Bureau of Mines
Division of Metallic
Minerals
-
Ore Dressing
and Metallurgical
Laboratories

CANADA

DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

OTTAWA August 2nd, 1943.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1463.

Examination of British Maddock Malleable Iron Universal Carrier Track.

Origin of Material and Object of Investigation:

On May 21st, 1943, Requisition No. 464, A.E.D.B. Lot Nos. 600 and 601, was submitted by Dr. C. W. Drury, Director of Metallurgy, Army Engineering Design Branch, Department of Munitions and Supply, Toronto, Ontario. This requested that a complete investigation be made on twenty-one British Universal Carrier links and pins produced by the Maddock foundry in England.

LINKS

X-Ray Examination:

Three links were X-rayed at the National Research Council (Ottawa). Several small cavities were present in the base of the eye-hole wall of the middle eye on the three-eye side of the link. Figure A is a positive of one of the X-ray pictures, illustrating the small cavities.

(Figure A comprises)
(Page 3.)

Chemical Analysis:

Drillings were taken from the centre of the grouser for chemical analysis. No attempt was made to determine the carbon content, as results obtained from malleable iron are not accurate.

	Per cent
Manganese -	0.28
Silicon -	0.43
Phosphorus -	0.056
Sulphur -	0.205

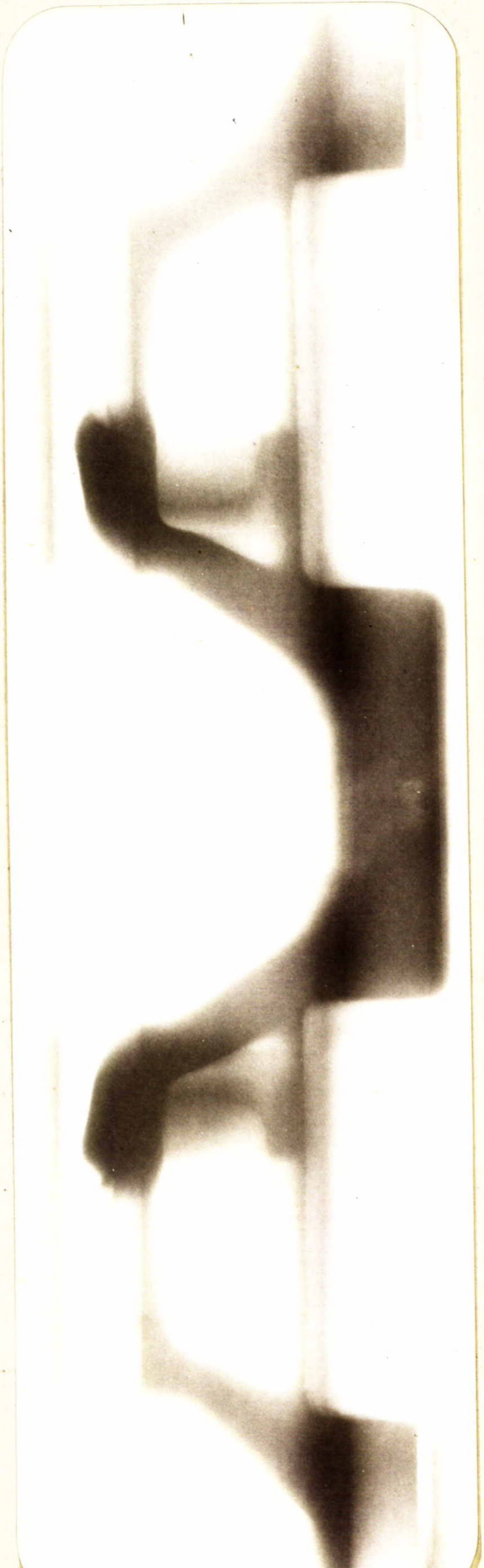
Bend Tests:

Bend tests were carried out, using 8-inch centres and a one-inch-radius block. The link is tested by laying it on the centre (ends up) and applying the load half way between them. Table I lists the loads and angles obtained for the six links tested.

Table I.

Link No.	Load, in pounds	Angle of bend, degrees
1	15,780	13.0
2	11,100	5.0
3	9,450	2.5
4	14,500	6.5
5	14,300	13.0
6	13,600	6.5

Figure A.



(Links, cont'd) -

Impact Tests:

Impact tests were made on both guide lugs (indicated by (a) and (b) in Table II), and the barrels of five links (lugs facing downward). A 50-lb. weight was dropped from 7 foot (350 ft-lb.) a number of times until failure occurred. Figure 1 illustrates the impact testing machine used. Figure 2 illustrates a link in position for a lug impact test. Table II shows the results obtained. A 400-ft.-lb. impact blow was used for the barrels.

