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R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1374.

Investigation of the Conversion of a
High Manganese Cast Iron
into Austenitic Manganese Steel.



CANADA

BUREAU OF MINES
DIVISION OF METALLIC MINERALS
—
ORE DRESSING AND
METALLURGICAL LABORATORIES

DEPARTMENT
OF
MINES AND RESOURCES
MINES AND GEOLOGY BRANCH

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Purpose of Investigation:

The Birmingham Electric Furnaces Limited, in England, has recently developed a process for converting a high manganese white cast iron into austenitic manganese steel. As conceived in England, this process aimed at casting a white cast iron containing the elements in the same proportion as austenitic manganese steel except that the carbon content was between 3 and 4 per cent. This high

(Purpose of Investigation, cont'd) -

carbon was then reduced by a decarburization treatment so that on quenching from a high temperature a material metallographically and physically identical to austenitic manganese steel was formed.

After some trials Birmingham Electric did not deem it advisable to remove by decarburisation the carbon in the centre of the part but attempted only to form an austenitic layer on the surface. They applied this decarburization process to casting track links and reported successful operation of the links in service.

These Laboratories have also performed some experimental work on a high-manganese cast iron, with a view to determining the feasibility of using the process in Canada.

It is possible to cast a white iron with a much lower carbon content than is used in England and for this reason a melt was cast in these Laboratories with 2.5 per cent carbon content. This lower carbon content minimizes the propensity of this material to cracking on quenching (a common occurrence in the material cast in England) and shortened considerably the decarburizing times.

Origin of Material:

It was considered advantageous at this time to cast only test bars, and experiment with them. Bars of 9/16-inch diameter were cast and the investigational work was conducted on test pieces which were ground to the desired dimensions.

Two melts were cast from an induction furnace, each melt being approximately 45 pounds. Hematite, pig iron, ingot metal, ferromanganese, and ferrosilicon were used to obtain the desired analysis.

Chemical Analysis:

| | <u>Melt No. 1</u> | <u>Melt No. 2</u> |
|--------------|-------------------|-------------------|
| Carbon - | 2.99 | 2.50 |
| Manganese - | 12.23 | 15.24 |
| Silicon - | 1.54 | 1.03 |
| Sulphur - | 0.028 | 0.040 |
| Phosphorus - | 0.052 | 0.038 |

DECARBURIZATION TESTS:

Decarburization may be effected by using a solid decarburizing medium or a gaseous decarburizing medium.

Decarburization Using 60 per cent Hematite Ore and 40 per cent Mill Scale.

Although the solid decarburizing medium was not used to conduct all of the experimental tests, it was desired to ascertain whether this method was feasible. If it were, some of the malleable iron foundries could make use of this process with very little change in technique or equipment, since many have annealing furnaces suited to this method of decarburization.

Therefore, samples 1 inch in diameter of Melt No. 1 were packed in a mixture of 60 per cent hematite ore and 40 per cent mill scale (pure hematite ore would decarburize more rapidly but would scale and pit the material greatly) and heated to 1680° F. for 96 hours, after which they were cooled slowly to room temperature. Scaling was about 0.011 inch on a 1-inch-diameter rod. The samples were then heated in a neutral atmosphere to 1960° F. and quenched in water. In the core structure (that part not changed in composition by the decarburization treatment), there appeared quenching cracks; these, however, did not extend into the austenitic surface layer (formed by decarburization) which was 1/8 inch deep.

The rate of decarburization by this method may be adjusted by altering either the temperature, the percentages

(Decarburization Tests, cont'd) -

of hematite ore and mill scale, or the length of decarburization treatment. However, this adjustment involves lengthy experiments and it is sufficient to note that a cycle similar to that now used to manufacture whiteheart malleable can be used to produce this high manganese material.

Decarburization Using a Gaseous Medium.

By using a carbon dioxide atmosphere, decarburization could be effected very easily and for this work was found to be a very simple method.

The advantages were

- (1) Any range of temperatures could be used; and:
- (2) The specimens could be quenched directly, thus obviating the necessity of a reheat.
- (3) Very little scaling resulted.

Previous experiments in these laboratories on whiteheart malleable indicated that a satisfactory method of decarburization by using CO₂ was one in which the test bars were placed on a tray in an airtight container. The tray rests on a bed of pure hematite ore. No portion of the test bars was in contact with the ore. The container was sealed and the air replaced by carbon dioxide. The system was then heated to the required temperature.

The decarburization in such a system takes place through the carbon dioxide which is converted to carbon monoxide by reason of its action on the iron carbide in the test bar. The carbon monoxide is then regenerated to carbon dioxide by the action of hot iron oxide, thus producing a continuous cycle as long as the iron oxide remains active.

