Combiner Bearing Failure

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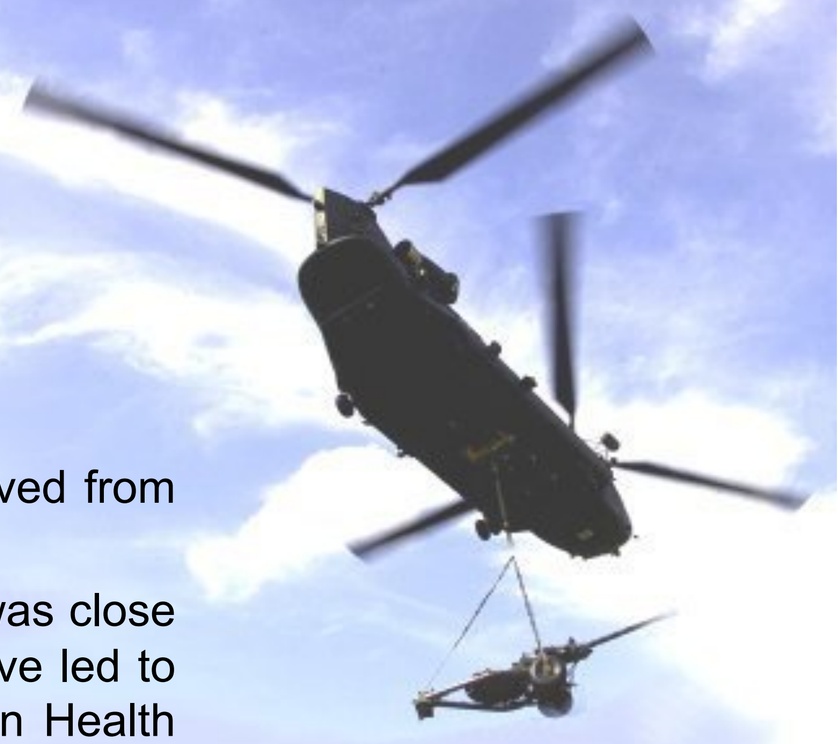

A vibration monitored combiner bearing from a RAF Chinook aircraft was removed from service with suspected wear damage.

Subsequent analysis discovered that the bearing displayed heavy spalling and was close to complete bearing breakup. If it had not been removed the bearing could have led to catastrophic failure of the aircraft. This represents a significant step forward in Health and Usage Monitoring (HUMS) of UK military helicopters.

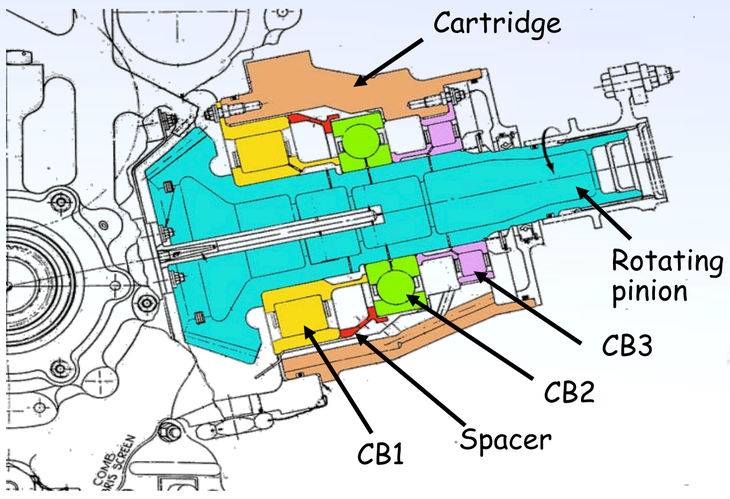

Fig 1: Schematic depicting location of Combiner Bearings 1,2 and 3.

The Chinook HC Mk II drive system has five transmissions (XMSNs): Fwd, aft, combiner and No 1 and No 2 engine. Engine drive shafts connect the two engine outputs to the combiner XMSN via two spiral bevel input pinions. These are mounted on the left and right hand sides of a spiral bevel ring gear which in turn is attached to the output shaft.

The two input pinion stacks incorporate three bearings, CB1, CB2 and CB3, see Fig 1. As part of the HUMS system the combiner XMSN is fitted with four accelerometers, one of which is physically near the left, CB1; it was this sensor that recorded an increasing trend, above the normal for the rest of the Chinook fleet, see Fig 2.

