotrljajnih ležajeva za bezbjednost i radnu sigurnost proizvodnih sredstava, ljudi i okoline", "Konferencija održavanja" KOD 2006, Tivat, jun 2006. godine,
[4] R. Bulatović, R. Tomović, " Savremeni trendovi uležištenja mašina i uređaja", Predavanje u okviru DAAD projekta „Entwicklung und Einführung eines Lehrmoduls für Produktentwicklung nach dem Karlsruher Modell", Niš, 2008.