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O T T A W A September 28th, 1942.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1309.

(M. and S. No. 7/D).

Examination of
Valentine Tank Sprocket Hub No. 15611-T.

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(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:

On September 17th, 1942, Dr. C. W. Drury, Director of Metallurgy, Army Engineering Design Branch, Department of Munitions and Supply, 24 Adelaide Street East, Toronto, Ontario, submitted a Valentine Tank sprocket hub (No. 15611-T) for examination. This part, reported to be made of SAE 4640 steel, had failed in service.

Object of Study:

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

Analysis:

A comparison of the composition of the part with the specification for SAE 4640 steel follows:

		As Found		Specification for SAE 4640
		-(Per cent)-		
Carbon	-	0.42	. . .	0.35 - 0.45
Manganese	-	0.68	. . .	0.05 - 0.80
Phosphorus	-	0.009	. . .	0.04 max.
Sulphur	-	0.069	. . .	0.05 "
Nickel	-	1.77	. . .	1.65 - 2.00
Chromium	-	2.22	. . .	
Molybdenum	-	0.21	. . .	0.20 - 0.30

Macro-Examination:

The hub failed because the spline collar broke away from the disc. It was noted that the fracture, which had the appearance of a fatigue failure, occurred at a sharp corner of this highly stressed part. These points are illustrated in Figures 1, 2, and 3.

A macro etch on a section of the spline collar revealed that the bottom edges of the splines were cracked. This is shown in Figure 4.

Physical Examination:

A 0.287-inch-diameter tensile bar and an izod test bar were machined from the spline collar. The results obtained, compared with the specified values, follow:

		Value Obtained		Minimum Specified Value
Ultimate stress, p.s.i.	-	93,663	-	134,500
0.1% proof stress, p.s.i.	-	62,133	-	
Yield point, p.s.i.	-		-	67,250
Elongation, per cent	-	28	-	17½
Reduction of area, per cent	-	51.8	-	
Izod value, foot pounds	-	55	-	55

The specification called for a Brinell hardness of 260 to 310. Readings were taken at points 1, 2, and 3, as shown in Figure 3. Brinell hardness values obtained were at point 1, 212; at point 2, 205; and at point 3, 250.

Microstructures:

Specimens 1, 2 and 3, from points 1, 2 and 3 in Figure 3, were removed and polished. After an etch of 4 per cent picric acid in alcohol was applied, a photomicrograph at 500 diameters was taken of each specimen. These are given at the end of this report. It will be noted that Specimen 3, from the outer edge of the flange, is composed of fine pearlite (sorbite), while the others, from the spline collar, are about 50 per cent pearlite and 50 per cent ferrite. An examination of the metal at the point of fracture failed to reveal any local defects.

Discussion of Results:

The composition of the part does not follow the specification for SAE 4640 steel, the sulphur being too high and considerable chromium being present. The sulphur, while high, might not markedly affect steel quality. The large amount of chromium present, however, effects a complete change of steel type, hardenability being considerably increased.

The cracks at the base of the splines do not have any bearing upon the failure investigated but were included in this report because they may be a source of future trouble. The splines appeared to be slightly bent and cracking may have occurred in this bending.

It will be noted that the hub has not the required ultimate and yield strengths. The most probable explanation for the higher hardness at the outside of the flange is that when the original forging was heat-treated this part was thinner than the rest and thus cooled faster. A faster rate of cooling in heat treatment, or a heat treatment of a partially machined forging, would have conferred a more uniform structure.

(Discussion of Results, cont'd) -

From all of the foregoing it would seem that the failure of the part was brought about, first, by the concentration of stress caused by lack of filleting at the point of fracture, and secondly, by incorrect heat treatment which lowered the elastic limit of the piece below the specified limit and thus decreased its fatigue resistance.

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Figure 1.

VIEW OF BROKEN HUB.