(Figure 1 appears on Page 5.)
(" 2 " " " 6.)

Table II.

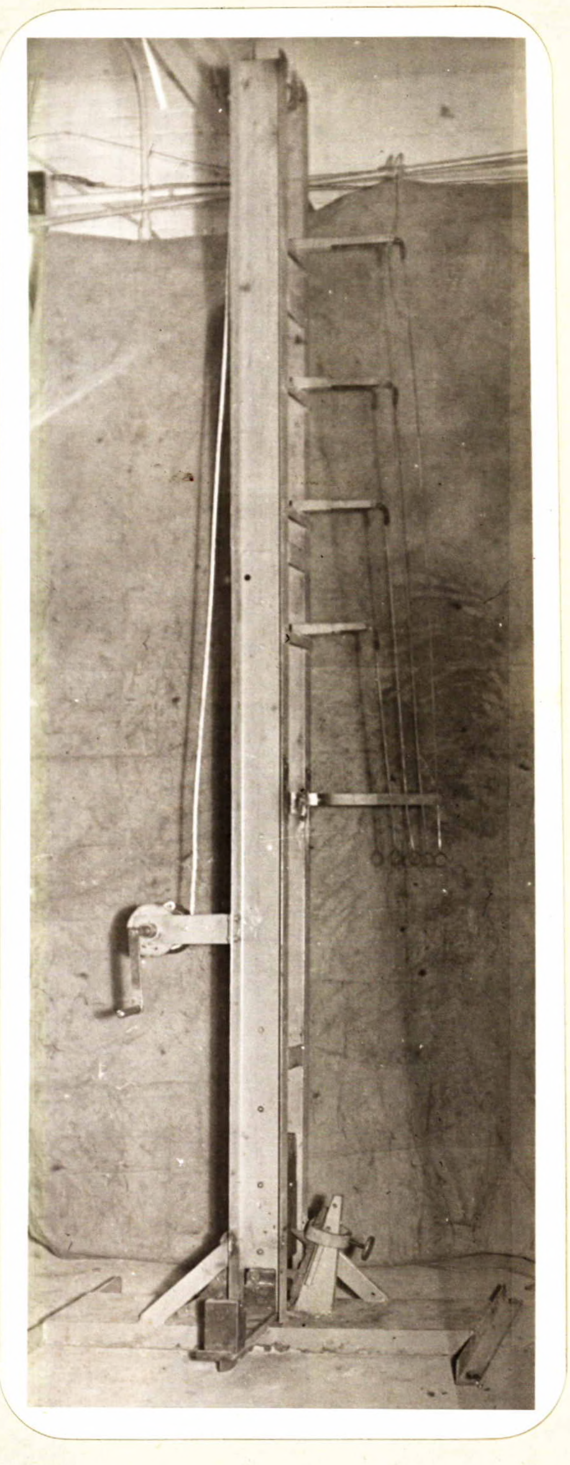
	L U G S			B A R R E L		
Link No.	No. of Blows	Ft. lbs.	Result	No. of Blows	Ft. lbs.	Result
1.	(a) 3	x350	- Failed	(3 (1	x350) x400)	- Failed
2.	(a) 3 (b) 2	x350 x350	- Failed)- ")	3	x400	"
3.	(a) 2 (b) 2	x350 x350	")- ")	2	x400	"
4.	(a) 1 (b) 2	x350 x350	")- ")	2	x400	"
5.	(a) 4 (b) 2	x350 x350	")- ")	3	x400	"

Hammer Test:

A link is considered to have sufficient ductility and toughness when the eye-holes will withstand the blows of a hammer until they are two-thirds of their original diameter. Four out of five links tested passed. Figure 3 illustrates the eye-hole of a link after it has been subjected to this test.

