FAILURE MECHANISM FOR WHITE METAL BEARINGS

BY

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History

There has been considerable historical interest in the failure of white metal bearings in the Canadian DND Maritime Forces. The Canadian DDEs which are Y.100 powered have had the occasional main gearing bearing failure, some 10–15 years ago and some more recently. Initially the lubricant was a 3 GP 358 which had a chloride-containing EP additive. It was fairly common to have stained bearings and stained steel surfaces on the gears. When sections were made of the bearing metal, on the occasion of an investigation, they proved to have a 0·002 to 0·003-inch tin oxide corrosion layer as described in the technical literature by various investigators. Staining on the steel surfaces proved to be mixtures of hydrated iron oxides.

The use of the EP-containing 3 GP 358 lubricant was discontinued about 1964 and since then one might have assumed that problems that might arise from the corrosion of the white metal surface would have abated. In actual fact, there have been several incidents of failed bearings, attributed to various causes including the corroded surface containing the hard, brittle tin oxide.

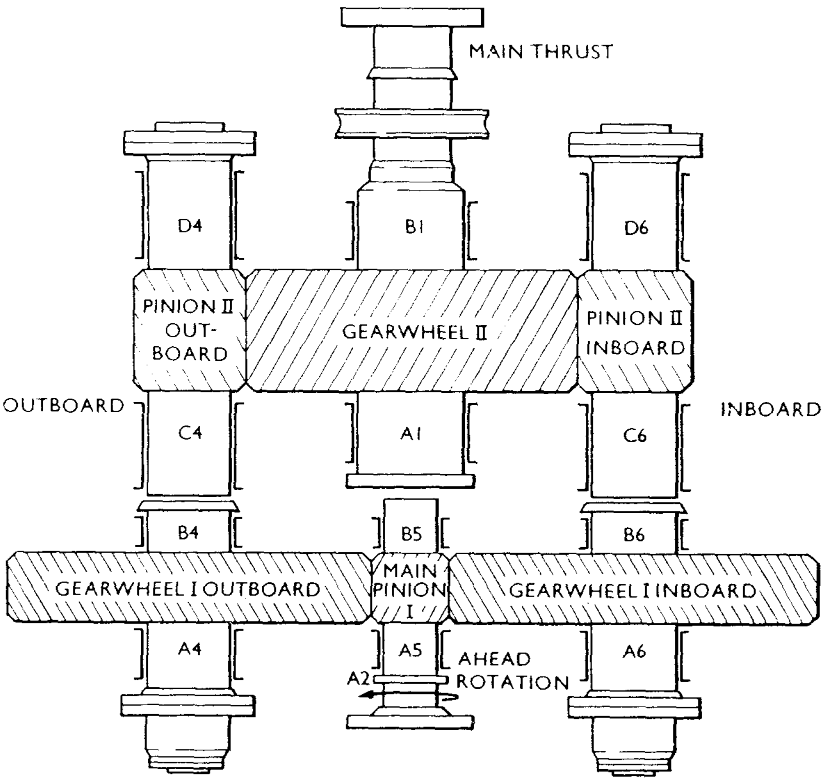

FIG. 1—ARRANGEMENT OF MAIN GEARING, Y.100

It is also true that gear boxes have not necessarily been opened over considerable periods of time, nor have the bearings with whatever incipient corrosion was present been removed or replaced.

A failure which occurred in July 1976 in the same Y.100 gearing will be described in some detail, as well as the diagnosis arrived at on the basis of the evidence available. A mechanism was postulated that may be more widespread than suspected heretofore.

It was with considerable interest then that the Reference was perused, as this indicated a concerted investigation by the U.K. Ship Department into various aspects of the problem.