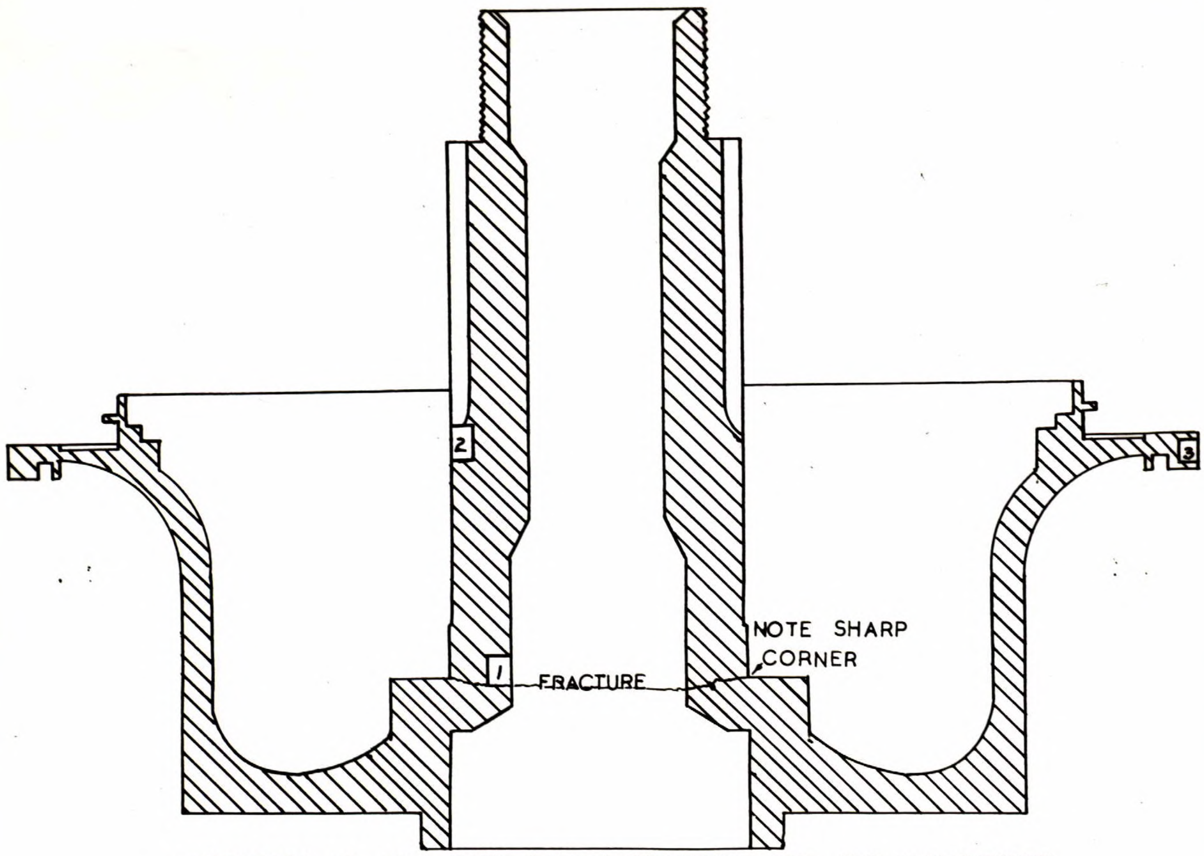
(Approximately ¼ size).

Figure 2.

VIEW OF FRACTURE.

(Approximately ¾ size).

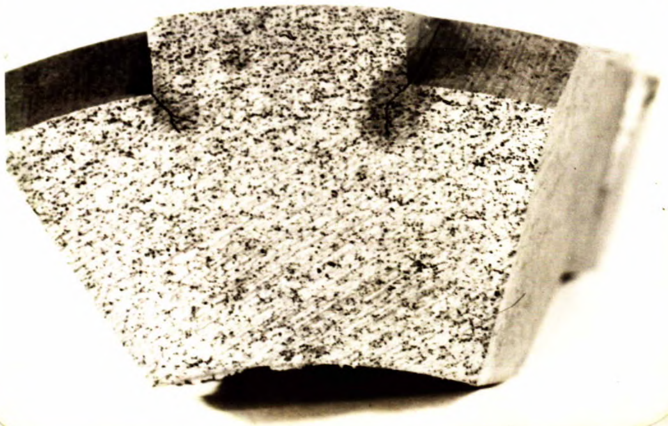
Figure 3.



