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OTTAWA July 12th, 1941.

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of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1050.

Experimental Work on Malleable Iron
Universal Carrier Track Links.

BUREAU OF MINES
DIVISION OF METALLIC MINERALS

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METALLURGICAL LABORATORIES

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
MINES AND GEOLOGY BRANCH

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Foreword:

Malleable iron track link production at the International Harvester Company of Canada Limited plant, Hamilton, Ontario, had at first been satisfactory but when production was increased poor physical properties (as determined by the bend test) were encountered in the links. The result was that link rejections became so high that less than forty per cent of the metal melted was going out as finished castings. Although large numbers of steel links were being produced there was still a heavy demand for the malleable castings. As a consequence, the Metallic Minerals Division of the Bureau of Mines (Ottawa) started an investigation of the link heat-treatment. As a result of this work two new methods of heat treatment were developed. Results obtained were sufficiently promising to warrant tests in actual production. Consequently, during the week of June 9th to 14th, heat-treatment tests were made in the Hamilton plant of the International Harvester Company of Canada Limited. In the following report these tests are described and test results obtained are given and discussed.

Production Method Followed and Bend-Test Results Obtained Immediately Prior to Test Runs:

Links were being produced in the following manner:

White iron (hardiron) castings were being annealed in an atmosphere containing sufficient CO_2 to slightly decarburize the link surface. In this anneal approximately 10,000 links are piled on each other. Furnace records showed that the bottom of the pile came to the annealing temperature (approximately 1700° F.) much quicker than the top. The top, however, cooled somewhat faster than the bottom, as cold gases entered at this point. The annealed link was heated for 30 minutes in a 35 per cent Parkcase cyanide bath, cooled along with other links in a sheet iron box (referred to as the "dog-house"), reheated for two minutes at 1400° F. in a low-strength cyanide bath, and then quenched in oil. Selected links were tested by bending between 8-inch centres. The week previous to the heat-treatment tests the bending strength of the links was less than 10,000 pounds on an average.

It had been noted that links which gave poor results in the bend test showed black areas around the pin-hole in the fracture. On examination, it was found that these black areas were graphitic. The location of these graphitic areas indicated that the graphite had come from the core wash. The use of graphite as a core wash had been discontinued but graphite-free links had not reached the heat treatment stage at the time of the tests. Recent tests made in Hamilton indicate that link properties have been improved by this graphite elimination.

Incidentally, it was noticed that bend-test results from the International Harvester laboratory were consistently lower than the results obtained from bend tests made in Ottawa on similarly treated links. It was evident, then, that the method of testing had some effect on the results obtained. Both laboratories tested at about the same rate of speed but in the International Harvester test the test was made in a stationary fixture while in the Bureau of Mines tests the link was supported on rollers. Breaking loads obtained by the latter method appeared to be about five hundred pounds higher.

Heat-Treatment Methods Developed in Bureau of Mines Laboratories:

Method 1.

Heat for 30 minutes in 50 per cent cyanide bath held at 1500° F. Quench in oil. Reheat for 30 minutes in a low-strength cyanide bath held at 1325° F. Quench in oil.

This method is dependent on the fact that the high-nitrogen case produced by the low-temperature cyaniding has a lower change point than the link core. The first heat treatment puts the case on the link and puts the core in proper condition for further heat treatment. The second treatment further adds to the case depth and produces a hard case backed by a tough spheroidized core. Excellent bend-test results were obtained in Ottawa from links treated by this method.

Method 2.

Heat for 30 minutes in a 30 per cent cyanide bath held at 1500° F. Quench in salt heated to 600° F. Hold in salt for half an hour. Quench in water.

The cores of links treated by this method were considerably harder than the cores of links heat-treated by the usual methods. However, the hot-quenched, or austempered, core has greater toughness for the same hardness. The hot-quench method also will harden thin sections while leaving thicker sections soft. It should therefore be particularly suited to link heat-treatment as it confers the maximum physical properties where they are needed, i.e., in the thin eye-hole section. Tests showed that the hard, strong eye-sections of the hot-quenched links were quite tough and ductile. Hot-quenched links also had good bending strengths. The method had the further advantage of making possible double the production from the same heat-treating equipment.