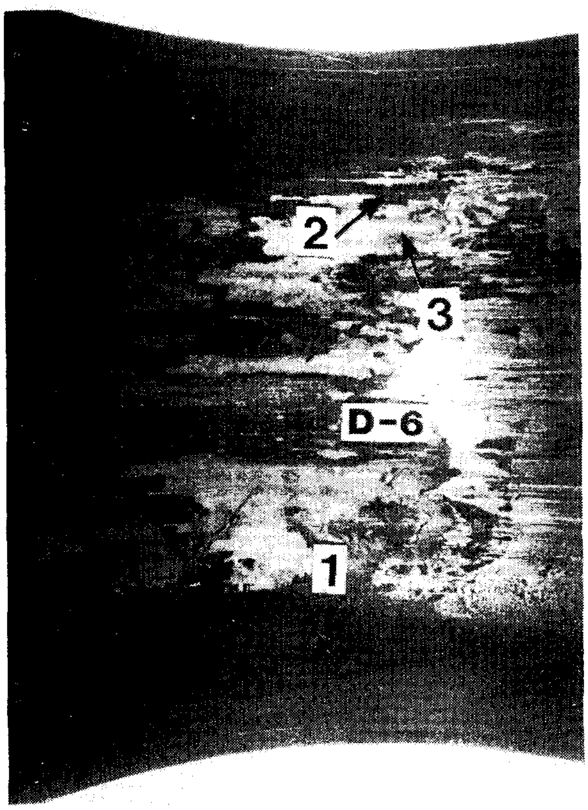

FIG. 2—WIPED BEARING D6
Arrow 1—Non-wiped but stained area
Arrow 2—Black oxide area
Arrow 3—Light greyish area from which black oxide scale has been lifted

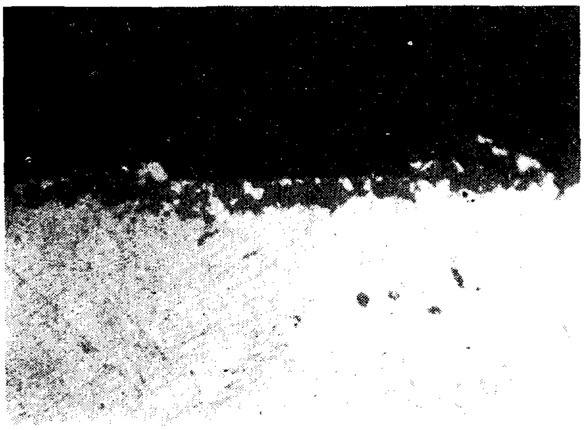

FIG. 3—MICROSTRUCTURE OF AREA INDICATED BY ARROW 1 IN FIG. 1.
DEPTH OF OXIDE APPROX. 0·0007 IN.

Investigation

During recent full-power trials a Canadian DDE experienced a failure in a pinion bearing. This occurrence was detected by a sudden temperature rise to 200°C in the secondary pinion aft bearing (D6) in the starboard main gearing (FIG. 1). There had already been some concern at the somewhat higher temperature of operation (approx. 93°C) noted in this area—some 10° to 12°C above that more generally experienced. The starboard propulsion unit was shut down and the ship returned on the port engine.

On examination when the gearing was opened up, it was found that the D6 bearing was wiped, FIG. 2, and that some of the smeared-off babbitt metal had accumulated in the recessed area. It was also found that the secondary pinion forward bearing (C6) was wiped in similar fashion.

All metal surfaces in the gear box had a brownish stain, presumably dating back to the period when the EP oil (3 GP 358) was used. Analysis of the brown stain removed from the steel bearing shell showed it to be hydrated iron oxide. An area of the stain on the babbitt surface was examined under the microscope. The structure shown in FIG. 3 indicates a corrosive attack on the babbitt to about

