BUREAU OF MINES
DIVISION OF METALLIC MINERALS

ORE DRESSING AND
METALLURGICAL LABORATORIES

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
MINES AND GEOLOGY BRANCH

O T T A W A November 22nd, 1940.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 928.

Report on a Stub-Axle from a 2-Pounder Gun.

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Origin of Problem and Nature of Investigation:

A letter from the office of the Director of Technical Research (H.Q. 46-1-75 / H.Q. 46-61-4 D.T.R.), Department of National Defence, Ottawa, Ontario, dated November 13th, 1940, asked for a report on the probable cause of failure of a stub-axle from a 2-pounder gun.

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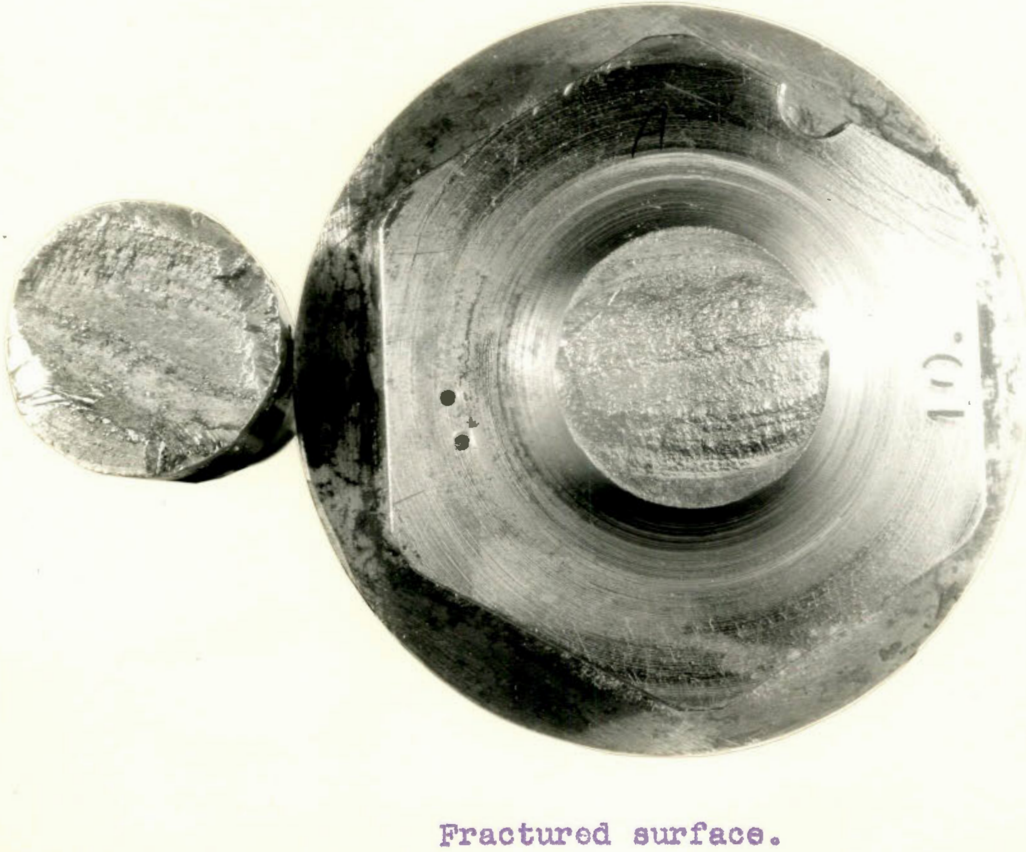
Macro-Examination:

Figure 1.

Axle as received.

The axle was machined out of a piece of bar stock. Fracture occurred at the base of the axle.

Figure 2.



