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R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1740.

Examination of a Broken Steel Shaft
from a Briquetting Press.

(Copy No. 10.)

Bureau of Mines
Division of Metallic
Minerals
-
Physical Metallurgy
Research Laboratories

CANADA

DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

OTTAWA November 13th, 1944.

REPORT

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Source of Material and Object of Investigation:

On October 21st, 1944, Mr. Lloyd G. Brewer, Mechanical Superintendent, Dominion Magnesium Limited, Haley, Ontario, submitted for metallurgical examination a broken roll shaft from a briquetting press. In a letter dated October 25th, 1944, it was stated that the shaft had been scored by ferrosilicon and calcine dust after about two months of service. The scored shaft was repaired by being built up with metal by electric-arc welding and then finished to size. The shaft was not heat treated after welding. The part was stated to have been made from SAE 4140 steel and to have been operated at a speed of 6 r.p.m. A full metallurgical examination was requested in order to determine, if possible, the cause of failure.

Macro-Examination:

Figure 1 is a photograph showing the half-section of the fractured surface of the shaft. The fracture has the appearance of a fatigue failure produced by alternating torsional stresses.

Figure 1.

(Approximately ½ size).

Chemical Analysis:

The chemical analysis of the shaft and the specified composition of SAE 4140 steel are given in the following table:

		SAE 4140 Specification	Shaft
		- Per Cent -	
Carbon	-	0.35-0.45	0.43
Manganese	-	0.60-0.90	0.92
Silicon	-	0.15 min.*	0.26
Phosphorus	-	0.04 max.	0.018
Sulphur	-	0.05 "	0.017
Chromium	-	0.80-1.10	0.86
Molybdenum	-	0.15-0.25	0.18

* Basic electric furnace steel.

Mechanical Properties:

Tensile and Izod test samples were taken midway between the surface and centre of the shaft. The following results were obtained:

Ultimate stress, p.s.i.	-	119,800
Yield stress, p.s.i.	-	90,000
Elongation, per cent in 2 inches	-	20.0
Percentage reduction of area	-	56.5
Izod impact, foot-pounds	-	74, 70
Brinell hardness	-	235

Hardness Tests:

A hardness survey was carried out on a cross-section of the shaft, starting at the outer surface in the weld metal and extending along the edge of the fracture to the centre of the shaft. The hardness was determined by the Vickers method, using a 30-kilogram load. The results obtained, together with the converted Brinell hardness numbers, are given in the following table:

Location of Readings		Vickers Hardness Numbers	Brinell (Converted)	Remarks
Weld metal	-	187	187	Approx. 1/16 inch apart.
" "	-	198	198	" " "
Transition zone	-	411	392	" " "
" "	-	418	398	" " "
Parent metal	-	234	234	Approximately 3/16 inch apart, for balance of readings.
		249	249	
		234	234	
		245	245	
		248	248	
		243	243	
		245	245	
		265	265	
		265	265	
		261	261	
		246	246	
		244	244	
		240	240	
		258	258	
		246	246	
		247	247	

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Microscopic Examination:

A specimen of the metal adjacent to the fracture was polished and examined under the microscope in the unetched condition. The steel was found to be fairly clean. After etching in a solution of 2 per cent nitric acid in alcohol the steel was re-examined. Three different structures were observed, (1) the low-carbon weld metal on the outer surface of the shaft, (2) the heat-affected zone next to the weld metal, and (3) the original structure of the parent metal. Figure 2 is a photomicrograph, at X100 magnification, showing the transition zone between the weld and the parent metal. A crack extending longitudinally nearly to the edge of the fracture can be seen in this photomicrograph.

Figure 2.

(Vickers hardness number of weld metal, 164-198.

(Vickers hardness number of parent metal in heat-affected zone, 334 to 418

X100, etched in 2 per cent nital.

SHOWING TRANSITION ZONE OF WELD AND PARENT METAL.

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Figure 3 is a photomicrograph showing the sorbitic structure of the parent metal in the unaffected zone.

(Continued on next page)

(Microscopic Examination, cont'd) -

Figure 3.

X100, etched in 2 per cent nital.

SHOWING ORIGINAL STRUCTURE
OF PARENT METAL.

Discussion of Results:

The chemical composition of the steel is within the range specified for SAE 4140 steel, except for the manganese content which is several points above the upper limit--this is of no significance. This type of steel is widely used for the manufacture of heavy-duty shafting. The mechanical properties of the shafting are satisfactory and indicate that the steel was properly quenched in oil from 1550° F. and drawn at around 1200° F. The hard intermediate zone near the weld would be brittle, as this steel has an impact value of less than 10 foot-pounds in the 400 Brinell range. This hard material would also be notch sensitive and therefore subject to fatigue failure. The microscopic examination showed cracks in this brittle zone.

In welding medium-carbon steels containing over 0.40

(Discussion of Results, cont'd) -

per cent carbon, special precautions should be taken to prevent the formation of brittle zones such as were found in the shaft. Preheating temperatures of 300 to 500° F. have been found effective in eliminating or reducing the formation of hard and brittle areas. By heating to 1100° F. to 1200° F., it is possible to restore the desired properties in the areas affected by the welding heat. The use of a low-carbon welding rod for this repair is considered good practice in so far as build-up is concerned. However, for the heavy abrasive conditions likely to be encountered it would not wear well, and it is recommended that the layer of low-carbon weld metal be covered with a hard facing metal. If only a small amount of metal is removed by wear hard facing metal could be used alone, but if much build-up is required the two-rod technique is best, as the weldment would be less brittle and cheaper to install. The most highly stressed part of the shaft would be at the fillet between the journal and the drum. Any discontinuities of section, such as the cracks observed in this area, would further induce stress concentration. It is most probable that the crack which caused this fatigue failure found its nucleus at this point.

In future repair work of this kind it is recommended that the part be preheated and held at 300 to 500° F. during the welding operation. Care should also be taken to prevent the shaft from cooling too rapidly. The shaft should be tempered after welding. If no furnace is available this can be done with an oxy-acetylene torch, using "Tempil" sticks to indicate temperature.

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