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OTTAWA February 8th, 1943.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1353.

Examination of a Broken Crankshaft from a Packard Marine Engine.

(Copy No. 10.)

BUREAU OF MINES
DIVISION OF METALLIC MINERALS

ORE DRESSING AND
METALLURGICAL LABORATORIES

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
MINES AND GEOLOGY BRANCH

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Origin of Sample:

A broken crankshaft from a Packard marine engine was submitted on January 5th, 1943, by Air Commodore A. L. Johnson, Department of National Defence for Air, Ottawa, Canada.

Object of Study:

An examination of the crankshaft was requested in order to determine, if possible, the cause of failure.

Chemical Analysis:

Drillings from the crankshaft proper, as well as from the attached counterweight, were chemically analysed. The results are as follows:

		Crankshaft	Counterweight
		- Per cent -	
Carbon	-	0.45	0.22
Silicon	-	0.29	0.22
Manganese	-	0.81	0.87
Sulphur	-	0.018	0.027
Phosphorus	-	0.014	0.016
Chromium	-	0.80	0.17
Nickel	-	1.76	Trace.
Molybdenum	-	0.23	Not detected.
Vanadium	-	Not detected.	0.017
Tungsten	-	Not detected.	Not detected.

Macro-Examination:

A general view of the crankshaft and a close-up of the fractured surface are given in Figures 1 and 2. The fracture has the appearance of a fatigue failure of the duplex type, with its nucleus at the start of a fillet in the under side of the crank pin (Point A, Figure 2).

One of the crank pins was sectioned about one-half inch off centre, polished, and immersed for one hour in a 50 per cent aqueous solution of hydrochloric acid at 170° F. Some of the flow lines of the piece leave the forging near the fillet in the under side of the crank pin (Point B, Figure 4). Figure 5 is a photograph of a macro-etched specimen taken from the broken crank pin at what is believed to be the nucleus of the failure. The flow lines leave the forging at the exterior edge of the fracture (Point C).

The sides of the crank pins in that part of the shaft in which end play would occur after fracture were deeply burnt. The bearing on the crank pin through which failure went was deeply scored. Some of the other bearings were scored much less deeply.

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Physical Examination:

A 0.505-inch tensile bar (2-inch gauge length) and an izod bar were machined from one of the crank pins perpendicularly to the main axis of the shaft.

Ultimate stress, p.s.i. = 167,500
Yield stress, p.s.i. = 152,000
Elongation in 2 inches, per cent = 16.5
Reduction in area, per cent = 53.5
Average izod value, foot pounds = 35
Vickers hardness number = 358

A hardness survey through a crank pin showed that the shaft was homogeneously hardened. The burnt part of the crankshaft had, in places, a Vickers hardness number of about 645.

Microstructure:

Figure 6 is a photomicrograph, at 100 diameters, of the inclusions in the steel near one of the crankshaft fillets. This is the worst area discovered and is not considered representative of the material. Figure 7 depicts, at a magnification of 1000, the structure of the steel in the crankshaft after it had been etched in 2 per cent nital.

A McQuaid-Ehn test revealed that the grain size was predominantly 8 with some grains 4-6.

Discussion of Results:

The composition of this part follows SAE 4340 specification closely. This type of steel is widely used for heavy crankshafts.

The discontinuity of some of the flow lines at the fillet in which fracture is believed to have originated would lower the fatigue limit at this spot. The actual reduction in fatigue limit, however, is thought to very with different

(Discussion of Results, cont'd) -

materials, inclusion contents, and the angle at which the flow lines meet the surface. In this connection, the following remarks by R. A. MacGregor, W. S. Burn and F. Bacon, in RELATION OF FATIGUE TO MODERN ENGINE DESIGN (Trans. North East Coast Inst. Engineers and Shipbuilders, vol. 51, 1935), may be of interest.

> "So far, experiments have established that there is a difference in fatigue strength using plain specimens having the grain running 'with' or across the bar. Across the grain appears to give about 15-20 per cent lower value than with the grain."

The inclusion content of the steel of this crankshaft is considered to be about normal.

The high hardness on the burnt parts of the crank pins shows that these were, in spots, heated above their critical point. This and the locations of the burns would seem to indicate that the engine was run after fracture had occurred. For this reason, the scoring on the bearings was probably not present before failure started.

The material in this crankshaft seems to be a steel of normal quality, accorded an acceptable heat treatment with resultant satisfactory physical properties.