Details of Heat-Treatment Tests Made in the International Harvester Plant, June 9th to 13th, 1941:

In the following tests the first heat treatment was made in a 35 per cent cyanide bath. When the link was given a second heating this was done in a low-strength cyanide bath.

Test No.	Heat Treatment.
1.	Heat 1500° F. for 30 minutes. Fast air cool. Reheat at 1325° F. for 30 minutes. Oil quench.
2.	Heat 1500° F. for 30 minutes. Oil quench. Reheat at 1325° F. for 30 minutes. Oil quench.
3.	Heat 1400° F. for 30 minutes. Oil quench. Reheat at 1325° F. for 30 minutes. Oil quench.
4.	Heat 1400° F. for 30 minutes. Quench in hot oil at 300° F.
5.	Heat 1400° F. for 30 minutes. Quench in hot oil at 400° F.
6.	Heat 1500° F. for 30 minutes. Quench in hot oil at 300° F.
7.	Heat 1600° F. for 30 minutes. Oil quench. Reheat at 1375° F. for 30 minutes. Oil quench.
8.	Heat 1600° F. for 30 minutes. Oil quench. Reheat at 1400° F. for 2 minutes. Oil quench.
9.	Heat 1600° F. for 30 minutes. Oil quench. Reheat at 1400° F. for 4 minutes. Oil quench.
10.	Heat 1600° F. for 30 minutes. Oil quench.
11.	Heat 1600° F. for 30 minutes. Quench in salt at 600° F. Hold 20 minutes.
12.	Heat 1600° F. for 30 minutes. Hot-water quench. Reheat at 1400° F. for 4 minutes. Oil quench.

Object of Heat-Treatment Tests:

Test No.	Object.
1.	To determine carbon solubility at 1500° F. To test effect of fast air cool. To determine whether case can be hardened from subcritical temperatures.
2.	Same as in Test No. 1, plus determination of the effect of the double quench.
3.	To determine carbon solubility at 1400° F. To see if low-temperature cyaniding aids case-hardening from a subcritical temperature.
4.	To determine carbon solubility at 1400° F. To test effect of hot quench.
5.	Same as in Test No. 4, plus determination of the effect of increasing the temperature of quenchant.
6.	To determine carbon solubility at 1500° F. To test effect of hot quench on this material.
7.	To determine carbon solubility at 1600° F. To test possibility of hardening case by quenching from just below 1400° F.
8.	To determine whether link properties can be improved by double quenching.
9.	To determine time needed in second bath when double-quench method is used.
10.	To test possibilities of a single-quenching operation.
11.	To test effect of hot-quench method on links containing considerable carbon in solution.
12.	To determine whether a hot-water - oil-quench method can be used in place of the double-oil-quench method.

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Test Results:

The following table gives the results of bend tests made on the various links:

(See table on next page)

(Test Results, cont'd) -

Test No.	Average bending load (pounds)	Average bending angle, degrees.	Remarks.
1.	8,645	5	Black fracture. Case soft.
2.	9,675	12	Black and white fracture. Case soft.
3.	6,590	10	Black fracture. Case soft.
4.	7,420	10	Black fracture.
5.	6,780	7	Black fracture.
6.	11,300	4	Case hard.
7.	-	-	No tests as case soft.
8.	11,420	6	Case soft.
9.	10,680	8	Case hard. Only one link tested.
10.	11,310	4(?)	Very brittle break at end of link.
11.	12,250	5	Hard case. Eye hardness, 32 Rockwell C. Tread hardness, 35 Rockwell C.
12.	-	-	Test unsuccessful as hot water splattered badly and did not cool properly.