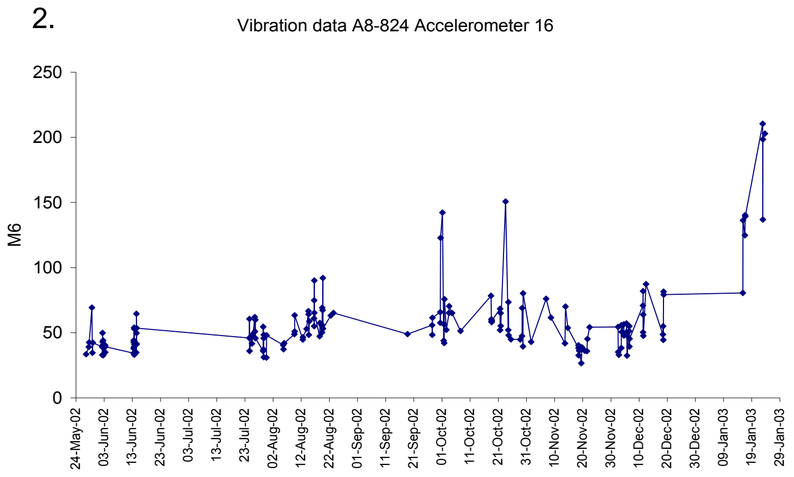

Fig 2: HUMS Vibration monitoring of CB1.

On the 23rd Jan 2003 the aircraft was grounded subject to a combining XMSN change. The oil filters were analysed and M50 steel, consistent with the material of the CB1 were discovered.

The left CB1 bearing was found to have significant damage to the rollers and outer race, see Fig 3. There was no other damage seen on the CB2, CB3 or other related areas of the XMSN.

The CB1 was dismantled to gain access to the inner bearing surface, see Figure 4.

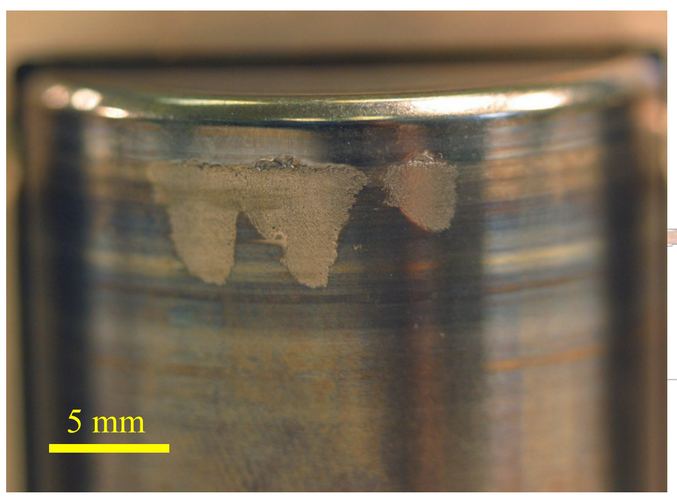

Fig 3: Damage to surface of roller bearing.

The CB1 bearing is composed of twelve 26mm diameter roller bearings, made from AMS 6278 Vim Var M50 Nil steel. This is a carburised heat treated steel from which the inner ring was also made. The outer ring is composed of Vim Var M50 through hardened steel.

When viewed from the centre of the transmission : the inner ring of bearing CB1 turns clockwise at 12,263 rpm and the cage also rotates clockwise but at approximately two-fifths the speed of the inner ring.

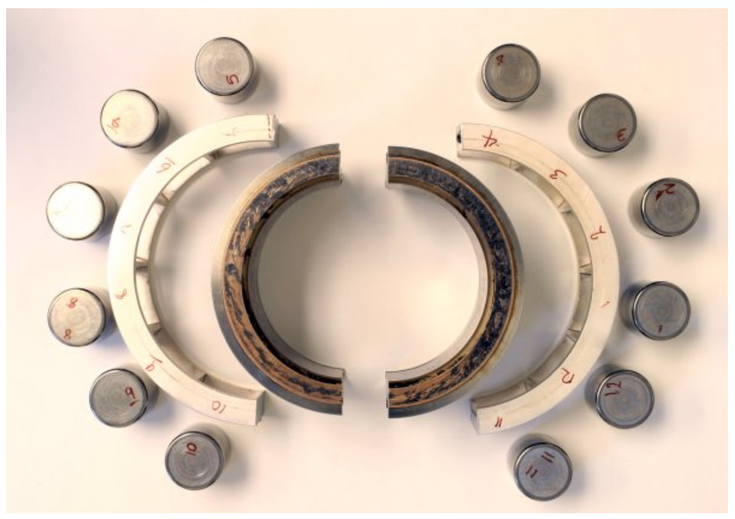

Fig 4: Dissected view of CB1.

Examination of the inner race, see Fig 5, revealed:

- Macropitting subsurface origin [S]
- Discoloration [D]
- Micropitting [M]
- Sliding (adhesive) wear [A]

Higher magnification examination was performed using a Scanning Electron Microscope, see Figure 6, which revealed a steep entrance wall (inclined at more than 45 degree angle to the contact surface). This commonly indicates a subsurface origin to the macro-pitting.