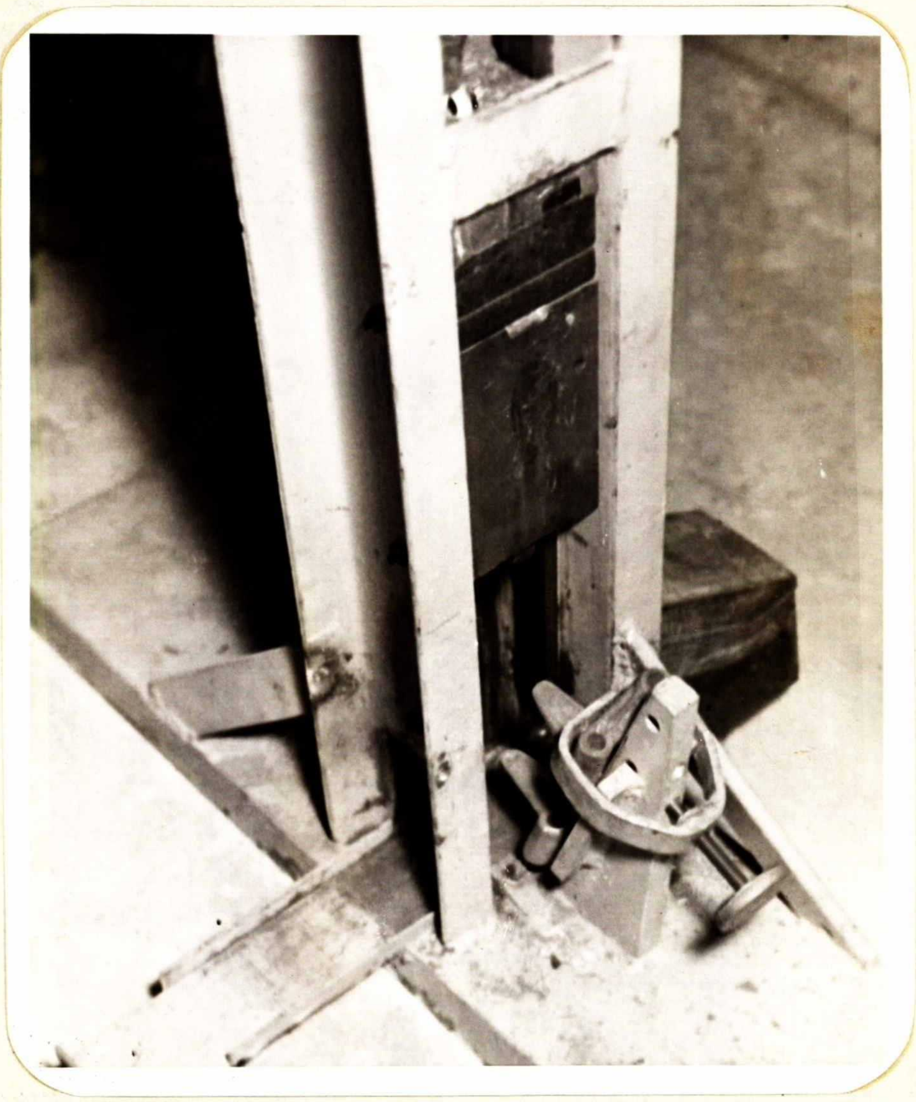
(Continued on next page)

Figure 1.



IMPACT MACHINE.

Figure 2.



FIFTY-POUND WEIGHT FALLING ON LUG.

(Hammer Test, cont'd) -

Figure 3.

EYE HOLE OF LINK - AFTER HAMMER TEST.

Hardness Tests:

A transverse section was cut from the centre eye hole on the three-eye side of the link. The Vickers hardness machine and a 10-kg. load were used. Readings were taken from the eye hole toward the grouser. Table III shows the results obtained.

Table III.

Transverse Gradient.

V.P.N.		Distance from eye hole toward grouser
125	-	0.14
135	-	0.06
100	-	0.04
100	-	0.03
73.6	-	.01
365		(Surface)

Brinell hardness readings were taken at the centre of a transverse section cut from the grouser. They varied from 321 - 341.

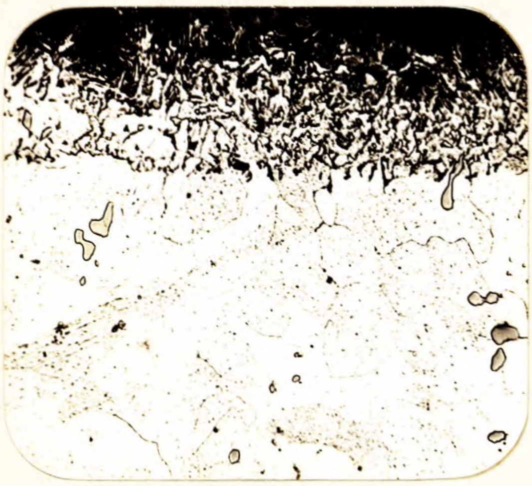
Case Depth:

The case depth varied from 0.003 to 0.005 inch.

