Lab.

OTTAWA June 26, 1946.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 2064.

Metallurgical Examination of Manganese Steel Dipper Tooth Which Broke in Service

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(Copy No. 4.)

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

CANADA
DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

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Origin of Material and Object of Investigation:

On May 15th, 1945, a broken manganese steel inserted dipper tooth point (Patt. 15220-X) (See Figures 1 and 2), was submitted for metallurgical examination by Sorel Steel Foundries Limited, Sorel, Quebec, per H. M. Brownrigg, Metallurgist.

The covering letter, dated May 7th, 1946, stated that the point had both bent and broken in service, and was typical of several similar failures. It was requested that a metallurgical examination be carried out in order to determine cause of failure.

Figure 1.

BROKEN DIPPER TOOTH

Arrows point to numerous transverse cracks.

(Approximately 1/5 actual size)

Figure 2.

BROKEN DIPPER TOOTH,

Showing Fracture.

Procedure:

1. Visual Examination:

Visual examination revealed numerous transverse cracks on the upper surface of the tooth in the fillet area and running parallel with the failure.

2. Chemical Examination:

The results of the chemical analysis are as follows:

		Per Cent
Carbon	-	1.18
Manganese	-	12.59
Silicon	-	0.76
Sulphur	-	0.010
Chromium	-	0.43
Nickel	-	Nil.
Molybdenum	-	Trace.

3. Hardness Examination:

Hardness readings were made with a Vickers hardness tester to determine the body hardness of the tooth. The depth of work hardening was determined by means of a Tukon microhardness tester. The results are as follows:

		Vickers	Rockwell "C" (Converted)
Body Hardness	-	285-291	28-29

Depth of Work Hardness (Tukon Hardness Tester)

Distance from Surface, (inches)		Hardness (Rockwell "C")
0.002	-	48
0.004	-	51
0.012	-	48
0.018	-	50
0.024	-	42
0.030	-	29
0.036	-	30

4. Microscopic Examination:

Figures 3 and 4, taken at X50 and X100 magnifications respectively, show the typical transverse surface cracks occurring in the fillet area on the upper surface of the tooth adjacent to the fracture. Figure 4 illustrates the transcrystalline nature of the cracks.

Figure 5, taken at X50 magnification, indicates the large grain size resulting from high pouring temperature.

Figure 6, taken at X100 magnification, shows brittle, intergranular excess carbides resulting from insufficient cooling rate. This condition is not representative of the structure of the steel in general.

Figure 7, taken at X50 magnification, shows porosity in the metal.

Discussion:

Visual and microscopic examination revealed the presence of numerous transverse surface cracks occurring in the fillet area on the upper surface of the tooth adjacent to the fracture. It should be noted that all the cracks occur in a direction parallel to the fracture, and it appears certain that failure must have resulted from a continuation of one of these cracks. It is also significant that failure occurred at the fillet on the top surface, at an area of maximum stress. Because no cracks were found on the lower, opposite surface of the tooth, it would appear that the propagation of the cracks and subsequent failure resulted from the application in service of load conditions in excess of the yield strength of the steel.

The chemical composition of the dipper tooth was found to be in agreement with the A.S.T.M. specifications. There does not appear to be any information reported in the literature concerning the effect of the various elements on the yield strength of austenitic manganese steels. Some manufacturers claim that chromium in moderate amounts increases the yield strength. The analysis shows a chromium content of 0.43 per cent. It is possible that increasing the chromium to 1.35 per cent may be more effective in raising the yield strength. A comparison of the chemical compositions of dipper teeth which have failed in service with those which have not failed might help to throw some light on this subject.

The results of the hardness test made with the Tukon hardness tester proved that some work hardness had taken place in the area where failure had occurred, but that this hardened layer was very shallow, not extending beyond 0.036 inch.

The shotblasting of steels for increasing the fatigue strength is now common practice. Prestressing of manganese steel dipper teeth might be tried. However, the loads would have to be very heavy in order to produce any appreciable depth of work hardening. It is possible that such treatment may retard the formation of the surface cracking encountered in this problem, but predictions would be extremely hazardous.

The heat treatment was found to be satisfactory. Excess carbides, indicating insufficient cooling velocity, were found in one isolated case (See Figure 6). Since no carbides were noted in the areas where cracking occurred, little or no significance can be attached to this one isolated case.

Casting porosity (See Figure 7) was also noted, but cannot be regarded as of much significance since a certain amount of porosity is to be expected.

Assuming that failure resulted from the application in service of loads exceeding the yield strength, and since very little information is available about increasing the yield strength by changes in the chemical composition, the only other alternative would be a change in design. There should be a greater thickness of metal in the fillet area, and the fillet radius should be made as great as possible.

