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OTTAWA May 12th, 1944.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1641.

Examination of Broken Austenitic Manganese
Steel Dipper Tooth.

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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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Foreword:

On April 14th, 1944, a broken piece of a cast manganese steel dipper tooth was received from Joliette Steel Limited, Joliette, Quebec. This was accompanied by correspondence signed by Mr. R. Rivest, of the company's Sales Engineering Department, requesting a complete metallurgical examination.

Description of Sample:

The minimum section of the broken tooth submitted was 2½ inches. There were evidences of cracks on the surface of this casting.

Chemical Analysis:

A sample was obtained for chemical analysis. The steel composition was found to be as follows:

		Per Cent
Carbon	-	1.42
Manganese	-	10.24
Silicon	-	0.16
Nickel	-	Trace.
Chromium	-	0.12

Microscopic Examination:

Two specimens were prepared for metallographic examination, one from the centre of the section and one from near the surface. These were polished and etched with 4 per cent picral. The structures are shown in Figures 1, 2 and 3, photomicrographs at X30 magnification.

Figure 1 shows the structure at the surface. Note that for a depth of about one or two grains the structure is normal for properly heat-treated manganese steel, while farther below the surface carbides begin to appear.

Figure 2 shows the structure existing about ½ inch below the surface. There are many carbides present and, also, cracks along the grain boundaries.

Figure 3 is the structure at the centre of the section. Note the abundance of acicular carbide. This is the characteristic "as cast" structure.

Heat Treatment:

The remaining portion of the broken tooth was heated at 1940° F. for 6 hours and then water-quenched. The observed structure was similar in all respects to the structure before this heat treatment. The structure existing about 1 inch below the surface after this heat treatment is

(Heat Treatment, cont'd) -

shown in Figure 4, at a magnification of 30 diameters. Note the presence of acicular carbides.

A piece, about 2" x 1½" x ¾", cut from the tooth, was heated to 1940° F. for 3 hours and water-quenched. The structure obtained by this treatment is shown, at X100 magnification, in Figure 5. Note that there are still some carbides present, although their amount has been greatly reduced.

Discussion of Results:

The obvious conclusion, after an examination of the structure present in the broken tooth when received, is that it was not properly heat treated. The metal section is just about the maximum for proper response to heat treatment. However, when soaked at 1940° F. for 6 hours and then water-quenched this structure persisted, and only when a small piece was treated could the bulk of the carbides be eliminated. Even this very ideal treatment could not eliminate all of the carbides. One would conclude, then, that the response of this steel to heat treatment, rather than improper heat treatment, was responsible for the presence of carbides after quenching.

Chemical analysis results show the carbon content to be 1.42 per cent and the manganese, 10.24 per cent. This is a shade over the maximum carbon usually specified for austenitic manganese steel and just over the minimum manganese usually specified for austenitic manganese steel. Evidently, with this combination of carbon and manganese, a marginal product is obtained, the austenite formed at the solution temperature not being sufficiently stable to prevent carbides from forming even on the most drastic quenching possible for this section. It would be advisable to lower the carbon to

(Discussion of Results, cont'd) -

about 1.2 per cent and raise the manganese to 13 per cent to obtain a metal that would not precipitate carbides on quenching this section size.

CONCLUSIONS:

1. The carbides present in the tooth as received were formed during quenching because the carbon was too high and the manganese too low to prevent their formation.

2. The presence of this massive acicular carbide is responsible for the failure of the tooth.

Recommendations:

It is recommended that an effort be made to hold the carbon within the limits of 1.0 to 1.3 per cent and the manganese within the limits of 11 to 14 per cent.

It is not recommended that any changes be made in the present heat treatment practice.

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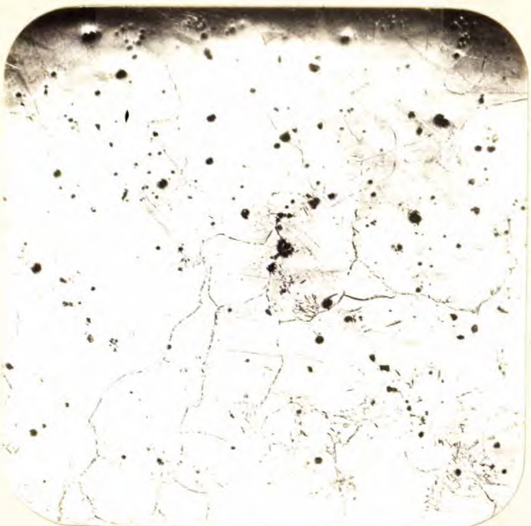
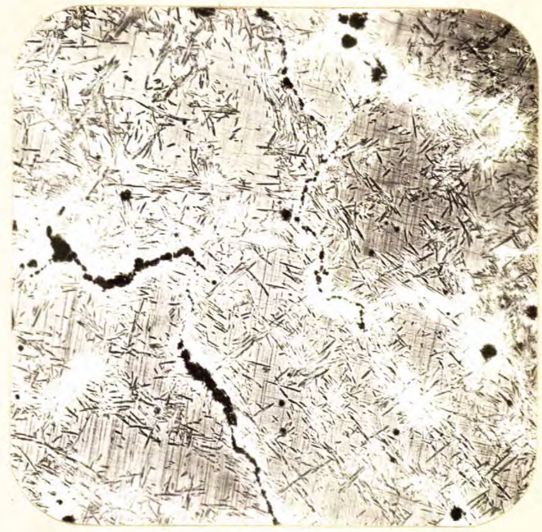
Figure 1.



