OTTAWA September 27th, 1941.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1099.

Survey of Manufacturing Processes,
Universal Carrier and Light Tank Track Links.

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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Introduction:

A good track link should have a tough core and a wear-resistant surface. Toughness, which combines strength and ductility, is needed to resist the high impact stresses developed in the track assembly under the extremely severe conditions encountered at high speed in rough terrain. Resistance to abrasion under high alternating stresses is required in order to minimize wear and reduce excessive lengthening of the track assembly.

Preliminary:

Toughness is a function of the metal composition, of the casting design and soundness, as well as of the core structure. Resistance to straight abrasion varies proportionally to hardness, while resistance to abrasion under heavy alternate stresses is rather a function of the surface structure, high carbon content of this surface (carbon would act as a sort of lubricant), work hardenability, etc.

SURVEY OF PRESENT MANUFACTURING PROCESSES.

The following is a short survey of recent developments in the manufacture of Universal Carrier or Light Tank track links:

BRITISH WHITEHEART MALLEABLE LINKS.

Description of Manufacturing Process:

In the making of whiteheart malleable links, the material used is a white cast iron low in carbon and silicon and high in sulphur (due to the high sulphur contained in the English cupola-melted pig iron). The castings are submitted to a very lengthy annealing in a decarburizing compound, generally pure iron oxide (Fe_2O_3), at 1700-1800° F. followed by slow cooling. The silicon content is kept low to prevent undue scaling during decarburization. This operation is definitely slowed down by the high sulphur content (and relatively low manganese), which sulphur, however, has the advantage of retarding the re-solution of carbon during the subsequent case hardening treatment(1) consisting of a first

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(1) The effect of silicon, manganese and sulphur has been fully discussed in Reports of Investigations Nos. 889 (August, 1940) and 872 (July, 1940) of the Bureau of Mines, Ottawa.

(British Whiteheart Malleable Links,
(Description of Manufacturing Process, cont'd) -

carburizing treatment at 1750° F. in 50 per cent cyanide, slow cooling, reheating to 1475° F. in cyanide, and quenching in mineral oil.

Composition -

		Per cent
Carbon	-	2.95 minimum
Sulphur	-	0.17 maximum
Silicon	-	0.66 "
Manganese	-	0.3 "

Casting temperature: 1900° F.

Malleabilizing: 120 hours at 1725° F. in hematite ore.

Decarburization: Extends below 3/16 inch.

Microstructure: File hard, martensitic case. The core contains ferrite, temper carbon particles, and pearlite; this last increases gradually up to the central zone of core.

Properties -

Transverse load: 12,000 to 13,000 pounds between 8-inch centres.
Bend: 8 to 12 degrees, as measured on broken parts.
Tensile strength: 40,000 to 50,000 p.s.i.
Elongation: 5-9 per cent.
Core hardness: 155 Vickers on edge to 245 Vickers in centre of thick section.
Surface hardness: 500 Vickers (5-kilogram load) minimum.

Remarks:

Advantages -

From the production point of view, it is possible to obtain a large output of sound castings at very low cost. The finished product is tough and has a hard surface having very good resistance to straight abrasion.

Disadvantages -

1. The resistance to abrasive wear is reduced considerably in the whiteheart malleable link by the soft ferrite base that is present under the hard case,

(British Whiteheart Malleable Links,
(Remarks, cont'd) -

(Disadvantages, cont'd) -

causing excessive deformation of the bearing hole (followed sometimes by peeling of the case) with a consequent stretching of the track assembly and failure at the thinner section of the lug bearing.

2. Unless the makers have considerable training in producing sound malleable castings the production may tend to be irregular in properties.

CAST STEEL LINKS.

1. - Hull Iron & Steel Track Links.

In collaboration with the Hull Iron and Steel Foundries Limited, Hull, Quebec, the Bureau of Mines at Ottawa has investigated the possibilities of a cyanided low-carbon steel link.

The experimental links were cast in sand moulds with S.A.E. 1030 steel. They were found to be sound and were given a double cyaniding treatment in an activated cyanide bath. The surface hardness was kept at about 640 Vickers (5-kilogram load). The transverse load varied from 14,000 to 17,000 pounds, the bend from 20 to 30 degrees, and the core hardness from 155 to 245 Vickers at the thickest portion.

Microscopic examination: Martensitic case, 0.015-inch thick, on a fine pearlitic steel core.