The 9/16-inch-diameter bars which were cast from

(Decarburization Tests, cont'd) -

the No. 2 melt were ground to tensile test specimens 0.450 inch in diameter in the gauge length and 0.650 inch on the grips. Short lengths of bars 0.450 inch in diameter were also ground to size to be used for micro examination.

Four test bars plus 4 short lengths, as mentioned above, were placed in the closed decarburizing system at 1960° F. for periods of 24, 32, 40, and 48 hours and immediately quenched into water. It was found that these test pieces scaled considerably, due to the fact that inadvertently they had been placed in the tray over wet hematite ore and while it was being heated to temperature the container was left open to the air in order to drive off the large amount of moisture that was present in the ore. However, previous experiments have proven that if the ore is well dried and the test bars are heated in a carbon dioxide atmosphere there will be no scaling.

Mechanical Testing:

The tensile test bars after treatment as above were tested without further machining. The results of these tests are shown in Table I below:

| Decarb Time | Depth of Decarburization | Vickers Hardness using 10 Kg Load | | | Tensile Strength lbs/sq.in |
|-------------|--------------------------|-----------------------------------|--------------|------|------------------------------|
| | | Outer Edge | Decarb layer | Core | |
| 24 hrs | .12" | 298 | 216 | 437 | 32,300 |
| 32 | .13 | 240 | 200 | 370 | 34,300 |
| 40 | .15 | 254 | 218 | 240 | 47,500 |
| 48 | .13 | 254 | 213 | 200 | 33,500 (flaw in specimen) |

Table I.

(Mechanical Testing, cont'd) -

Hardness tests were conducted on all of the decarburized specimens. The results are shown in Table I.

Depth of Decarburization:

This was measured from the specimens used for microscopic examination. The depth of decarburization for the various decarburizing times is also shown in Table I.

Microscopic Examination:

The specimens (taken from Melt No. 1) which were packed in hematite ore and mill scale were cut up for microscopic examination. Each specimen was given a metallographic polish and etched in a 2 per cent solution of nitric acid in alcohol.

Figure 2 shows the decarburized layer after heating one specimen to 1960° F. and water-quenching. The austenitic structure is apparent. The edge of this specimen did not show a martensitic structure and it was concluded that the rate of diffusion of carbon to the surface was identical to the rate at which it was being removed.

Figure 3 is a photomicrograph, at X100 magnification, of the core structure of this material.

A specimen for microscopic examination was cut from each piece that had been treated in CO₂ for 24, 32, 40 and 48 hours. Each specimen was etched in a 2 per cent solution of nitric acid in alcohol and examined under the microscope at X100 magnification. Figure 4 is a photomicrograph of the decarburized layer and this is representative of this layer in all four specimens. Figure 6 is a photomicrograph, at X100, of the structure of austenitic manganese steel. These two structures are identical. Figure 5 is a photomicrograph taken

(Microscopic Examination, cont'd) -

of the core or undecarburized layer. In the specimen which had been decarburized for 32 and 48 hours, there was little of this structure remaining.

Discussion of Results:

The microstructure proves that a material metallographically identical to austenitic manganese steel can be produced from a high manganese cast iron. Figures 2 and 4 are photomicrographs of structures which are typical of austenitic manganese steel. The austenitic layer illustrated by these figures, when peened with a hammer, showed considerable increase in hardness. This phenomenon is typical of austenitic manganese steel. The core material is hard and brittle and apparently when it contains more than 3 per cent carbon is susceptible to cracking on water-quenching. This condition was prevalent in the iron produced in England.

Tensile tests on decarburized test pieces indicate that the strength increases with the amount of decarburization. The presence of the white iron core accounts for the low tensile strength, which increases as the core disappears.

Hardness surveys of the pieces used for micro-specimens indicate that the austenitic layer has a hardness closely approximating that of austenitic manganese steel.

The closed system of decarburizing presents a very simple method and permits the use of high temperatures.

CONCLUSIONS:

1. The feasibility of converting, by decarburization, a high manganese white iron into a material which is metallographically and physically similar to austenitic manganese steel is established.

2. Experiments in Great Britain have proven that the process can be used successfully in the production of track links. This report does not attempt to prove that track links cast from high manganese cast iron and decarburized will be satisfactory in service, but it is concluded that they will be satisfactory if properly prepared and treated.

The process does not attempt to lower, by means of decarburization, the carbon content throughout the link, but removes sufficient carbon from the surface to form an austenitic layer there that, when subjected to wear, work-hardens as in an austenitic manganese steel link. Pitch measurements of an experimental track produced in England indicated that the increase in pitch is considerably less in a track which is cast from manganese iron and then decarburized than it is in a manganese steel track. This is thought to be due to the presence of the hard core, which is more resistant to stretch.