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DISCUSSION OF TEST RESULTS:

Tests Nos. 1, 2, 3 and 7 show that under International Harvester conditions a quench from below critical temperature of the core does not harden the case even when the case is formed at 1400° F. This means that the case and core have similar critical temperatures, i.e., that the Parkcase bath produces a low-nitrogen case. Subcritical-temperature case-hardening was effective in Ottawa because the 50 per cent NaCN,

(Discussion of Test Results, cont'd) -

30 per cent Na_2CO_3, 20 per cent NaCl bath produced a high-nitrogen case.

The low bend-test results and black fractures of Tests Nos. 1 to 5 show that under International Harvester conditions carbon solubility obtained in 30 minutes at 1500° F. is not satisfactory, while carbon solubility obtained in 30 minutes at 1400° F. is practically negligible. To obtain satisfactory carbon solubility at 1500° F., the half-hour soaking time would have to be increased. This is not allowable as it would interfere too much with production.

Heat-treatment methods based on subcritical-temperature hardening, then, would seem to be out of the question, for if this method is to be effective cyaniding must be done, even with baths of optimum composition, at temperatures not exceeding 1500° F., because cyaniding at higher temperatures results in too low a nitrogen content in the case. If, however, it is possible to increase the soaking time the method is worthy of consideration, as the time involved in the second heat is not critical as it is in the method now being used. The method has the further advantage of producing a link with a tough spheroidized core.

Hot quench tests made from 1400° F. were not satisfactory because carbon solubility was too low. Tests Nos. 6 and 11, however, definitely indicated that the hot-quenching method had possibilities and that best results could probably be secured by allowing the isothermal transformation to take place around 600° to 700° F. Hardnesses produced in this treatment were well above the specified

(Discussion of Test Results, cont'd) -

maxima but these high hardnesses were not associated with brittleness and the eye-hole flattened and the guiding lug bent under hammer blows without any sign of cracking. (See photographs at end of this report).

Tests Nos. 8 and 9 indicate that the double-oil-quench method led to an improvement of the link bending strength, although it was necessary to leave the link somewhat longer in the second bath if the case was to be hardened. This is because the link enters the bath colder than in the usual heat treatment. Double-oil-quenched links also gave much better results in an International Harvester test specially designed to test the impact strength of link assemblies. Izod impact test specimens cut from single-quenched and double-quenched links showed that the impact strength of the metal in the latter link exceeded by more than forty per cent the impact strength of the iron in the single-quenched casting. The bend test, then, does not tell the whole story, as it does not indicate the resistance of the material to impact, an important property in carrier chain. It is not surprising that the double-quenched link has superior properties, for in the single-quench operation the final heat-treatment has no effect on the core of the link which is in the laminated-pearlite annealed condition produced by slow cooling in the "dog-house". This annealed metal is not tough. The core of the double-quenched link, however, is in the tougher quenched-and-drawn condition, for the final heat-treatment not only hardens the case but draws

(Discussion of Test Results, cont'd) -

the oil-quenched core. Three photomicrographs showing the core structures of single-quenched, double-quenched and hot-quenched links follow this report.

Tests Nos. 10 and 12 showed respectively that a single-treatment link was too brittle and that a hot-water quench could not be conveniently substituted for the first oil quench.

Experimental Work in Progress:

Dr. R. Potvin, of the Bureau of Mines, who has conducted the experimental work on link heat-treatment in Ottawa, is now preparing a report of his findings. A point of considerable interest brought out by his work is that links annealed at the bottom of the annealing furnace have better properties after the case-hardening treatment than have links annealed at the top of the furnace. "As annealed" links from top and bottom of the charge differ in that the former contains much pearlite while the latter is practically ferritic. This indicates that the top links have cooled more rapidly in the final stages of the annealing operation. In the heat treatment the dissolved carbon of these top links apparently becomes too high, with the result that they are embrittled. If a shallower case-hardening is allowable the properties of top links could probably be improved by heating them for a shorter time in the first cyanide bath.

Incidentally, Dr. Potvin's work shows that heavy decarburization of the link is not necessary and that decarburization need only exceed case depth.