(Continued on next page)

(Cast Steel Links,
(Hull Iron & Steel Track Links, cont'd) -

Performance -

An experimental track link assembly was tried on a light tank (Mark VI-B). The results, only two breakages and an increase of 1.69 per cent in the pitch, were considered remarkable.

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2. - Ford No. 4 Steel.

This steel is made continuously by the Ford Company of Canada Limited, at Windsor, Ontario.

Composition -

		Per cent
Carbon	-	0.45-0.50
Silicon	-	0.30-0.40
Manganese	-	0.70-0.90
Sulphur	-	0.06 maximum
Phosphorus	-	0.06 "
Copper	-	0.6 "

Heat Treatment -

Normalize at 1600-1650° F.

Heat to 1500-1525° F.

Quench in water at 90-100° F.

Draw at 950° F. for 2-2½ hours to a Brinell hardness of 255-285.

(Continued on next page)

(Cast Steel Links,
(Ford No. 4 Steel, cont'd) -

Properties -

Tensile	-	125,000 p.s.i.
Elongation	-	10 per cent.
Brinell hardness	-	277.
Transverse load of tread	-	18,400 pounds.
Bend angle	-	8° average.

Performance -

A test showed no breakage after 2,464 miles and an increase of 4.5 per cent in the pitch. Another test showed a stretch of 3.15 per cent and no breakage at 1500 miles.

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Remarks on Cast Steel Links:

Advantage -

A more uniform product can be made in both the low-carbon and the Ford No. 4 steels; the strength of the final product is higher than that of the whiteheart malleable.

Disadvantages -

The production cost of cyanided low-carbon steel is slightly higher than that of Ford No. 4 steel. Although not possessing the toughness of this latter, the wearing quality of the low-carbon steel would likely be better since the heat treatment to which the Ford No. 4 is subjected is apt to give surface decarburization. This, combined with the high-temperature tempering, would tend to produce a much softer skin than that obtained in the cyaniding treatment.

BLACKHEART MALLEABLE LINKS.

Description of Manufacturing Process:

Blackheart malleable (short cycle) is made by annealing (malleabilizing) a white cast iron high in carbon and silicon and low in sulphur. A well-annealed blackheart contains most of its carbon as temper carbon precipitated in a ferrite matrix. The high silicon content of blackheart, by slowing down the migration of carbide, will cause excessive scaling and lessen the amount of decarburization in the castings subjected to packing in a solid decarburizer like hematite. Furthermore, high silicon will decrease appreciably the cyaniding speed.[2] Therefore, if the silicon is high, as in the short-cycle blackheart, the case-hardening treatment will render the core extremely hard and brittle.

In collaboration with the International Harvester Company Limited, Hamilton, Ontario, the Bureau of Mines at Ottawa undertook to investigate the potentialities of various methods of heat-treating:

(1) to reduce scaling during the decarburization,

(2) to reduce the bulk introduced by the use of hematite in decarburization, and

(3) to obtain higher toughness in the cyaniding.

It was found that part of the properties of blackheart and whiteheart could be combined by using a low-silicon iron in which the manganese was in atomic excess over the sulphur and was therefore acting as the carbide-stabilizing element.

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(2) Bureau of Mines Report of Investigation No. 889 (1940), pp. 14-19 and 20-21.

(Blackheart Malleable Links,
(Description of Manufacturing Process, cont'd) -

Composition -

		Per cent
Carbon	-	2.8
Silicon	-	0.50 to 0.80
Sulphur	-	0.05 to 0.06
Manganese	-	0.30

The use of a higher manganese content, although promoting the speed of decarburization as was experienced, led, however, to casting difficulties and to poor results in field tests.

A method using a gaseous medium for decarburizing was investigated at the Bureau of Mines at Ottawa in order to replace the slow and cumbersome method of decarburizing in a solid medium. That new method made it possible to shorten the total time of the castings in the furnace, to increase considerably the number of castings treated in a furnace of a given size, to control with accuracy the decarburization, to minimize handling of castings, and to reduce scaling.

Making use of the above method on a large scale, the International Harvester Company of Canada Limited at Hamilton, Ontario, is treating close to 15,000 Universal Carrier track links per week in a single furnace. A gas having a CO_2:CO ratio of approximately 3 to 1 is generated by burning gas and air. The gases entering the furnace are baffled to prevent local cooling and scaling due to excess CO_2.

Complete cycle (7,500 pieces in one load) -

Heating time	-	40 hours.
Holding at 1700° F.	-	40 to 50 hours.
Cooling to 1400° F.	-	10 hours.
Cooling to 1200° F.	-	20 to 30 hours.