3. The process is suited to iron foundries and malleable iron foundries. The charge may be melted in air furnaces and cupolas. In Great Britain use was made of a cupola and a rotary furnace to melt and cast experimental links.

4. Decarburization can be conducted in any type of furnace in which a controlled atmosphere can be maintained. Furnaces which make use of suitable packing compounds may also be used. For large outputs continuous furnaces may be employed. A closed system for decarburization, as described in this report, may also be used with good results.

(Continued on next page)

(Conclusions, cont'd) -

5. The experimental work conducted in England was done with an iron containing 3.5 to 4 per cent carbon. It is recommended that the carbon content be kept to about 2.75 per cent. This can be done quite readily and has the advantage that the lower carbon reduces the decarburizing times and also the possibility of quenching cracks forming.

6. Most track links are designed so that the thickness of metal at any point is not great. This factor lends itself readily to a process such as this, since the thinner the section the smaller will be the amount of core material remaining after decarburization.

7. If further information is desired, and the steel casting shortage becomes serious enough to warrant it, additional investigation should be conducted on actual links.

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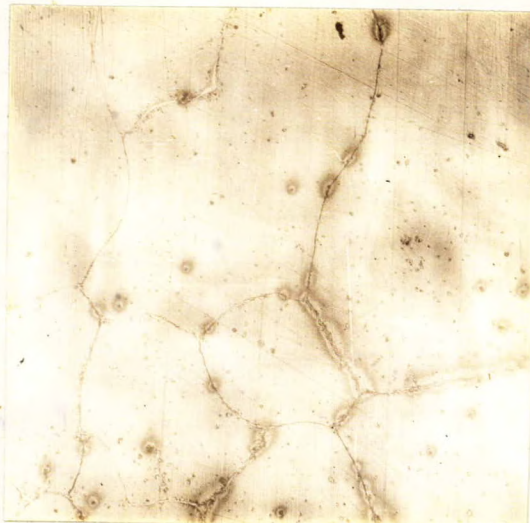
Figure 1.



X200, nital etch.

"AS CAST"

Figure 2.

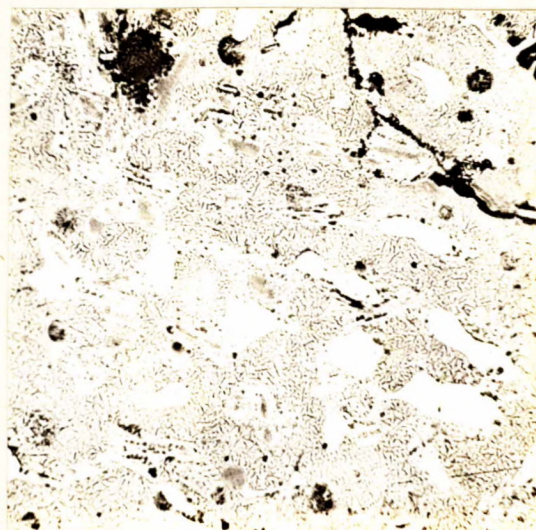


X200, nital etch.

DECARBURIZED LAYER.

Manganese cast iron packed in hematite ore
and mill scale at 1680° F. for 96 hours,
heated to 1960° F., and water-quenched.

Figure 3.



X100, nital etch.

CORE STRUCTURE.

Same treatment as for Figure 2.

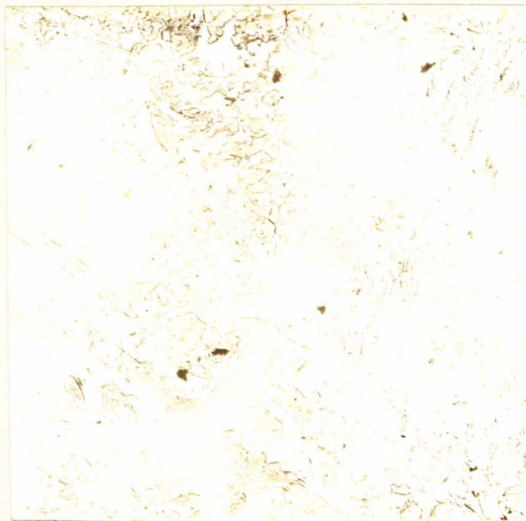
Figure 4.



X100, nital etch.

AUSTENITIC STRUCTURE
PRODUCED BY DECARBURIZING IN CO₂.

Figure 5.



X100, nital etch.

CORE STRUCTURE
BENEATH AUSTENITIC LAYER.

Figure 6.



X100, nital etch.

STRUCTURE OF AUSTENITIC
MANGANESE CAST STEEL.