Classic wear failures revisited

Johannesburg based consulting engineer, Tim J Carter, B.Tech, C.Eng, FIMMM, talks about wear failures and the importance of using the best possible lubricants and lubrication strategies.

In any engineered system, wear is inevitable and is, ultimately, the life-limiting factor. The life of an engineered system is therefore inevitably linked to the wear properties of the system in the environment in which it is operated.

Wear failures are not new and few are novel. They do, however, vary in their importance. Wear life must be, of necessity, related to the system in use. In, for example, an air-to-air missile, a wear life of a few minutes is acceptable, since it then exceeds the flight time and the device will self-destruct. A Formula 1 racing car engine needs only to function for about five hours, after which it will be either re-built or discarded. One motorcycle race engine was known to have had a usable life of only about 750 km.

A replacement hip joint, however, needs to operate without maintenance or external lubrication for several decades. This operating period is known as the wear design life, and failure to achieve it will allow an enemy aircraft to escape, a motor racing driver to say rude things about his pit crew, or a person having to return to hospital to have his or her hip joint replaced prematurely.

Axle drive gears

A load-haul-dump vehicle is a specialised form of front-end loader, designed to operate within the confines of an underground mine.

Frequently operated by remote control because of the hazards of falling rock in deep-level mining operations, these vehicles live, of necessity, a hard life. Failure involves recovery of the vehicle to the surface for repairs and redeployment to the underground work site after repairs, both of which add to the cost of repairs and to prolonging down time, leading to significant production loss.

In this example, the vehicles were prone to failure of the drive axle gears after about 8 000 to 10 000 hours for a new axle and about 2 200 to 2 400 hours for a re-manufactured unit. When a re-manufactured axle suffered gear failure after only 1 800 hours, a warranty claim triggered an investigation into the cause.

Metallurgical examination of both components showed no deficiency to which failure could be attributed. Both were of a suitable material and had been properly case-carburised and hardened. No microstructural anomalies were found, other than a little retained austenite in the hardened surface. Also, the case depths, measured by hardness traverse, were considered satisfactory.

The investigation therefore turned to the operation of the vehicle. It was reported that the manufacturer specified a lubricant to MIL-PRF-2105E, which contains a range of lubricant grades, and the mine had selected a premium quality 80W90 oil, which was the only gear oil available on the mine to prevent mistakes during top-up. This oil has a maximum temperature rating of 35EC, which is low when compared to the ambient temperatures found in deep mining operations where the rock temperature can exceed 45 °C. A change to an 85W140 grade, with a maximum temperature tolerance of over 65 °C has eliminated the problem and no further failures have occurred in more than three years.

Bearings

Plain bearings usually give a long and trouble-free life when properly supplied with an appropriate clean lubricant at the correct pressure and temperature. Lack of any of these, low pressure, high temperature or debris from either external contamination or normal wear will quickly destroy the bearing, usually with catastrophic results (Figure 2).

This set of six big-end bearings from an aircraft engine failed through lubrication failure, resulting in the destruction of the engine and a narrow escape for the pilot.

The passage of an electric current through a rolling element bearing will lead to arc pitting and the formation of micro-cracks within the pit (Figure 3). Such damage will seriously limit the remaining life of any rolling element bearing, in a heavily loaded unit to a few minutes.

Rolling element bearings normally suffer wear in three distinct phases during their life. During initial operation, the raceways and rolling elements are burnished, removing the machining marks left by the manufacturing process. Later, the raceways gradually dull, acquiring a grey appearance caused by abrasion from contaminants in the lubricant.

It is at this point that the bearing should be discarded and a replacement installed. If left in service, rolling contact loadings will initiate rolling contact fatigue leading to spalling of the surface and failure of the bearing.

Rolling contact fatigue will affect any two surfaces where rolling contact under load occurs, and gears are no exception. Pitting due to rolling contact fatigue is common where heavy loading is encountered.

If a rolling element bearing is subjected to heavy loadings whilst stationary, the rolling elements can indent the raceways, causing brinelling.

A similar effect, known as 'false brinelling' occurs when a bearing is allowed to vibrate or oscillate through a small angle of rotation. Whilst the two appear to be similar, the causative factors are different. Whilst brinelling is a purely mechanical mechanism, usually occurring in a single loading event such as an impact, false brinelling is a wear process and occurs over a period of time.