FIG. 4—MICROSTRUCTURE OF BLACK SCALE SHOWN BY ARROW 2 IN FIG. 1. TIN OXIDE LAYER IS APPROX. 0·002 IN. THICK

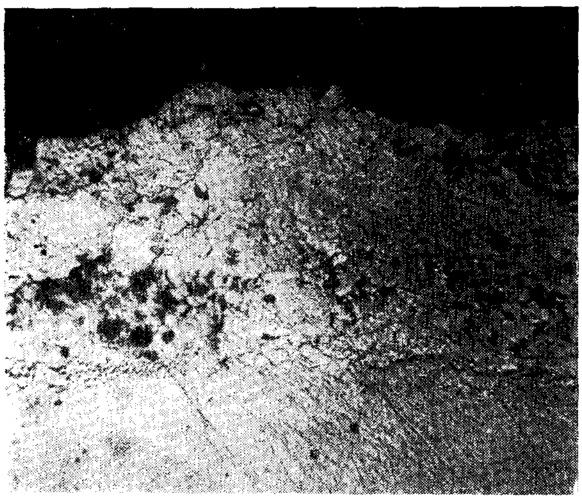

FIG. 5—MICROSTRUCTURE OF AREA UNDER BLACK SCALE SHOWN BY ARROW 3 IN FIG. 1

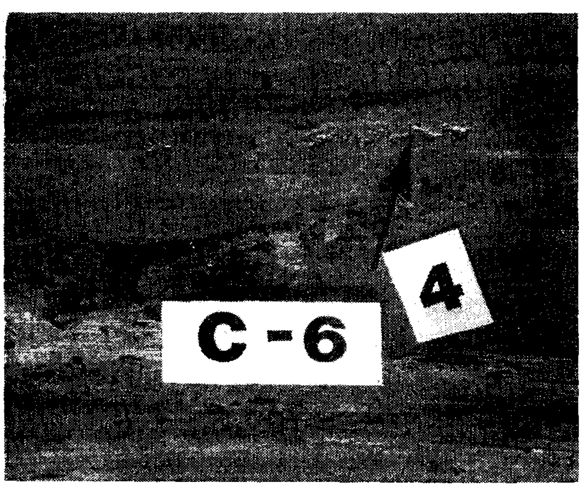

FIG. 6—PORTION OF WIPED BEARING C6 SHOWING SOME BREAK-UP BY FATIGUE

0·001 inches depth. Chemical analysis confirmed that the black areas were tin oxide. Incidentally, tin oxide is known to be hard and abrasive, and some light scoring of the journals at C6 and D6 confirmed this. It was noted that in the area of the wipe there were dark areas (arrow 2) and lighter areas (arrow 3). The dark areas, practically black, had some tendency to blister slightly and a thin black scale could also be lifted off with a knife blade, leaving the lighter area (arrow 3). Samples of the thin black scale and the lighter area (of arrow 3) were mounted and examined under a microscope. FIG. 4 shows the microstructure of the black scale which is almost wholly tin oxide and has a thickness of 0·002 inches. FIG. 5 shows the microstructure of the lighter area, and it may be noted that it has some oxide in it, possibly 5 per cent. One might have expected this area (once the black scale is removed) to be reasonably good bearing metal, even if melted and solidified again. Close examination of bearing C6 which had wiped at some earlier period showed a small worn area (FIG. 6, arrow 4) where the babbitt metal was tending to break-up by fatigue. This finding suggests that babbitt from beneath the black scale may not be suitable for continued service probably because the oxide and dross weaken the babbitt. The bearing should be re-metalled or replaced.

It would appear then that a sequence of events has been occurring along the following lines:

(*a*) staining (by corrosion) of the babbitt metal at some time in the past;

(*b*) bearing clearance somewhat below the desired

0·011 to 0·015 inches, as indicated to this unit by naval engineering personnel;

(*c*) at full power, the clearance tends to be insufficient for adequate cooling by oil flow;

(*d*) this clearance and temperature rise must be a borderline situation because most bearings seem to have survived;

(*e*) however, for bearing C6 and D6 the temperature rise was sufficient to cause further reaction with the babbitt producing additional thickness of tin oxide (shown in FIG. 4);

(*f*) the expansion resulting from the additional tin oxide would further restrict the clearance, leading to further temperature increase;

(*g*) it is suspected that a slight expansion of the journal also contributes to a reduced clearance when running hot;

(*h*) once the melting point (approx. 220°C) of the babbitt is reached, the metal would flow and oxide would be displaced, improving the clearance, and the temperature would subsequently drop;

(*j*) with continued service of the damaged bearing, the partly weakened lighter area (of arrow 3) where it experiences bearing wear tends to break-up by fatigue (as in FIG. 6).

It would appear likely that this sequence probably occurred over a long time period, with oxide growth during the temperature stress of full-power operation.

Based on the above sequence, this unit recommended that suitable clearances had to be ensured for continued service reliabilty. Stained bearings of adequate clearance were not a problem.

Discussion

Checking back through the available records tends to suggest, at least from the appearance in photographs of some of the failures, that this mechanism would fit. Details, of course, are incomplete and hence such a diagnosis must remain a possibility only for the earlier failures.

