Understanding how fatigue contributes to bearing failure

Fatigue is one of the primary causes of rolling bearing failure. Dr Steve Lacey describes the various types of fatigue and what measures can be taken to correct any problems that occur in practice, the reliability of rolling bearings is very high. Around 90% of rolling bearings produced in the world actually achieve or exceed their machine’s running time. Around 9.5% of rolling bearings are replaced during routine maintenance work, even though they may still be in good condition. Less than 0.5% of rolling bearings actually fail prematurely, with most of these caused by poor handling, incorrect mounting or assembly, or maintenance errors.

There are many different causes of rolling bearing failure. As well as fatigue, other causes of bearing damage include wear, running marks, corrosion/erosion, and overload. In the majority of cases bearing damage cannot be attributed to a single cause and rarely can a bearing failure be characterised by just one feature. It is therefore only possible to ascertain the causes of damage and to give advice on remedial measures once all of the details of the case have been carefully analysed and the operating conditions are, for the most part, known.

Fatigue is often considered as the classic failure mode of rolling bearings. Fatigue can be classified into ‘subsurface’ and ‘surface’ fatigue. Subsurface fatigue is caused by the shear stresses that occur within the material below the surfaces that undergo rolling motion. The direction of the shear stress changes, inducing an alternating load that is present in only a small area of the material. The depth of the maximum shear stress beneath the surfaces depends on the load, the modulus of elasticity and the radii of the rolling components.

The weakest point of a rolling bearing is the highly loaded ‘short segment’ where the entire load is supported by a short section of the raceway. This is where material fatigue typically begins. The first fissure starts where there is sufficiently high stress, ie load, at some weak point in the material. Repeated overrolling leads to structural changes and micro-cracks in the material, which creep to the surface, resulting in particle pitting.

Premature subsurface fatigue can be caused by excessive loads, inadequate lubrication, improper handling or fitting, faulty installation design (incorrect shaft and housing tolerance limits), misalignment, contamination or a reduction in hardness at high temperatures.

Another type of subsurface fatigue is flaking (or spalling). This typically occurs as a result of fatigue at the contact points of the rolling elements and raceways, usually when the bearing has reached the end of its normal life span. Fatigue begins with subsurface fissures which progress to the surface and cause material fragments to break loose. Once started, the problem increases as the loose fragments are scattered around the raceway and the bearing becomes unserviceable, with increasing vibration and noise and possible eventual failure.

If a longer operating life is required, a bearing with a greater dynamic load rating must be selected.

Selection of appropriate mounting fits based upon the operating conditions, adequate sealing, accurate installation, use of proper fitting techniques, proper lubrication and maintenance should help the bearing to achieve its design fatigue life.

Where rolling bearings have been selected and lubricated correctly in accordance with the load conditions involved, subsurface fatigue is less significant as a failure mode, and in practice, is very rare.

Fatigue damage often begins at the material surfaces due to inappropriate lubrication and poor cleanliness between the rolling contact surfaces. This is known as surface fatigue. Depending on how advanced the damage is, there may be a high number of indentations caused by overrolled fracture fragments. Generally, the causes of surface fatigue damage can be classified into three groups: contamination, poor lubrication, and slipping/skidding. Contamination of the bearing or lubricant is often a result of foreign particle ingress. If solid contaminants are overrolled into the raceways, they leave visible surface indentation marks that spread themselves in the cycling direction.

Poor lubrication is another cause of surface fatigue. Roller surface fatigue is often caused by unsuitable oil with too high water content. Poor lubrication generates very different damage patterns depending on the load situation. For example, tiny, very flat pits can appear under a relatively low load and simultaneous slippage. These pits occur in large numbers and appear as ‘flecks’ on the bearing raceway. This is often referred to as ‘grey staining’, ‘micro-pitting’ or ‘braiding’.

During trial runs of rolling bearings and ball bearings without load, there is a risk of damage due to slipping (skidding) between the roller and the raceway. The rolling elements slide on the raceways when the load is low and lubrication is poor. This damage is visible in the form of slippage tracks or ‘smears’ on the surface of the roller and raceway.

Smearing is often caused by inadequate lubrication and can occur at the contact surfaces between rollers and their guide ribs, when rolling elements are subjected to severe acceleration on their entry into the load zone and in situations where the bearing load is too light with respect to the speed. Smearing can also occur on the bore and outside diameter of bearings due to relative motion between the bearing surfaces and the shaft and housing.

Improved lubrication and careful selection of the bearing to suit the operating conditions should prevent the occurrence of smearing. The bearing rings should be fitted with sufficient interference.

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