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INVESTIGATION OF THE CAUSE OF FAILURE OF THREE AXLES FOR MINE HEAD SHEAVES

by

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PHYSICAL METALLURGY DIVISION

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SUMMARY OF RESULTS

Three mine sheave wheel axles which failed after thirty years' service were examined and found to have failed by fatigue. Two of the failures were initiated at small radius fillets on the axles; the failure of the other axle was initiated by corrosion pitting. Recommendations have been made to help eliminate future failures of this type.

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(13 pages, 2 tables, 5 illus.)

INTRODUCTION

On December 29, 1958, a written request was received from the Province of Manitoba, Department of Mines and Natural Resources, Mines Branch, to determine the properties and possible cause of failure of three axles for mine head sheaves.

These three axles, according to the letter, had all failed in a similar manner within a period of six months. Single failures of this type are extremely uncommon and the occurrence of three caused great concern.

All fractures occurred flush with the outside of the sheave hub next to the inside edge of a supporting babbitt bearing.

MATERIAL RECEIVED

The bearing ends of each of the three axles were received on February 23, 1958. The three pieces bore no identifying markings, and one end of each of the three axles contained a fractured surface.

The axles were identified in the laboratory as follows:

Axle A: -	Approx. 6-in. long	3-7/16 in. diameter
Axle B: -	Approx. 8-in. long	3-7/16 in. diameter
Axle C: -	Approx.13-in. long	3-5/8 in. diameter

The appearance of the fractures, as received, is shown in Figure 1.

INVESTIGATION PROCEDURE

1) Visual inspection of fractured surfaces and surface of axles adjacent to the fracture.
2) Chemical analysis.
3) Mechanical properties (tensile, impact and hardness tests).
4) Metallographic examination.

1. Visual Inspection of Fractured Surfaces

In all three axles, the fracture consisted of two distinct areas. The larger area exhibited a smooth surface due to the propagation of a fatigue crack which initiated at the periphery. The smaller and rougher part of the fracture, largely enclosed by the smoother part, showed where the final break occurred. The appearance of these fractures is typical of fatigue failures in rotating bending.

The outside surfaces of axles A and B adjacent to the fractured surfaces showed indications of a small fillet. The outside surface of axle C adjacent to the fracture showed a marked degree of corrosion pitting.

According to information received, all the sheaves are of the bicycle type, each weighing between 2,500 and 3,000 lb complete with its respective axle. The sheave attached to axle C (7 ft diameter), normally carried a maximum load of approximately 10,200 lb, and during operation rotated at 54 rpm.

Due to the axles being received without identification, it was difficult to match information received with the other two axles (A, B), both being of the same diameter (3-7/16-in.). However, one axle operated under these conditions: bicycle type sheave 6 ft 10-7/16 in. diameter, normal maximum load 14,784 lb, operating speed 45 rpm. The remaining axle operated as follows: bicycle type sheave 6 ft 11-1/8 in. diameter, normal maximum load 13,534 lb, operating speed 45 rpm.

The specifications to which the axles were manufactured are not available; their length of service is estimated at thirty years.

2. Chemical Analysis

Drillings from the three axles were submitted for chemical analysis, and the results obtained are given in Table 1.

TABLE 1

Chemical Analysis

Axle	C %	Mn %	Si %	S %	P %	Ni %	Cr %	Mo %
A	0.42	0.78	0.28	.015	.029	1.20	.53	0.17
B	0.40	0.76	0.28	.015	.029	1.20	.51	0.16
C	0.20	0.40	0.01	.047	.013	N.D.	.03	0.09

It would appear that axles A and B are made from identical steel conforming to the analysis of Atlas Steels grade SPS 245. Axle C conforms satisfactorily to the analysis of type AISI 1020 semi-killed steel.

3. Mechanical Properties

The tensile properties of each sample were determined using a standard 0.505 in. diameter tensile test bar with a 2 in. gauge length. Brinell hardness values were determined at the mid-radius of each axle. The results obtained are given in Table 2.

TABLE 2

Mechanical Properties

Axle	UTS psi	Yield Point psi	Elong. %	Red. in Area %	Brinell Hardness
A	101,200	61,500	28.5	55.1	205
B	101,500	63,800	29.0	56.7	201
C	50,600	23,400	44.0	60.5	98

4. Metallographic Examination

Photomicrographs of the etched structures of the three axles are shown in Figures 2, 3 and 4. All samples for metallographic examination were cut from the fractured ends of the axles and at right angles to the fracture surface. There is a marked similarity between the microstructures of axles A and B, both showing the type of ferrite -pearlite structure which would be expected from the chemical analysis and the mechanical properties. The microstructure of axle C also appears to be consistent with the chemical analysis and mechanical properties.

The samples were also examined in the unetched condition. The type and amount of non-metallic inclusions were consistent with good steelmaking practice.

DISCUSSION

The fractured surfaces on all three axles are typical of fatigue failures. The axles A and B show indications of a fillet on the surface adjacent to the fracture face; the small radius (1/4 in.) used for this fillet would give a stress concentration factor of about 1.75 and would account for the failures originating in this region.