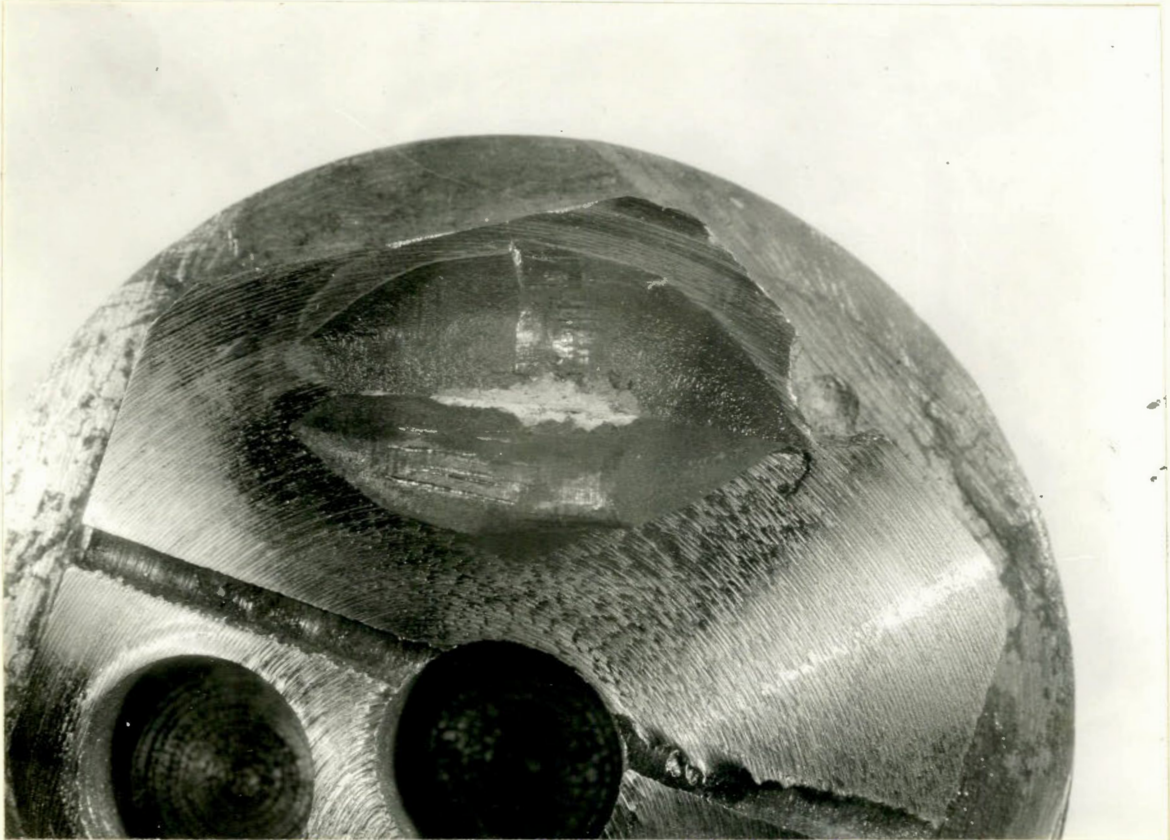
Fractured surface.

(Continued on next page)

(Macro-Examination, cont'd) -

Figure 2 shows the nature of the fracture. Smooth crescent-shaped fatigue cracks can be seen on opposite sides of the shaft, reducing the effective cross-section to about 70 per cent of its original area.

Figure 3.



Flaw uncovered in machining for impact test. x2.

In preparing samples for impact and micro-examination, a flaw was uncovered. This is shown in Figure 3. As the surface shown at (A) in Figure 2 was machined down, a crack appeared. A cold chisel was used to pry open the crack and expose the flaw. The defect as shown in Figure 3 is about 1-3/8 inches long and 3/8 inch wide, running perpendicular to the surface of the bar stock.

Micro-Examination:

Figure 4.

Edge of fracture.
x100, unetched.

Figure 4 shows the fractured surface passing through a dirt cavity.

Figure 5.

Dirt inclusions in steel.
x100, unetched.