(Continued on next page)

(Blackheart Malleable Links,
(Description of Manufacturing Process, cont'd) -

Properties as Annealed -

Tensile strength: 75,000 to 85,000 p.s.i.
Elongation: 6.25 per cent.

Decarburization - A pure ferrite zone of approximately 0.025" is obtained.

Cyaniding - The cyaniding is done in two Ajax-Hultgren furnaces. The first cyaniding (30 minutes) is followed by a slow cooling.(3) The second cyaniding is of short duration to a temperature of about 1400° F., followed by an oil quench.

Properties as Cyanided -

Transverse load test: 11,000 to 15,000 pounds between 8-inch centres.
Bend: 6° to 14°.
Surface hardness: File hard.
Core hardness: 160 to 275 Vickers.

Performance - After 1,500 miles, no breakage, stretch 1.2 per cent; at 2,000 miles, one breakage, stretch 4.1 per cent.

Microscopic Examination - The martensitic case is from 0.07 to 0.010 inch thick and lies on a ferrite substratum. The core structure is mostly sorbitic with temper carbon particles.

Remarks:

Advantages -

Ease of casting, low cost of production of this type of partially decarburized blackheart malleable. Furthermore, the actual foundry capacity available is large.

Disadvantages -

The main disadvantage is the absence of uniformity in production. However, it is very probable that once the first difficulties always inherent to a new method are smoothed out a more uniform product will be obtained.(4)

(3) A double oil-quenching treatment would result in a tougher core: Report 1050, July 12th, 1940, Ore Dressing and Metallurgical Laboratories, Bureau of Mines.

(4) Some sources of difficulties met with in the manufacturing of malleable iron track links are discussed in Report No. 1075, Ore Dressing and Metallurgical Laboratories, Bureau of Mines, Ottawa.

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(Blackheart Malleable Links, cont'd) -

Potential Methods Investigated:

1. - Cyaniding -

Cyaniding of partially decarburized and well annealed blackheart malleable at a temperature just below its critical point.(5)

Properties -

Transverse load: 9,500 pounds.
Bend: 30°.
Case hardness: 500 Vickers (5 kilo-load).
Core hardness: 150 Vickers.

Microstructure - A nitride-martensitic case was observed (approximately 0.008 inch thick after 50 minutes in cyanide) on a ferrite-temper carbon core.

Performance - No field test was made; results on bend tests would seem to indicate a possible excessive stretching due to low yield point and soft ferrite core.

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2. - Oil Quench and Draw -

Blackheart malleable subjected to oil-quenching and drawing showed a tendency to give a very poor surface hardness when a sufficient core toughness was obtained. It was felt that a field test was unnecessary, since the poor properties observed on the links thus heated would obviously lead to excessive wear in service.(6)

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3. - Austempered Blackheart Malleable -

This method would consist in heating the castings in a decarburizing atmosphere at the start; near the end of the cycle, however, the atmosphere is rendered carburizing

(5) Discussed in detail in Investigation No. 1020, Ore Dressing and Metallurgical Laboratories, Bureau of Mines, Ottawa, May, 1941.

(6) See Report of Investigation No. 1075, Ore Dressing and Metallurgical Laboratories, Bureau of Mines, Ottawa, September, 1941.

(Blackheart Malleable Links,
(Potential Methods Investigated, cont'd) -

(Austempered Blackheart Malleable, cont'd) -

in order to obtain a high carbon content in the skin layer. The casting after the above annealing cycle is heated for a short time at 1400° to 1425° F. and then quenched in a salt bath at 550° to 650° F. for 30 to 45 minutes to obtain sufficient transformation.

Properties -

Transverse load: 12,000 pounds between 8-inch centres.
Bend: 6 degrees.
Core hardness: 295 to 325 Vickers.
Surface hardness: 300 to 400 Vickers.

Performance - A complete set assembly has been made for a field test. No report has been received yet on its performance.

Remarks:

Great toughness is obtained at the lug portion, where it is especially desirable; the core hardness is also higher at the bearings. However, the toughness of the tread portion is somewhat lower than with the cyaniding and oil-quenching method.

GENERAL CONCLUSION:

New methods and new materials have been successfully developed in this country for manufacturing Universal Carrier and Light Tank track links and have proved to be very satisfactory, comparing favourably with the British whiteheart malleable link with regard to performance and to facility and low cost of production.

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