Microscopic Examination:

Transverse microspecimens were cut from several shoes and polished. The unetched specimens indicated the presence of inclusions. Figure 4, photomicrograph at X200 magnification of the nital-etched specimen, illustrates the cyanided case at the eye-hole surface and also the decarburized area immediately below the case. Figure 5 (X200) shows the structure of the link at the centre of its thickest section.

Figure 4.



X200, nital etch.
EYE-HOLE SURFACE-CASE AND DECARBURIZED AREA.

Figure 5.

X200, nital etch.
CORE OF LINK

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PINS

Chemical Analysis:

Drillings were taken from the core of a pin for chemical analysis.

(Continued on next page)

(Chemical Analysis, cont'd) -

		Per cent.
Carbon	-	0.101
Silicon	-	0.26
Sulphur	-	0.027
Phosphorus	-	0.017
Manganese	-	0.55
Nickel	-	1.94
Chromium	-	Trace
Molybdenum	-	0.07

Heat Treatment:

It was reported that these pins had been heat treated as follows:

25 minutes in rapideep at 1740°F; oil quenched; reheated to 1440° F.; and oil quenched.

Hardness:

The surface hardness of the pins varied from 729 to 871 V.P.N., using a 10-kg. load. The core hardnesses were 183 to 195. Hardness gradients were carried out on the face of a transverse microsection cut from each of two pins. Table III lists the results obtained.

Table III. - Vickers Hardness Numbers.

Sample No.	At the Surface	As depths in inches from the surface 0.005	0.010	0.025	0.050	0.075	0.10
2	871	605	345	222	183	185	183
3	792	503	417	238	187	187	193

Case Depth:

Transverse specimens were etched in nital. The case depth was measured from the surface to the first point of colour change using a Brinell microscope. The samples measured gave depths of 0.008 to 0.010 inch.

Impact Tests:

Seven pins were subjected to an impact of 45 foot pounds, using the standard inspection machine. All passed.

Bend Tests:

Bend tests were carried out on the standard bend test machine. The pin rests on 8-inch centres, and a 12-inch-radius bending block is used. Pressure was applied until the first audible or visible crack occurred. The deflection in inches at this point is shown in Table IV.

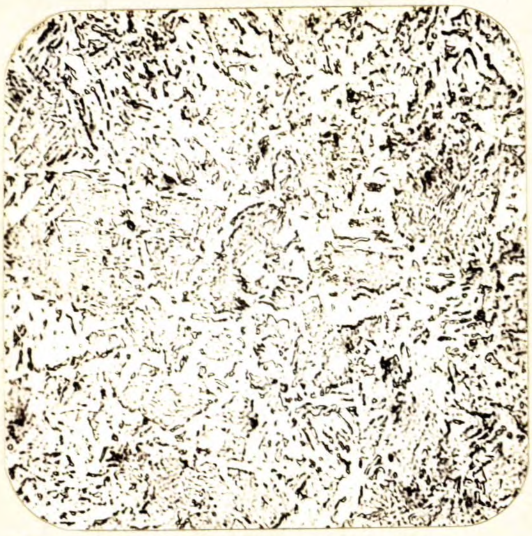
Table IV.

Pin No.		Deflection in inches
1	-	0.325
2	-	0.25
3	-	0.23
4	-	0.34

Microscopic Examination:

Transverse microspecimens were cut from several pins and examined in both the unetched and nital-etched state. The unetched samples showed that the steel was quite clean. Figures 6 and 7 are of two typical cores. These were taken at X500 magnification. Figure 8 (X500) shows the case structure of the pins at the immediate surface.

Figure 6.



X500, nital etched.
CORE OF PIN.

Figure 7.

X500, nital etched.
CORE OF PIN.

(Microscopic Examination, cont'd) -

Figure 8.

X500, nital etched.

CASE OF PIN.

Tempered Martensite.

DISCUSSION:

Links -

Some small cavities are present in the upper part of the grouser at the centre eyehole on the three-eye side of the link. This, however, should not have any deleterious effect on the service of the link.

The blackheart malleable links which were produced in Canada had to pass the following physicals.*

(1) The guide lugs had to withstand one blow of 112 foot-pounds. (29-pound weight dropped from 4 feet).

(2) The barrel had to withstand at least one 112 foot-pound blow to pass.

(3) To be acceptable, a link had to take a load

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* It is of interest that the first two of these tests were not required by specification but were imposed on their own product by the manufacturers, the International Harvester Company of Canada Limited, Hamilton, Ontario, in order to ensure greater reliability in service.

(Discussion, cont'd) -

> of 10,000 pounds on the bend test before breaking, and after breaking show a bend angle of at least 5 degrees.