The metal contained a considerable quantity of dirt, as is shown in Figure 5. The inclusions tended to be grouped in areas. The fracture ran through quite a few foreign inclusions.

(Continued on next page)

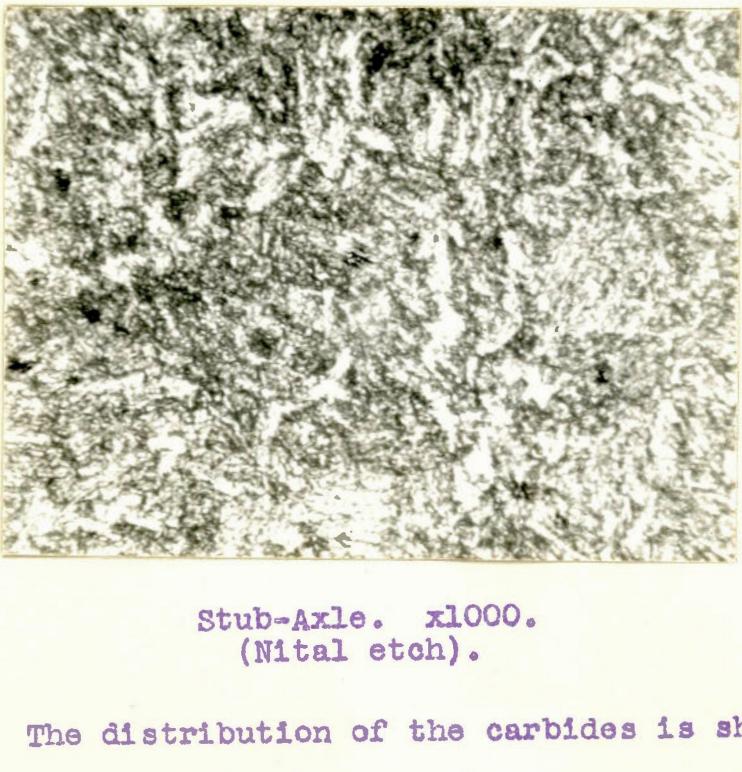
(Micro-Examination, cont'd) -

Figure 6.

Stub-Axle. x100.
(Nital etch).

The structure shown in Figure 6 is that of a fine-grained alloy steel.

Figure 7.



Stub-Axle. x1000.
(Nital etch).

The distribution of the carbides is shown in Figure 7. This is typical of a good quality nickel steel.

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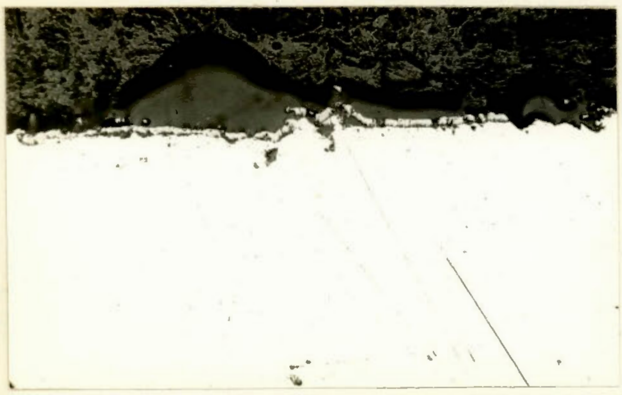
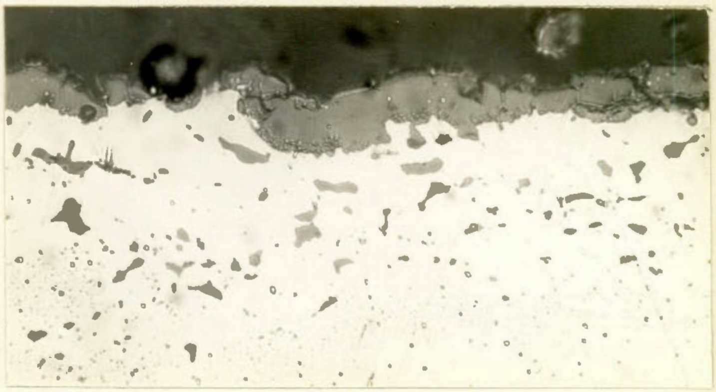
(Micro-Examination, cont'd) -

Figure 8.



