OTTAWA August 23, 1945.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1922.

Metallurgical Examination of Three Austenitic Manganese Steel Samples.

(Copy No. 6.)

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 June 26, 1945, Sorel Steel Foundries Limited, Sorel, Quebec, submitted for metallurgical examination three (3) samples of austenitic manganese steel. The samples had been flame-cut from three castings which had the following history:

100-1. A sample of thin ball mill liner which ran for 574 days. This is considered a record for manganese steel.

100-2. Sample of thick liner taken from the same ball mill and having the same history as 100-1.

100-B. Sample from four (4) foot Symons Crusher Mantle. The mantle stretched so much in use it had to be replaced. It crushed 12,000 tons, against an average of about 35,000.

1922
8-a.c
L.H.M.

Chemical Analysis:

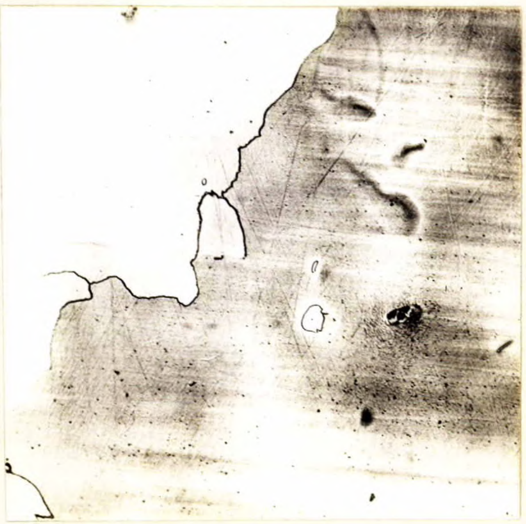
Sample No.	Carbon, per cent	Manganese, per cent	Silicon, per cent	Chromium, per cent
100-1	1.18	13.16	0.63	1.15
100-2	1.31	13.15	0.65	1.75
100-B	1.22	12.83	0.21	0.04

Microscopic Examination:

Microscopic examination of specimens taken from the three castings showed them to be free from blow holes and to contain no more than the usual amount of non-metallic inclusions.

The microstructures of Samples 100-1 and 100-2 were not completely austenitic but contained a mixture of austenite and cementite. Figure 1, a photomicrograph at X250 magnification, shows the microstructure of Sample 100-1. The cementite occurs as small particles within the austenite grains.

Figure 1.



X250, etched in 2 per cent nital.

SAMPLE 100-1.

Austenite and particles of cementite.

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1922

(Microscopic Examination, cont'd) -

The microstructure of Sample 100-2 contained more cementite than that of Sample 100-1; also, the greater proportion tion of the cementite is found at the austenite grain boundaries rather than within the grains. See Figure 2, a photomicrograph at X250 magnification.

Figure 2.

X250, etched in
2 per cent nital.

SAMPLE 100-2.

Austenite with relatively large particles of cementite located at an austenite grain boundary.

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The microstructure of Sample 100-B consists of large-grained austenite (see Figure 3, a photomicrograph at X100 magnification).

(Continued on next page)

(Microscopic Examination, cont'd) -

Figure 3.

X100, etched in
2 per cent nital.

SAMPLE 100-B.

Completely austenitic microstructure,
of large grain size.

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Discussion:

All three samples were free from casting defects such as shrinks and blow holes. They have a normal inclusion content and, apart from the higher chromium content of Samples 100-1 and 100-2, their chemical composition is in agreement with A.S.T.M. specifications for austenitic manganese steel.

It has been shown, however, that Castings 100-1 and 100-2 differ from Casting 100-B in three respects: (a) They have chromium contents of 1.15 and 1.75 per cent respectively, while that of Casting 100-B is not significant; (b) they have been so heat-treated that their microstructures consist of austenite and cementite, whereas in Sample 100-B the carbides are all in solid solution to give a completely austenitic microstructure; (c) Casting 100-B has a much larger austenitic grain size than the others, which, of

(Discussion, cont'd) -

course, indicates a higher pouring temperature.

Despite the fact that these samples may be classified in the same way on the basis of service, it is significant that they have also been used for different purposes, i.e., Samples 100-1 and 100-2, functioning as ball mill liners, would be subject to different stresses and conditions of wear than Casting 100-B, the mantle of a cone crusher. It is felt that the ball mill liners gave such excellent service, not because they have attributes of ideal austenite manganese steel castings, but because they have properties particularly suited to ball mill liners for a particular type of ball-milling operation.

Austenitic manganese steel owes its good wearing properties to a surface layer of martensite, the product of the austenitic break-down which occurs when the metal is subject to the impact of heavy cold work during service. If the metal is not subject to cold work (and quite likely some types of ball mill liners are not), the austenite does not break down and the material does not wear well.

