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INVESTIGATION OF FAILURE OF STUB AXLES ON ROAD GRADERS

by

R. D. McDONALD

PHYSICAL METALLURGY DIVISION

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R. D. McDonald*

SUMMARY OF RESULTS

The examination showed that the stub axles failed due to fatigue. The cause of the failure was due primarily to the low strength level of the axles when compared with the requirements shown in the specification. This low strength level resulted from inadequate, or probably lack of a final heat treatment, and the application of a lower alloy material than that stated in the specification.

In addition to the above, it was observed that the heat treatment, hardness and tensile strength level shown on the specification drawing, are not suitable for the steel required.

There was evidence of slight decarburization, and of poor machining in the fillets, both of which could be factors which contributed to the failure.

*Senior Scientific Officer, Physical Metallurgy Division, Mines Branch, Department of Mines and Technical Surveys, Ottawa, Canada.

INTRODUCTION

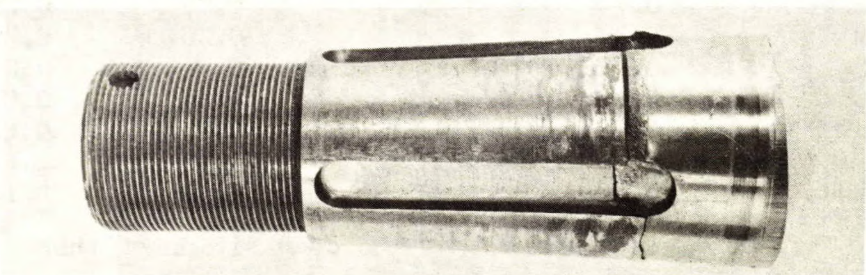
In a letter dated December 11, 1961, The Dominion Road Machinery Company Limited, Goderich, Ontario, requested assistance in determining the cause of "premature failures" of grader stub axles. Two of the failed axles were submitted for investigation.

VISUAL EXAMINATION

Figures 1 and 2 show a transverse and a longitudinal view of the two axles submitted, one of which had not broken off completely.

2/3 actual size

Figure 1. Surface of the fracture of one of the failed axles, showing fatigue markings originating at the keyway at the top of the photograph.



1/2 actual size

Figure 2. Longitudinal view of the incompletely broken axle showing a well opened crack.

The examination revealed that both fractures resulted from fatigue originating at a keyway, progressing to the second keyway, and then to final failure. Although it is likely that the failures originated at the bottom fillets in the keyways, there is some indication that a crack might initiate at the edge of a keyway at a junction with the surface of an axle. The fractures progressed through approximately two-thirds of the cross-section prior to final failure.

There was visual evidence of poor machining in the keyways, frequently resulting in a slight groove or step at the junction of a fillet and the side wall. The fractures show indications of adequate ductility.

CHEMICAL COMPOSITION

The composition of material obtained near the fracture of the axle (1) that had broken off completely, is compared in Table 1 with typical compositions of Atlas machinery steels Ultimo-4 and SPS-245. The percentages of only the three elements shown were determined for axle (2).

TABLE 1

Chemical Composition (Per Cent)

	Grader Axles (1)	Grader Axles (2)	Ultimo-4	SPS-245
Carbon	0.41		0.45	0.40
Manganese	0.70		0.75	0.75
Silicon	0.23		0.20	0.20
Sulphur	0.014		0.030 max	0.030 max
Phosphorus	0.030		0.030 max	0.030 max
Chromium	0.48	0.56	0.75	0.60
Nickel	1.09	1.06	1.75	1.25
Molybdenum	0.18	0.18	0.40	0.15

This comparison shows that the composition of these axles is similar to SPS-245 and is low in alloy content for typical Ultimo-4 material.