Hardnesses produced by the hot-quenching treatment

(Experimental Work in Progress, cont'd) -

exceed the specified maxima; consequently, before these links could be accepted they would have to be tested in service. With this object the International Harvester Company have shipped 400 links to Ottawa for hot-quenching treatment as these cannot be conveniently treated at the Hamilton plant. After being heat-treated these links will be returned for assembly and test in a carrier.

Conclusions:

The tests showed that the subcritical-temperature method of hardening was not suited to International Harvester conditions. They also showed that the hot-quenching method had considerable promise. This work is being continued. It is also believed that the superiority of the double-quenched link over the single-quenched casting was demonstrated and it is thought that this double-quench method of heat treatment should be adopted.

Granting the superior properties of steel links, there is no reason why the malleable iron link should not be used in universal carriers, as the physical properties of a properly heat-treated blackheart malleable link would appear to be more than adequate for the service. Indeed, where conditions are such that surface abrasion is high the case-hardened malleable iron link might well give better service than a steel link heat-treated to a 275 Brinell hardness because under these conditions eye-hole wear might become excessive in the latter link.

Objection has been raised to the use of a case-

(Conclusions, cont'd) -

hardened casting on the ground that the hard irregular outer zone would cause link embrittlement. The case on an oil-quenched link, however, is not file-hard and consequently has a certain ductility. Service behaviour of the oil-quenched case-hardened links would seem to indicate that the presence of such a case does not lead to casting embrittlement.

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GSF:PES.

Figure 1.

Slightly enlarged.

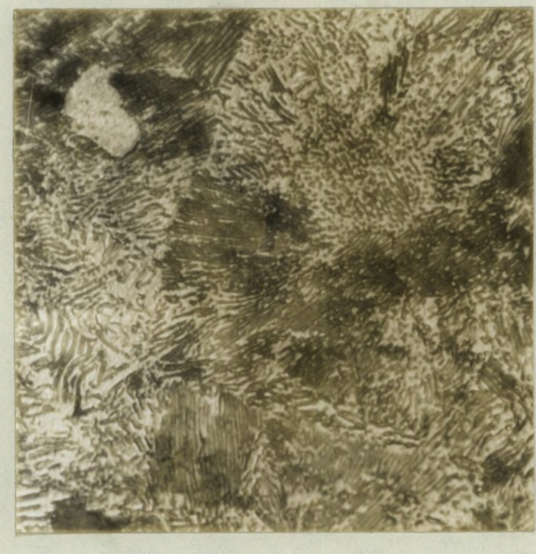
Eye-hole of link heated to 1600° F., held for 30 minutes, and then quenched in salt at 600° F. Crack-free. Flattening of eye-hole produced by hammer blows.

Figure 2.

Slightly enlarged.

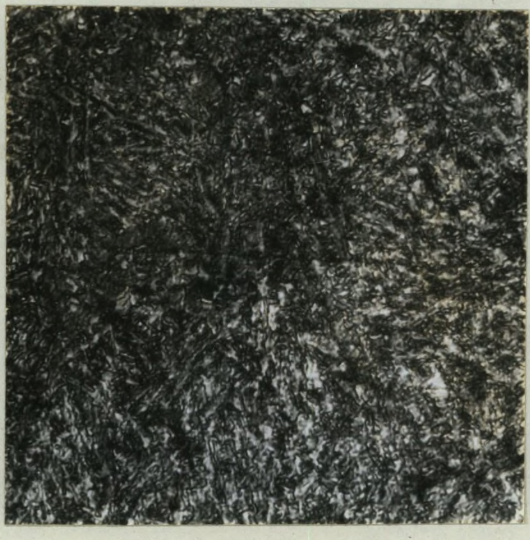
Same link as in Figure 1, showing crack-free guiding-lug bending produced by hammer blows.

Figure 3.



X1500, Nital etch.
Core of single-quenched link.

Figure 4.



X1500, Nital etch.
Core of double-quenched link.

Figure 5.

X1500, Nital etch.
Core of hot-quenched link.

GSF:PES.