X30, picral etch.

PHOTOMICROGRAPH SHOWING STRUCTURE AT SURFACE OF BROKEN TOOTH.

Figure 2.

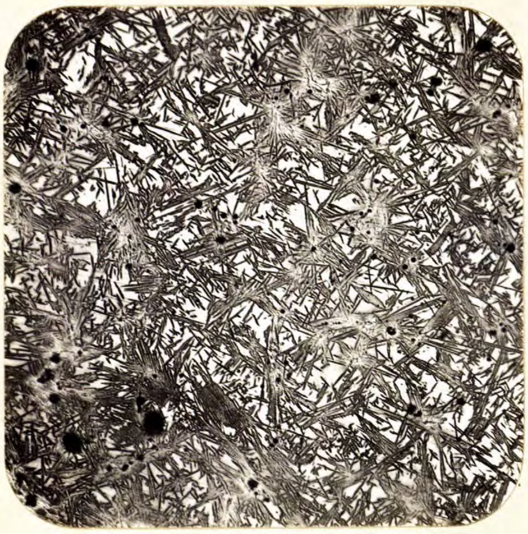


X30, picral etch.

PHOTOMICROGRAPH SHOWING STRUCTURE AT A DISTANCE OF ABOUT $\frac{1}{2}$ INCH BELOW THE SURFACE OF BROKEN TOOTH.

Note increased amount of carbides.

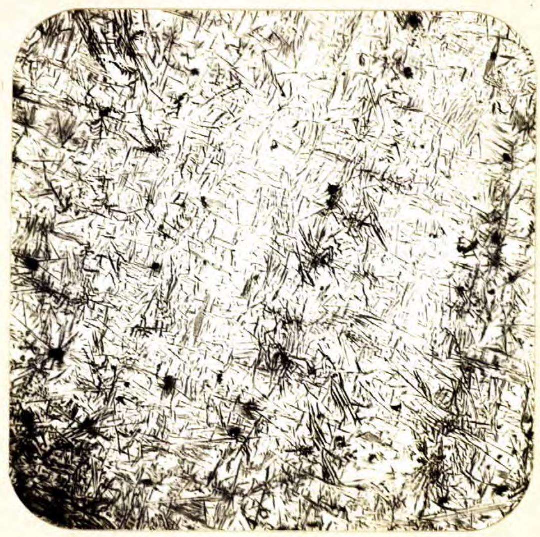
Figure 3.



X30, picral etch.

PHOTOMICROGRAPH SHOWING STRUCTURE AT CENTRE OF SECTION.

Figure 4.

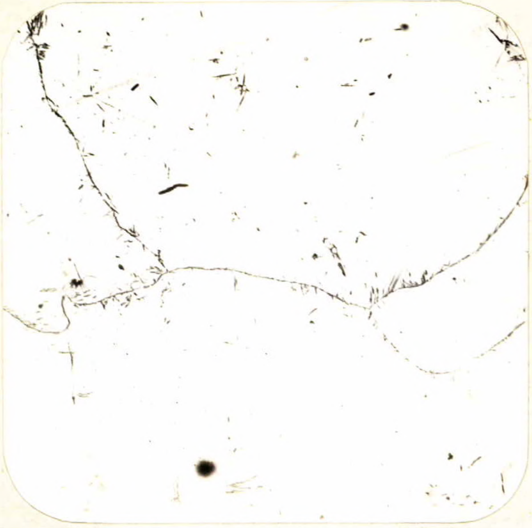


X30, picral etch.

PHOTOMICROGRAPH SHOWING STRUCTURE 1 INCH BELOW SURFACE AFTER COMPLETE TOOTH WAS HEATED AT 1940° F. FOR 6 HOURS AND WATER-QUENCHED.

Note presence of carbides.

Figure 5.



X100 picral etch.

PHOTOMICROGRAPH SHOWING STRUCTURE AFTER HEATING PIECE, 2 x 1½ x ¾ INCHES IN SIZE, AT 1940° F. FOR 3 HOURS AND WATER-QUENCHING.

Note presence of carbides at grain boundaries.

HVK:GHB.