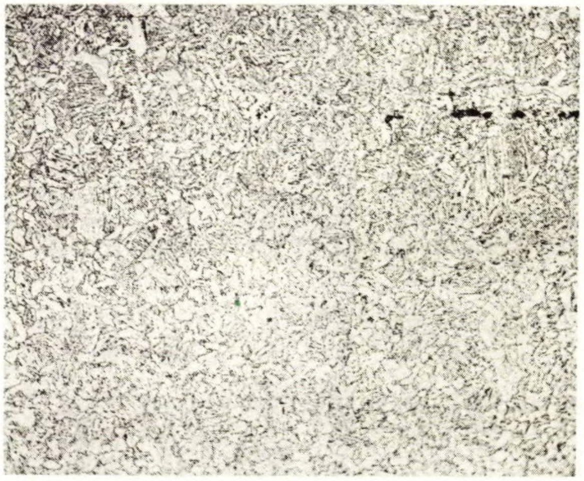
HARDNESS TESTS

Several hardness tests were carried out on the cross-sections of both axles. These show a reasonably uniform hardness averaging 201 Brinell throughout the cross-sections.

The hardness values obtained are indicative of an ultimate tensile strength of approximately 100,000 to 105,000 psi. The hardness and tensile strength requirements shown on the assembly drawing, GR-C-3037, are 250 Brinell and 150,000 psi, respectively.

METALLOGRAPHIC EXAMINATION

The examinations of both axles show microstructures typical of a low alloy steel that has received a normalizing and spheroidizing heat treatment. Each of the microstructures consists of spheroidized carbides in a ferritic matrix. The microstructure is shown in Figure 3.



Etched in 2% nital X250

Figure 3. Microstructure of a section taken near the fracture of the completely broken axle. This microstructure could be developed by a normalizing and spheroidizing heat treatment.

DISCUSSION

The most significant results of this examination concern the hardness and tensile strength. It is evident that the mechanical property requirements shown on the drawing (250 Brinell and 150,000 psi ultimate tensile strength) do not coincide with those indicated by the hardness values (201 Brinell average) shown by the tests. Furthermore, the 250 Brinell value does not coincide with the 150,000 psi specified on the drawing. In fact, 250 Brinell represents approximately 122,000 psi, and 150,000 psi represents approximately 300 Brinell.

The analyses of these shafts showed that SPS-245 had been used instead of Ultimo-4. Atlas Steels Limited list a hardness of 241 Brinell and 117,000 psi for a 4 in. section of this material after oil quenching and tempering at 650°C (1200°F). The same heat treatment on Ultimo-4 would provide approximately 136,000 psi at 277 Brinell. A tempering temperature of 660°C (1225°F) is not listed but would provide a slightly lower strength level.

The slight decarburization observed at the surface would further reduce the strength level of a thin layer of surface material thereby contributing to the initiation of fatigue failure.

From the above comments, one can readily select the following points for consideration in the interest of improving the product:

1. A reassessment of the strength and hardness requirements should be made, and when this has been done, the correct heat treatment can be established to provide the required properties, eg, a section of Ultimo-4 steel of 4 in.

diameter, oil quenched and tempered at 650°C (1200°F) provides a tensile strength of 136,000 psi and a hardness of 277 Brinell. These values will be lower for Atlas SPS-245 steel.

2. Drawing GR-C-3037 should be corrected because it apparently provides the heat treatment plant with the requirements and heat treating procedures. None of these requirements as shown, hardness, strength or draw treatment, is in agreement either for Ultimo-4 or SPS-245 materials.

3. Some improvements are desirable in machining keyway fillets to avoid grooves or steps which were detected at junctions of fillets and side walls.

4. It is probable that the material used for these axles was in the condition of "best machinability" for Ultimo 4 (ie normalized and reheated to 675°C (1250°F)) and had not received a quenching treatment. Although quenching may have been attempted, the technique has not provided a quenched microstructure. This could account for the very low strength level.

CONCLUSIONS

1. The failures resulted from fatigue originating at a keyway.
2. The material is similar to Atlas machinery steel SPS-245 and not Ultimo-4, as shown on drawing GR-C-3037.
3. The material is much lower in strength level and Brinell hardness than the requirements shown on drawing GR-C-3037
4. The material has not received an adequate quench and temper to provide the desired strength level.
5. The instructions provided on drawing GR-C-3037 do not give correct information for the development of a strength level of 150,000 psi, ie, the hardness is too low and a tempering temperature of 660°C (1225°F) would not provide a strength level of 150,000 psi in a 4 in. section of Ultimo-4.

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