If the bearing is operating at high speed, the primary function of the lubricant is that of coolant, to dissipate the heat generated by the elastic strain produced by the loadings on the bearing. If the supply of lubricant is insufficient to remove this heat, the unit will rapidly overheat and the rolling elements and cage will melt.

Figure 1: Both the crown wheel and pinion for the underground front-end loader were severely worn. It was noted that neither exhibited any signs of misalignment: a) Crown wheel wear; b) Pinion wear.

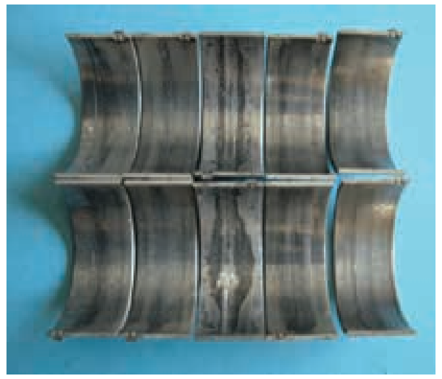

Figure 2: Five of the big end bearings from an aircraft engine after a lubrication failure. The sixth bearing was completely destroyed.

Frequently operated by remote control because of the hazards of falling rock in deep-level mining operations, underground downtime associated with repairs of load haul trucks can lead to significant production losses.

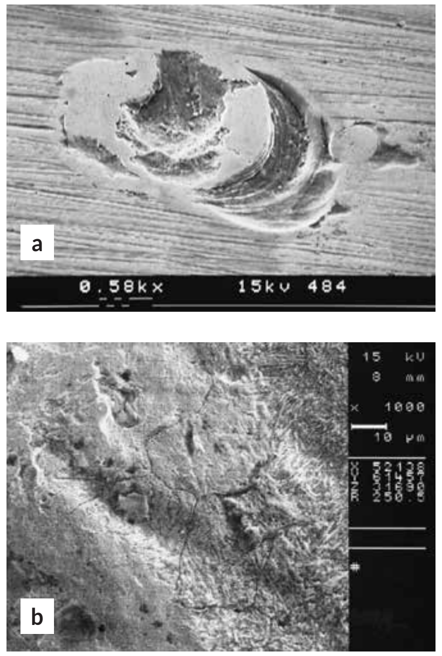

Figure 3: a) Arc pitting on a bearing raceway; b) Micro-cracking within arc pit.

Figure 4: Rolling contact fatigue in a bearing leading to spalling of the raceway.

Figure 5: a) Inner race from a high speed bearing after bearing after lubricant failure; b) Rolling elements from a high-speed lubrication failure showing melted cage debris.

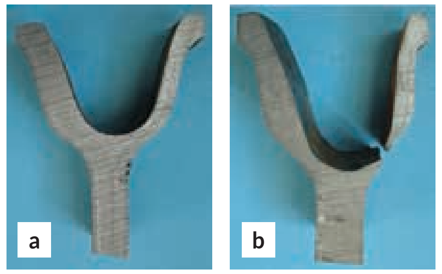

Figure 6: a) Wear of one side of a sheave; b) Failure of a sheave through wear.

Figure 7: a) Fretting on the external surface of a taper shaft; b) A fatigue failure initiating from of a taper shaft.

Rope sheave

The sheaves used to change the direction of a wire rope used for hoisting suffer from wear as a result of the unavoidable metal to metal contact. Whilst this wear can be mitigated by proper lubrication, it is the life-limiting factor for a sheave in either a crane or a mine winder.

Wear occurs in the tread area of a sheave, where the contact pressure is highest, and usually affects one side more than the other due to the angle at which the rope enters the sheave, known as the flight angle. (Figures 6a and b). This wear can be detected either visually or, if the sheave is covered with rope lubricant, by feel, since it leaves an irregularity in the tread surface in the shape of the winding rope.

Fretting

When two surfaces are in relative cyclic motion without lubrication, adhesive wear, known as fretting will occur. This phenomenon results in pitting, from which fatigue can initiate leading to failure of one or both components, (Figure 7).

This phenomenon can be avoided by either preventing the relative movement of the surfaces, or by treating them with a solid lubricant to prevent adhesion and wear.

Conclusion

While wear is inevitable wear failures can be avoided by acting in time and by lubricating the contact surfaces to best suit the application. ❑