Conclusions:

1. Failure was most likely caused by the application in service of loads in excess of the yield and ultimate tensile strength of the metal.

2. The chemical composition and the heat treatment were found to be satisfactory.

Recommendations:

1. It is recommended that consideration be given to changing the design of the tooth. There should be a greater thickness of metal in the fillet area, and the fillet radius should be made as great as possible.

(Recommendations Cont'd)

2. It is suggested that pre-peening of the highly stressed surfaces be tried in order to increase the fatigue strength of the metal.

3. A study should be made of the performance in service of dipper teeth cast from metal containing a higher chromium content, e.g., 1.35 per cent.

4. A statistical comparison should be made of the chemical compositions of dipper teeth which failed in service with those which did not fail.

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(Figures 3 to 7 follow,)
(on Pages 7 to 9.)

Figure 3.

X50, unetched.

TYPICAL TRANSVERSE SURFACE CRACKS OCCURRING IN THE FILLET AREA ON UPPER SURFACE OF TOOTH ADJACENT TO THE FRACTURE.

Figure 4.

X100, nital etch.

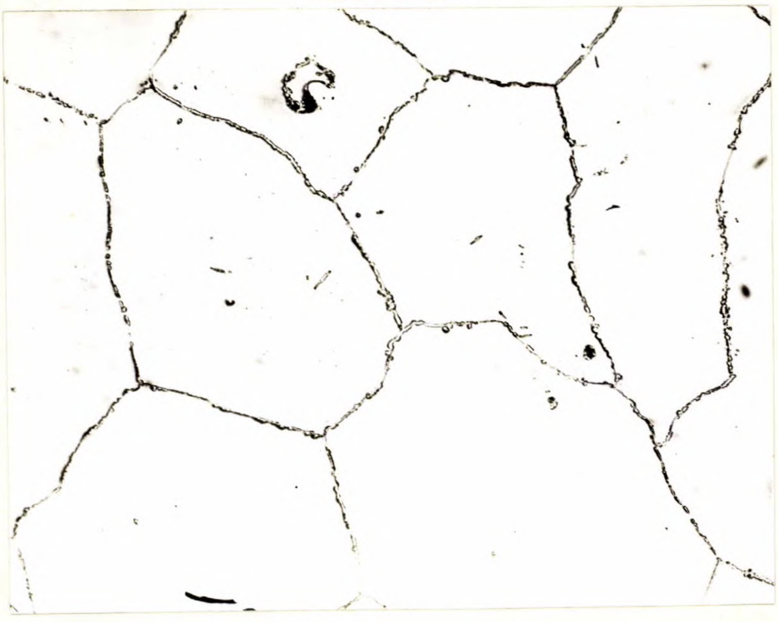
Note transcrystalline surface crack.

Figure 5.

X50, nital etch.

LARGE GRAIN SIZE RESULTING FROM
EXCESSIVE POURING TEMPERATURE

Figure 6.

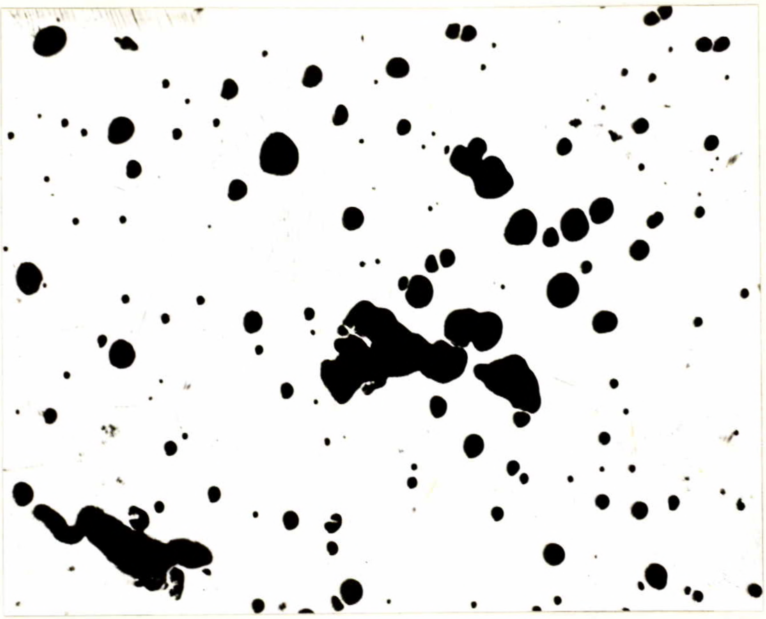


X100, nital etch.

BRITTLE, INTERGRANULAR, EXCESS CARBIDES
RESULTING FROM INSUFFICIENT COOLING RATE.

This is an isolated area and is not representative
of all of the steel.

Figure 7.



X50, unetched.

CASTING POROSITY.

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