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OTTAWA November 9th, 1943.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1529.

Examination of Two Broken Shafts
from Two Double-Worm Speed Reducers
Used in Operating a Beatty Naval Training
Tilting Platform.

(Copy No. 6.)

Bureau of Mines
Division of Metallic
Minerals
-
Ore Dressing
and Metallurgical
Laboratories

CANADA

DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

OTTAWA November 9th, 1943.

REPORT

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ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1529.

Examination of Two Broken Shafts from Two Double-Worm Speed Reducers Used in Operating a Peatty Naval Training Tilting Platform.

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Source of Material and Object of Investigation:

On October 26th, 1943, Mr. Louis Fleck, works manager, Alexander Fleck Limited, Ottawa, Ontario, submitted for examination two broken reduction gear shafts used in operating a Peatty naval training tilting platform. It was stated that these gears, manufactured by D. O. James, Chicago, Ill., were new and had failed in a trial run while rotating at a speed of 500 r.p.m. under no load. The shaft of Reducer No. 1 broke after running two hours, while the shaft of Reducer No. 2 failed after running 48 hours.

Macro-Examination:

The break occurred, in each case, at the base of the fillet in the shaft. The fracture indicated that failure may have been of the progressive type.

Hardness Tests:

Hardness tests were made on the surface and cross-section of each shaft, and also on the worm gear of Reducer No. 2, using the Vickers method. The following values were obtained:

Vickers Hardness Numbers

	Core	Case	Shaft surface	Worm surface
Load used -	5 kg.	5 kg.	10 kg.	10 kg.
Reducer No. 1 -	160	265	245	N.D.
Reducer No. 2 -	214	347	286	666

(N.D. = Not determined).

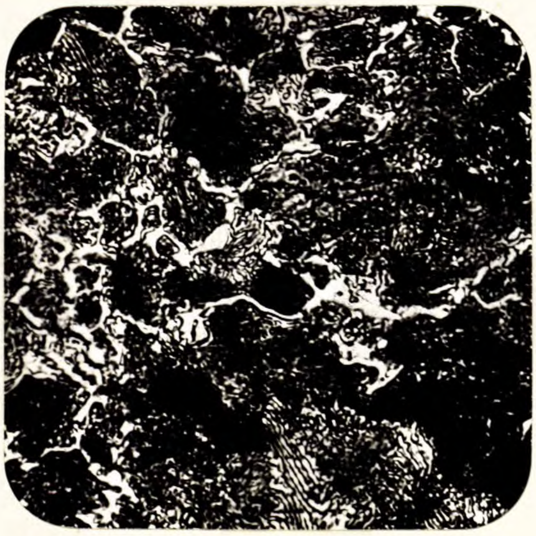
Microscopic Examination:

Specimens were cut from each shaft near the point of failure and prepared for microscopic examination. The steels of the two shafts were examined under the microscope in the unetched condition and found to be fairly clean. Figures 1 and 2 are photomicrographs, at X1000 magnification, showing the nital-etched structure of the case of the shaft of Reducers Nos. 1 and 2 respectively. The samples were over-etched in order to make easier the identification of the free carbide particles. The background is pearlite, the iron-iron carbide eutectoid. This pearlite appears lamellar in certain areas which etch more lightly. Apart from these lamellar areas, all other white etching material is iron carbide. Figures 3 and 4 are photomicrographs at X100 magnification and show respectively the nital-etched structure of the core of the shaft of Reducers Nos. 1 and 2. Here the light areas are

(Microscopic Examination, cont'd) -

ferrite (the iron constituent) and the dark etching material is pearlite.

Figure 1.



X1000, etched in 2 per cent nital.

CASE, NO. 1 REDUCER SHAFT.

Figure 2.

X1000, etched in 2 per cent nital.