Edge of flaw.
x100, unetched.

Figure 9.



Edge of flaw.
x500, unetched.

Examination of the flaw shown in Figure 3 shows a layer of slag on the surface of the flaw. This slag is composed of oxides and silicates. The metal is decarburized at the surface of the flaw.

Hardness:

Tests taken across the diameter of the shaft show a uniform hardness of 350 V.H.N.

Impact:

A test piece cut parallel to the rolling axis gave an Izod impact value of 84-87 foot pounds.

Chemical Analysis:

(Per Cent)

	Stub-Axle as found.	Two steels recommended by their manufacturers for use in axles. S.A.E. 2335	Firth FN-3
Carbon	0.33	0.30 - 0.40	0.25 - 0.40
Manganese	0.65	0.50 - 0.80	
Silicon	0.26	0.15 - 0.30	
Sulphur	0.031	0.04 max.	
Phosphorus	0.029	0.05 max.	
Chromium	0.21		
Nickel	2.96	3.25 - 3.75	2.75 - 3.25

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(Chemical Analysis, cont'd) -

The analysis corresponds to that of nickel steels commonly used for axles.

DISCUSSION OF RESULTS:

Machining -

The rough machined surface on this axle lowers its bending fatigue strength. According to Sachs (Iron Age, Sept. 5, 1940), a ground finish would probably have 20 per cent greater bending fatigue strength.

Flaw -

It is apparent that a slag-and-oxide seam existed in the billet. This was not discovered after rolling although its decarburized surface indicates that the flaw extended to the outside of the bar.

The slag seam shown in Figure 3 is not in a part of the axle which is under stress. However, it is possible that the lot of steel from which this axle was made may have more flaws in it. The metal may be classed as "unsound".

Foreign Inclusions -

Foreign inclusions, or "dirt", affect the physical properties of metal, especially its resistance to alternating stresses. Without having had the opportunity to run fatigue tests on this lot of steel we cannot state the exact effect of these inclusions. However, it is significant that the fracture passed through a group of inclusions. Most of the "dirt" is in the form of oxides.

Microstructure -

The structure of the metal shows finely dispersed carbides indicative of a satisfactorily quenched and drawn alloy steel.

(Discussion of Results, cont'd) -

Impact Strength -

The steel is strong and tough. If no serious foreign inclusions or flaws were present, and the machined surface were smooth, this material should give good service under severe conditions.

Hardness -

The hardness (350 V.H.N.) indicates that the tensile strength of the material is about 165,000 p.s.i. and the theoretical fatigue strength is about 82,000 p.s.i. Hardened steel is very sensitive to notches, flaws, and inclusions. These defects lower the actual fatigue strength.

Soft steel is less sensitive to the "notch effect", therefore its actual fatigue strength is not affected so much by minor flaws.

The influence of hardness on the suitability of machine parts similar to an axle is shown as follows:

V. H. N.	Remarks.
100	Too plastic.
--	Unsatisfactory because of low fatigue strength.
200	Suitable for rough machined parts.
300	Suitable for smooth machined parts.
400	Suitable for ground finish parts.
500	Unsatisfactory because of high notch sensitivity and brittleness.

Chemical Analysis -

The analysis is that of a medium carbon nickel

(Discussion of Results, cont'd) -

(Chemical Analysis, cont'd) -

steel. Steels of this type are considered satisfactory for use as axles.

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<u>Conclusions</u>:

1. The metal is strong and tough.
2. It is hard enough to be very sensitive to notches or "stress raisers".
3. Flaws in the metal probably acted as "stress raisers" and lowered the actual fatigue strength to the point where the axle failed.

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