CONCLUSIONS:

The examination shows flow-line discontinuity as the only discovered metallurgical defect. It is felt that the burning and scoring of the shaft occurred after the fatigue failure. If this had not been the case, high temperatures, such as must have been present to harden the metal, would have led to the fatigue failure by severely stressing the metal at the surface.

It is extremely difficult to diagnose conditions

(Conclusions, cont'd) -

for failure solely from a metallurgical examination, as mechanical defects rather than metallurgical deficiencies are more often the cause of machine failure. Certainly, if only a comparatively few of these shafts are failing in service the trouble is more likely to be mechanical. Such things as shafts out of balance (which the boat operator would be aware of prior to failure); elastical deformation of the shaft in twisting and bending in service, so that the bearings would be only partially effective in supporting the load (a condition which would show up as plastically deformed or "bell-mouthed" bearings); shaft vibrations and loading exceeding those usually encountered in service (and which would also be known to the boat operator); would all be more likely causes of failure than any metallurgical defect.

While it is difficult to be dogmatic, in the absence of complete evidence, it is felt that failure in this case may well have been due to mechanical causes with flow-line discontinuity a contributing cause. It is felt that this examination is only one of many where metallurgical and mechanical investigations should parallel each other.

Scientific shot-blasting of portions or all of this crankshaft may possibly lead to a decrease in the number of failures being encountered, as this shot-blasting would certainly raise the fatigue strength at critical zones.

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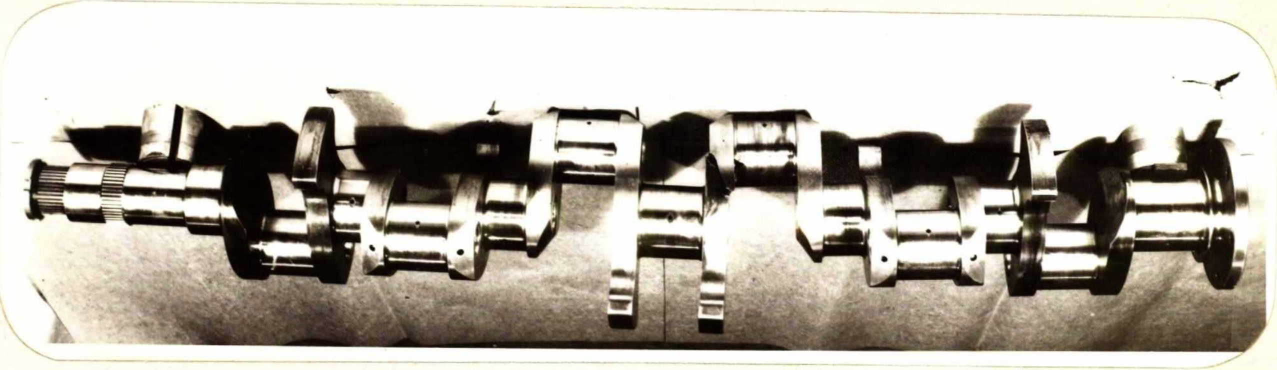
LPT:GHB.

Figure 1.



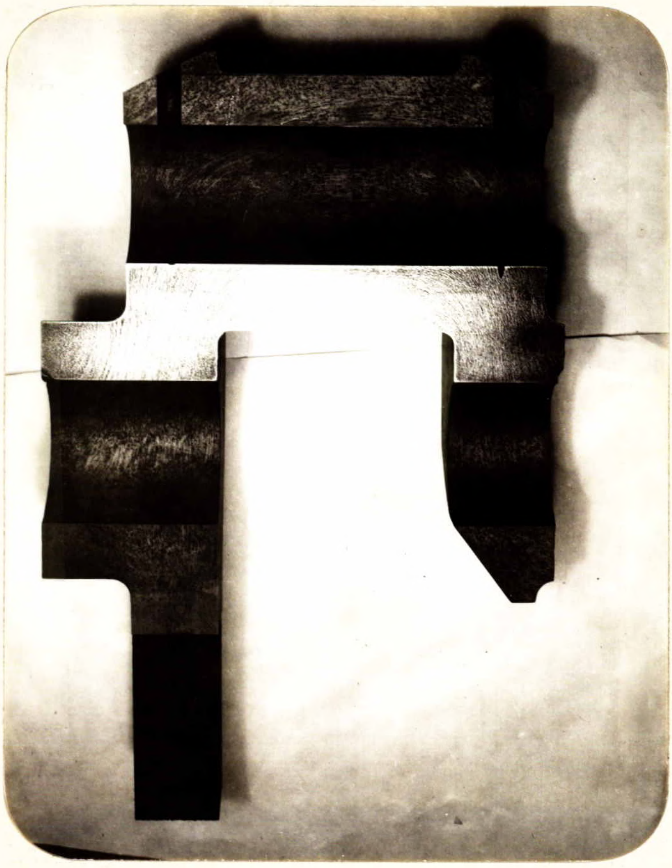
CRANKSHAFT AS RECEIVED.