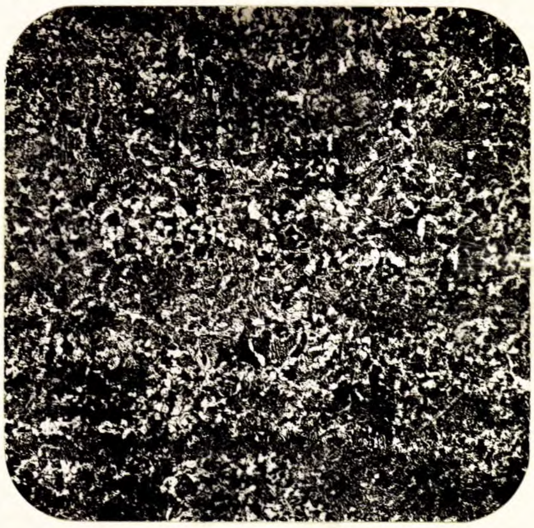
CASE, NO. 2 REDUCER SHAFT.

Figure 3.

X100, etched in 2 per cent nital.

CORE, NO. 1 REDUCED SHAFT.

Figure 4.



X100, etched in 2 per cent nital.

CORE, NO. 2 REDUCED SHAFT.

Discussion of Results:

Failure was undoubtedly of the fatigue type, as the shaft at no time was required to resist suddenly increased loads.

Hardness tests revealed that only the worm part of the shafting had been hardened in heat treatment. The soft case at the point of fracture would have relatively low fatigue strength and this fatigue strength would be further lowered by the presence of free carbides in the case (as revealed in the microscopic examination). The percentage of ferrite and pearlite in the core, and the lamellar nature of the pearlite in both case and core, both indicate a relatively slow cooling from well below the upper critical range. The coarseness of the pearlite and the general structure of the case of Shaft No. 1 indicate that the portion at the point of failure was cooled in the box as a final heat treatment. The low hardnesses of the case and core are also consistent with this assumption. In Shaft No. 2, greater fineness of structure, and higher hardness at the point of failure, indicate that this material was finally normalized. Assuming that both steels had the same inherent grain size and were carburized at the same temperature, one could assume from the greater fineness of structure of Shaft No. 2 that this steel was normalized subsequent to carburizing rather than removed from the box and cooled in air. If, however, these two steels had markedly different inherent grain sizes and carburizing temperatures, this assumption is not necessarily correct.

In bending stresses such as these gear teeth receive in service, the fatigue strength of surface material is all-important. It is not surprising that this shafting failed prematurely, for it is well known that free grain boundary carbides, such as were found to be present, lead to early failure of cased parts. Indeed, small arms manufacturers

(Discussion of Results, cont'd) -

have found it necessary to take elaborate precautions to ensure carbon diffusion in order to eliminate this free carbide condition, as parts not so treated fail after very little service although properly heat-treated in all other respects.

The examination would indicate that the manufacturer of the shafting apparently did not consider that it had very much to resist in the way of fatigue stresses and that only the worm portion need be wear-resistant. The performance in service showed that this assumption was not correct and that an unhardened shafting (except the worm, which was probably flame hardened) was not satisfactory. If it is desired that the shafting be carburized, it is apparent that this should be done in a low-energy compound which would insure against the production of too high a carbon case. Failing this, a diffusion heat-treatment which would produce a case of approximate eutectoid composition should follow the casing. Optimum heat treatment would involve a quench from above the upper critical, a second quench from about fifty degrees Fahrenheit above the lower critical, and a low-temperature draw. A simple, single-quench heat treatment would probably be adequate for this part. Shotblasting would also offer additional insurance against fatigue failure. The possibility of using one of the standard engineering steels for this part might also be considered.

Conclusions:

The presence of a soft, high-carbon case in the shaftings is considered to have been responsible for these premature failures under alternating stresses. It is considered that the steels should be used in the hardened

(Conclusions, cont'd) -

condition and that the carbon in the case should be as nearly the eutectoid composition as possible. As an alternative, a medium-carbon steel might be used. Shotblasting should also be considered.

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