RECTANGLES 1, 2, AND 3 SHOW WHERE SPECIMENS FOR THE MICROSCOPE WERE TAKEN.

This drawing is not to scale.

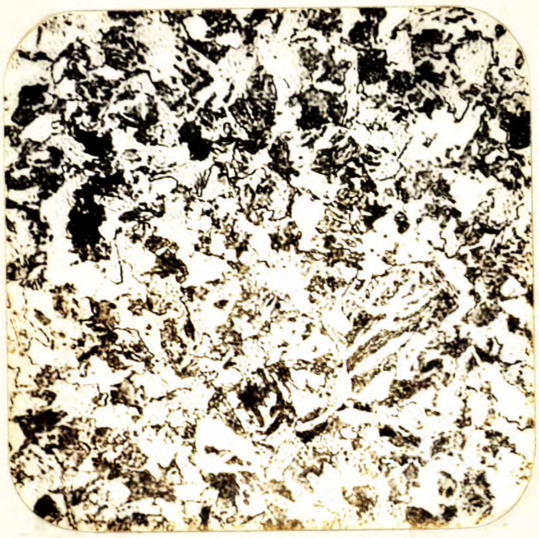
Figure 4.



CRACKS AT THE BASE OF THE SPLINES.

(Approximately 2½ times actual size).

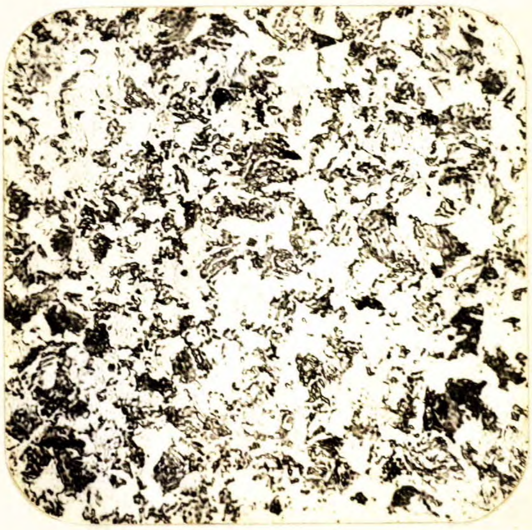
Figure 5.



X500, picral etch.

MICROSTRUCTURE AT POINT 1 IN FIGURE 3.

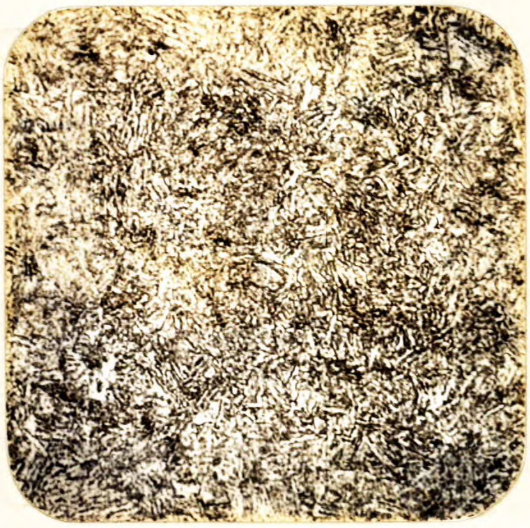
Figure 6.



X500, picral etch.

MICROSTRUCTURE AT POINT 2 IN FIGURE 3.

Figure 7.



X500, picral etch.

MICROSTRUCTURE AT POINT 3 IN FIGURE 3.

LPT:NEB.