From the information supplied on the axles and an examination of the fractures, it is considered that the majority of the thirty years' service of the sheave wheels and axles was completed before a crack was initiated, and after initiation a relatively short time elapsed before the complete fracture occurred. Due to the fact that the axles A and B had run for a long time without failure, it is also considered that some increase in axle loading occurred a relatively short period before complete failure. This increase in axle loading could take many forms, e.g., change in bearing alignment, partial or complete seizure of one or both bearings, or higher operating rope loads.

Axle C showed no indication of a fillet on the shaft, but adjacent to the fracture surface was a band of heavy corrosion pitting. Examination showed that small hairline cracks had developed at the base of some of the pits. This is illustrated in

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Axle C showed no indication of a fillet on the shaft, but adjacent to the fracture surface was a band of heavy corrosion pitting. Examination showed that small hairline cracks had developed at the base of some of the pits. This is illustrated in

Figure 5. It is considered that the method of failure has been one of corrosion fatigue, whereby the most severe cracks developed on approximately the same plane at the edge of the hub, and joined up to form a continuous crack around the periphery of the shaft. The central location of the fibrous portion of the fracture indicates a high stress condition, due to stress concentrations at the roots of the corrosion pits. This condition need not necessarily be associated with higher applied load.

CONCLUSIONS

Three mine sheave axles, which failed after about thirty years' service, were examined and the following conclusions were drawn:

1) The fractures were all characteristic of transcrystalline fatigue failure.
2) Fatigue failure of axles A and B was initiated at a stress concentration due to a small radius fillet used at the change of diameter on the shafts; it is considered that some increase in loading during the latter part of their life was responsible.
3) Failure of axle C was initiated by corrosion;

from the appearance of the surface of the shaft, it is probable that the corrosion pitting was due to attack by the atmosphere. The pits caused by corrosion acted as stress raisers.

4) No specifications were available for the material of the shafts, but the microstructure in each case was consistent with the chemical composition and mechanical properties, and showed no abnormalities.

RECOMMENDATIONS

In order to increase the fatigue resistance of the shafts, the following proposals are put forward:

1) Increase the fillet radius on axles A and B; a 1 in. fillet, for example, would reduce the stress concentration to 1.28.
2) Protect shaft C from corrosion, particularly in the region of the sheave hub.
3) Check the alignment of the shaft, and lubrication of the bearings, and avoid excessive loads.
4) Use a material of higher strength, e.g., heat-treated SPS 245 steel.

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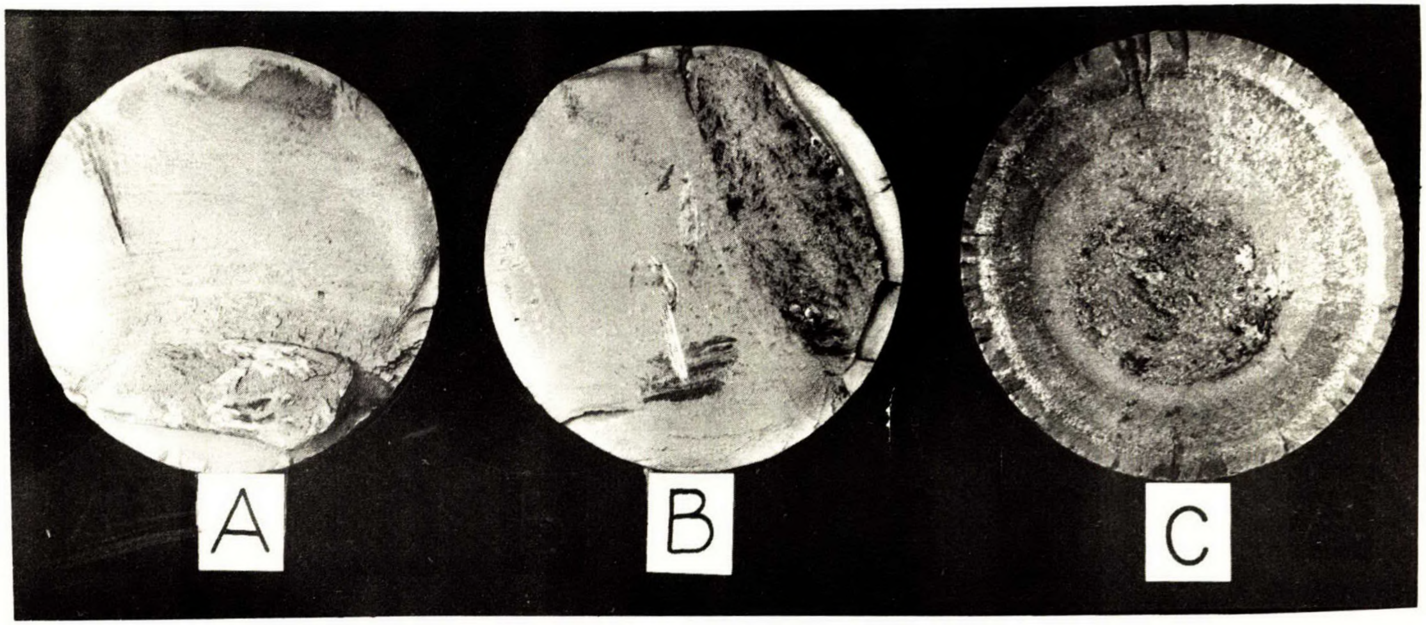

Figure 1. - Fracture surfaces of the three axles, as received.