It is claimed that the addition of from 1 to 3 per cent of chromium reduces the amount of cold work necessary to properly harden austenitic manganese steels. The fact that Samples 100-1 and 100-2 have a significant chromium content is a plausible explanation for their unusally good service.

It is, moreover, a well-known fact that the presence of small carbide particles in a softer matrix will produce remarkable wearing properties in a steel. It is therefore notable that these two ball mill liners have such a microstructure, with particles of iron-manganese carbide in an austenitic matrix. This structure gives better wear resistance than a completely austenitic structure <u>if the operating</u>

(Discussion, cont'd) -

conditions do not involve any cold work to the metal, but it does so at the expense of ductility, particularly when the carbide particles are located at the grain boundaries. From the record of these ball mill liners, it would appear that for such parts full ductility is not required and therefore the properties of Castings 100-1 and 100-2 were particularly well suited to their uses.

There is no apparent reason for the unsatisfactory behaviour of the Symons crusher mantle, other than that the service stresses imposed have exceeded the yield strength of a properly heat-treated casting of this composition. The yield strength of austenitic manganese steels is always low in proportion to the tensile strength, i.e., for a tensile strength of approximately 125,000 p.s.i. the yield strength would be about 35,000 p.s.i.

Microscopic examination has shown that the heat treatment of Casting 100-B was satisfactory and has produced a completely austenitic casting, which is considered the optimum condition for parts such as crusher mantles which must have considerable toughness as well as resistance to abrasive wear. The grain size of this casting is unusually large but, although this would likely reduce the impact strength, it is not known to cause low yield values. Assuming, then, that the casting in its optimum condition has not given satisfactory service, there is only one way, other than increasing the size of the section, to improve this condition and that is by a change in the chemical composition. It is generally agreed that silicon up to a limiting critical value is very valuable in increasing the yield strength and resistance to flow without substantial sacrifice of toughness. Some manufacturers claim that the addition of moderate amounts of

(Discussion, cont'd) -

chromium has the same effect. It is suggested that a comparison of chemical analysis of this mantle with others which have given more satisfaction may yield some information on this problem.

In general, this investigation has shown that the best service life is not necessarily obtained from austenitic manganese steel castings with a chemical analysis and heat treatment which has produced a completely austenitic microstructure. Variations in both factors might well be made to suit castings intended for different uses.

Obviously, more detailed information indicating which properties or characteristics of austenitic manganese steel are best suited to specific uses would be quite valuable to manufacturers of mining equipment. However, this investigation, as well as others in the past, was of necessity limited by the lack of information available about the working conditions under which the part failed, as well as the manner in which it failed.

Two factors determine the life of an austenite manganese steel casting: wear, and breakage. Wear is a function of the surface and is not necessarily influenced by the hardness of the body of the casting. Breakage, on the other hand, involves strength and ductility. Thus the value of a metallurgical examination would be greatly enhanced if, before it was started, some record had been made of the extent of wear, and if it was reported whether the casting had failed by fracturing or was removed because it had worn too thin. Also of value would be a record of the type of equipment, such as size of ball and type of ball mill, which might help to determine whether the metal had been subject to impact stresses or only to abrasive action.

(Discussion, cont'd) -

More consideration should also be given to the sample submitted. In castings of thick section, such as crusher cones, variations in microstructure may occur throughout the section or it may be advantageous to measure the amount of decarburization on surfaces which have not been exposed to wear. For such reasons, samples cut from the casting should be accompanied by a short description or a sketch showing the location from which it was taken, particularly with respect to any points of failure such as cracks or fractures.

As information regarding the working conditions which cause failure is obtained and correlated with the physical characteristics, laboratory tests, such as hardness, mechanical and bend tests, can be carried out and the results can with some assurance be used to predict service life of manganese steel castings in mining equipment.

<u>Conclusions</u>:

1. Samples 100-1 and 100-2, reported to have given record-breaking service as ball mill liners, are characterized by relatively high chromium contents. The heat treatment given these parts has not produced a completely austenitic microstructure.

2. Sample 100-B has a completely austenitic microstructure of relatively large grain size. It is suggested that the cause of failure might be determined by comparing the chemical composition of this with more satisfactory cone crusher mantles.

3. This investigation has indicated that improved manganese steel castings for mining equipment could be produced by using a different heat treatment and chemical

(Conclusions, cont'd) -

composition for ball mill liners as compared with cone crusher parts.

Recommendations:

1. It is recommended that further samples be submitted to check the results of this investigation, and that the samples should be accompanied, when possible, by a record of wear and manner of failure, as well as a description of the size and type of machine from which they were taken.

2. If samples are flame-cut, they should be approximately 1 foot square and the thickness of the casting.

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