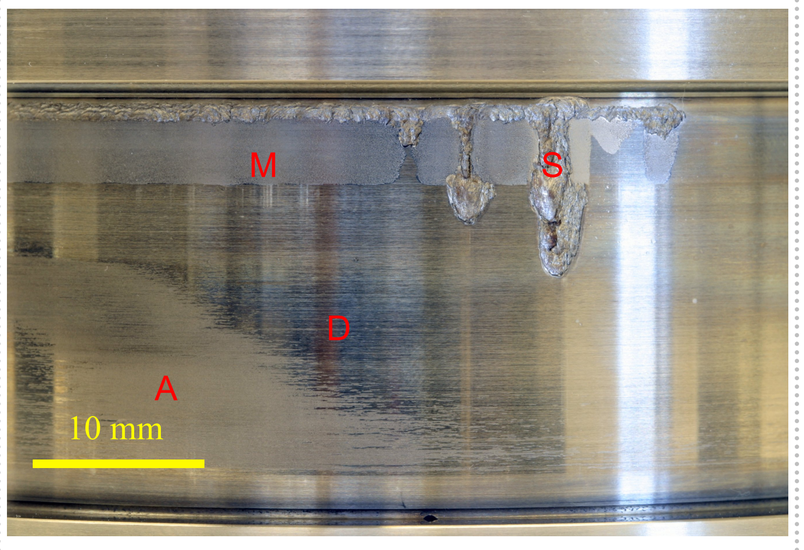

Fig 5: Inner bearing surface, rollers past left to right.

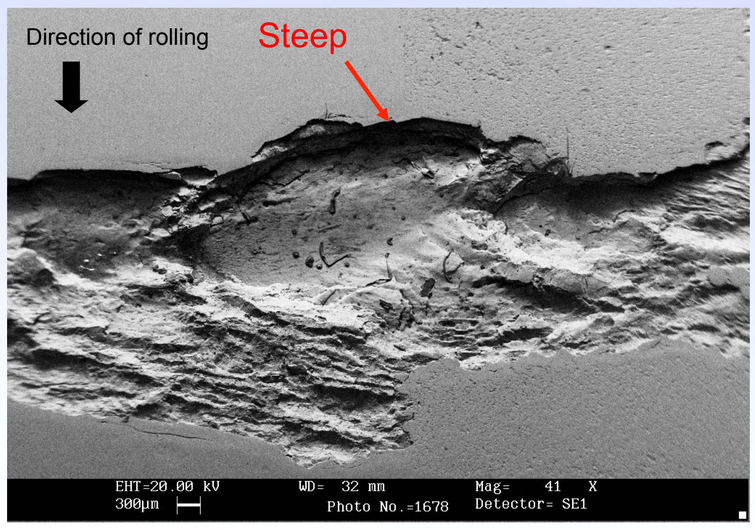

Fig 6: SEM micrograph showing spalling on inner bearing surface.

The SEM was also used to examine the surface damage to the rollers shown in Figure 3. It was also found to be macropitting but surface origin, i.e. secondary and probably caused by debris from the inner ring. Figure 7 shows how the micro-cracking extends the damaged area.

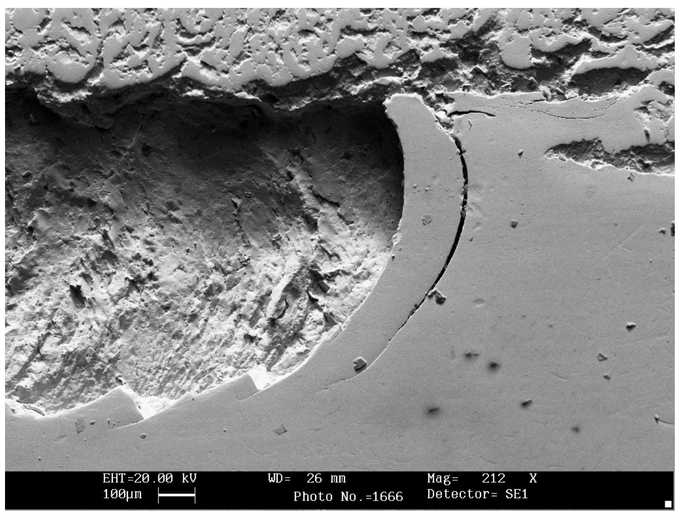

Fig 7: SEM micrograph showing spalling on a roller surface (Fig 3).

Macropitting is defined as macro-scale Hertzian contact fatigue. It is failure by the formation of macroscopic craters in the contact surface as a result of fatigue crack propagation in the Hertzian stress field. Rolling Contact Fatigue (RCF) occurs as a result of normal fatigue, i.e. the bearing has reached the end of its normal life span. However this is not so in this case, the bearing was removed after 660 hours of use. The rated LB10 value (the life at which 1 out of 10 bearings will begin to break down) of the CB1 was 3600 hours. The bearing was not due for a service for another 1400 flying hours.

The cause of the subsurface macropitting of the CB1 inner ring was probably the result of an inclusion or other minor defect. Unfortunately, as in this case, it is common to loose the origin evidence as the damage spreads. RCF is a exponential effect, under the loads present in a combining transmission once pitting had begun the bearing would have been in its last 10% of life.

Therefore it is likely that this bearing would have lead to a catastrophic bearing failure (and possible loss of a/c) within 60 flying hours. HUMS prevented this.