(Approximately 1/9 size).

Figure 2.

(Approximately ¾ size).

Figure 3.



VIEW OF ETCHED CRANK PIN
SHOWING ATTACHED WEIGHT.

(Approximately ½ size).

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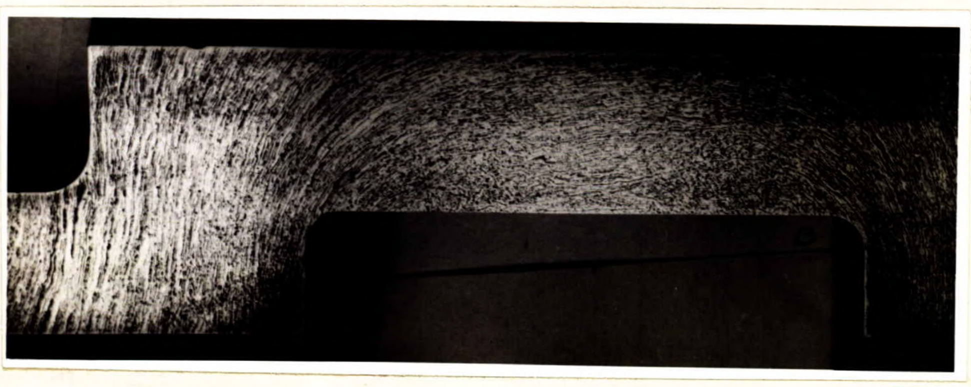
Figure 4.



FLOW LINES NEAR FILLETS
IN UNDER SIDE OF CRANK PIN.

(Approximately to size).

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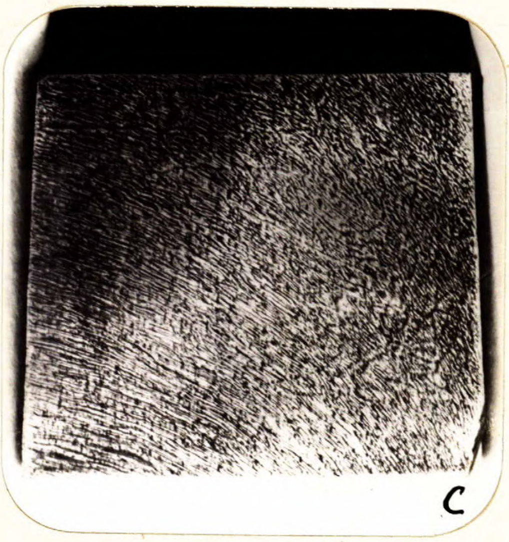
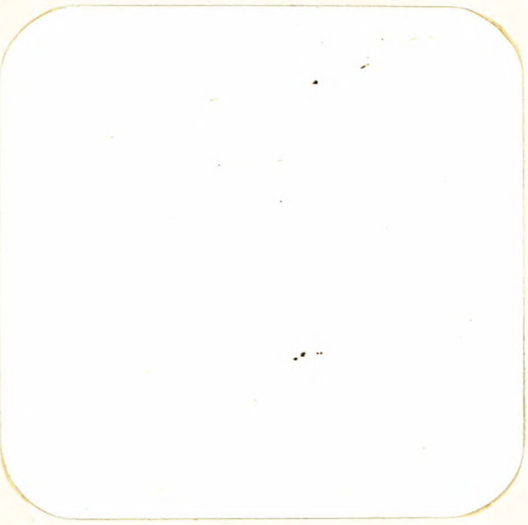
Figure 5.



(Approximately 2½ magnification).

Figure 6.



X100, unetched.

INCLUSIONS PRESENT
IN THE STEEL.

Figure 7.

X1000, nital etch.

STRUCTURE OF STEEL
IN CRANKSHAFT.

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