The Reference provides several views or evidence supporting the suggested mechanism. These include:

(*a*) 'At high temperatures, thicker films can form directly without electrolytic action.' And the author's experience that '. . . those (bearings) with highest running temperatures usually showing the most severe attack.'

(*b*) 'Rust (Fe_2O_3) can function as a supplier of oxygen to tin in acidic conditions' (Bryce and Roehner)*. In the case here, with steel components stained and covered with hydrated iron oxides, a possible contributor to the action was present.

(*c*) 'Thrust bearings operate at higher temperatures than journal bearings and this may be one of the reasons why they are attacked more readily.' The relation between high temperature and oxide formation is supported, but it has also been found that the reduced clearance which can occur with journal bearings (and proven by actual measurement in this specific example) provides the required conditions for tin oxide growth.

(*d*) The reference to a fatigue failure (FIG. 8 of the Reference) has some elements of interest, specifically that 'the corrosion has been aggravated by the conditions of high local temperature . . . .' This certainly fits the view taken here of, and recorded evidence of, high local

*Ref. 1 of the Reference.

temperature, but due to a reduced clearance. As already indicated, evidence of fatigue or of a less-than-sound-appearing metal seemed to be associated with metal which was melted earlier from the overheating sequence.

(*e*) The report on results of research with exposure of bearings to higher temperatures (up to 157°C) (Reference, pp. 63–5) had a very significant finding—that only the loaded pads showed any evidence of corrosion, and that the unloaded pads which were exposed to the same temperature of the bulk oil did not. Assuming that the loaded faces suffered more severe conditions (including higher temperatures) these results tend to support Canadian findings of a 0·001-inch oxide layer on relatively non-loaded areas, and on those areas that failed a thickness of 0·002 inches of oxide.

The following further comments are relevant:

(*a*) The tendency here has been to consider tin oxide layers of more than 0·0025-inches thick as reason to replace the bearing to avoid possible cracking and spalling off of hard pieces which could lead to damage. It is interesting to find that the Reference and others report that thicker oxide layers have not caused failure.

(*b*) Canadian naval experience of trouble attributed to or related to this corrosion has included hardly any thrust bearings—failures have been largely journal bearings including main gearing and several auxiliary machinery bearings (eight in the somewhat incomplete records). The review of recent years' experience given in the Reference is, however, the reverse.

(*c*) The statement (Ref. p. 67) that so few journal bearings have failed 'is clear evidence that stannic oxide corrosion does not, by itself, pose a significant threat to bearings of this type' is endorsed by the recommendation here allowing continued service of journal bearings where there is *adequate* clearance (allowing for the oxide).

(*d*) A remark that is particularly liked is that this problem of corrosion is one that 'simmers gently in the background' and 'only on rare occasions . . . due to a small change in the environment boils over into prominence'. Those words tend to fit rather well the case history here described. Certainly 'it simmered' for a long time until the clearances became such that a chain of events culminating in higher temperature and lessened clearance 'boiled over' into failure.

It is hoped that some of these findings and views will be useful in the Ship Department's search for additional service experience.

Conclusions

A case history has been described in which sufficient details were available to suggest a sequence of events leading to overheating and failure. The mechanism suggested, i.e. tin oxide growth under the influence of increasing temperature, tends to fit some of the known facts of the role that the oxide layer can play, as indicated in the Reference and elsewhere.

Reduction of the hazard would appear to hinge largely on ensuring freedom from corrosion by appropriate choice of oils and further by ensuring sufficient clearance so that additional oxide growth is avoided.

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The opinions expressed in this article are those of the author and not necessarily those of the Canadian Department of National Defence.

Reference:

Dunford, J.J., B.Sc., R.C.N.C., 'The Blackening of White Metal Bearings', *Journal of Naval Engineering*, Vol. 23, No. 1, p. 54.

THE MARINE ENGINEERING DAGGER COURSE

The Marine Engineering Dagger Course (see *Journal of Naval Engineering*, Volume 23, No. 2) has been approved by the Council for National Academic Awards as a M.Sc. degree course in marine engineering. The first officers to receive the award will be those who successfully complete the course which started in May 1976.