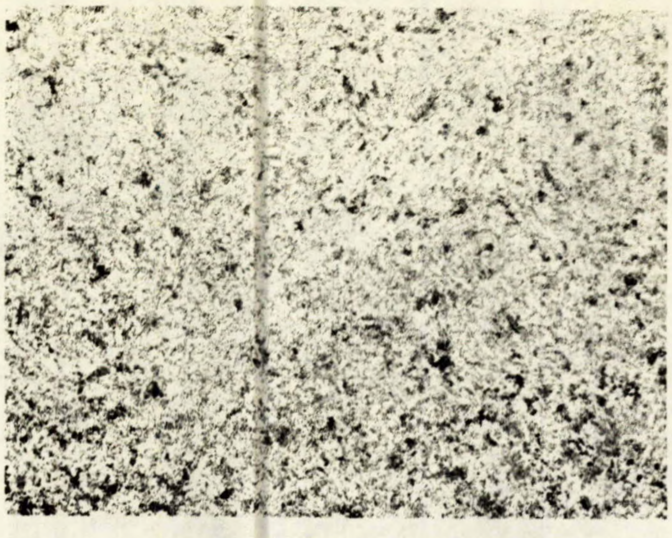

Figure 2. - Axle A - taken at right angles to fracture face.
(X100; Etched in 2% Nital)

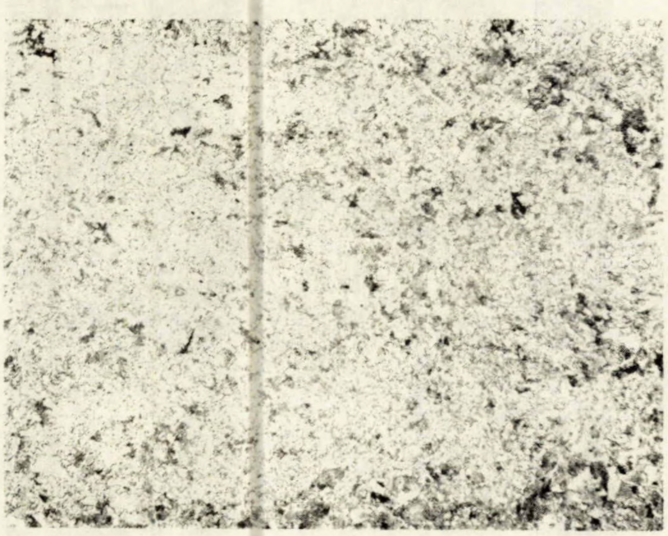

Figure 3. - Axle B - taken at right angles to fracture face.
(X100; Etched in 2% Nital)

Figure 4. - Axle C - taken at right angles to fracture face. (X100; Etched in 2% Nital)

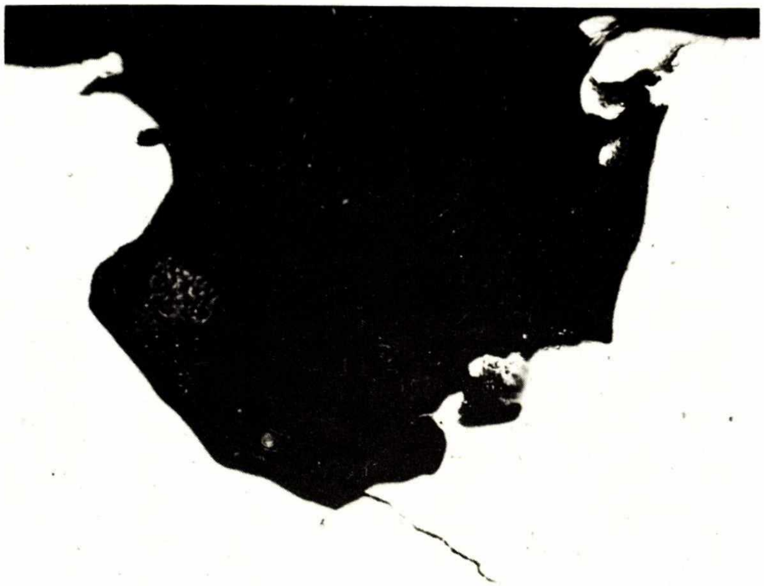

Figure 5. - Axle C - taken at right angles to fracture face, showing a corrosion pit with crack at the root. (X400; Unetched)