Of the six links, subjected to the bend test, one failed; it took 9,450 pounds and had a 2.5 degree angle.

One link failed in the hammer test out of five tried. It would appear from these results that in the process of manufacture a certain number of brittle links are produced.

The links have good resistance to impact. Nine guide lugs were tested and only one failed. This test, however, was carried out using a 350-foot-pound blow. The barrels were capable of withstanding 400-foot-pound blows.

Whiteheart malleable is produced by pouring white cast iron, usually high in sulphur and low in carbon and silicon, into sand moulds. These castings are then malleabilized by heating in large furnaces surrounded by a mixture of new and spent iron ore for several days at a temperature of 950° to 1000° C. A removal of carbon from the white iron takes place. The time at the temperature controls the depth of decarburization produced.

Microscopic examination of the links indicated that the thin sections were almost completely decarburized under the thin cyanided case. The thicker section, such as the internal portion of the grouser, consisted of a higher-carbon area. This part showed a much higher hardness, 321-371 Brinell.

The specification requires that the surface hardness be 500 Vickers on the inside of the eyehole. The value obtained, using a 10-kilogram load, would indicate that this requirement has been met in the very surface material. In service, this outer hard skin would be expected to wear better than the surface on the homogeneous type of cast-steel link made for the Canadian

(Discussion, cont'd) -

track. However, this outer hardened layer is very thin and wear in the carbonless iron immediately under it would be very rapid once the skin has been removed. From the standpoint of wear only, then, the Canadian-made link might be reported to perform better than the type of link under examination. In so far as pitch change is concerned, eyehole stretch is equally as serious as wear. In this respect, the Canadian-made link would have a much higher elastic limit than the completely decarburized material surrounding the eyehole of the British-made link.

Incidently, from the wear standpoint, it would seem pointless to demand exceedingly high hardness in a pin surface when the hardness of the link eyehole is such that link wear, not pin wear, must control pitch change. Of course, if the fatigue strength of the pin is considered, hardness is important. This point is discussed below.

<u>Pins</u> -

The pins conform to the chemical analysis specifications of B.S.S. 5005/102.

They pass the drop impact test specified by O.A. 214. Three out of four pins passed the bend deflection of 0.25 inch minimum prior to the first audible or visible case crack. The pins have hard, thin cases and soft cores.

In the field tests carried out at Windsor, Ontario, the softer-surface homogeneous pins (46-51) Rockwell 'C' had a much longer life than the harder-surface SAE 3115 cased pins. It is felt that the superior performance of the homogeneous pin indicates failure in the cased pins as starting below the outer hard surface zone. If this theory is correct, then a soft-cored pin would fail by fatigue at a lower mileage than a hard cored one, due to the presence of a softer material at the

(Discussion, cont'd) -

zone of failure. Field tests showed that soft-cored, thin-cased pins failed at a lower mileage than hard-cored pins. It must be pointed out that the soft-cored pins had somewhat softer cases than the hard-cored pins. Consequently, judgment as to the correctness of the above theory must be delayed until such time as field test results conclusively prove that, with the same case depth and surface hardness, a soft-cored pin fails at an earlier mileage than a hard-cored pin.

The core structures given in Figures 6 and 7 show the differences, both in the amount and the dispersion of the ferrite encountered in the investigation of these pins. Fineness of core structure as well as of case structure is desirable to produce the strongest type of pin. The case structure shown in Figure 8 is well-refined tempered martensite.

CONCLUSIONS:

Links -

1. Small cavities are present, but in a position where no deleterious effects should result in service.

2. One of the six links tested failed the bend test.

3. One of five links subjected to the hammer test failed.

4. The impact resistance of the links was satisfactory.

5. A cyanided case depth of 0.003 - 0.005 inch has been obtained.

6. A deep zone of practically carbonless iron is present immediately under the case. This is 0.15 inch deep in some sections. Such a condition is condusive to link stretch.

7. The process of manufacture evidently produces

(Conclusions, cont'd) -

some links which are brittle.

Pins -

1. The steel used for the pins conforms to B.S.S. 5005/102 in chemical analysis.

2. The pins pass the drop impact test of 45 foot-pounds without breaking in two.

3. Three out of four pins tested passed the minumum bend deflection of 0.25 inch without audible or visible case cracking.

4. The pins have hard cases and soft cores.

5. The case depths are 0.008 - 0.010 inch.

6. A variation in core structure is observed.

7. The case structure is tempered martensite.

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SLG:GHB:LB.