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# REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1559.

Investigation of Universal Carrier Track Links and Pins After 4,913 Miles in Field Test.

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(Copy No. 16.)

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

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
Mines and Geology Branch

O T T A W A January 3rd, 1944.

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## Investigation of Universal Carrier Track Links and Pins After 4,913 Miles in Field Test.

**Abstract**

**Eight links which failed after 4,913 miles in field test have been examined. Six of these were given a special salt quench heat treatment. Two were the regular production standard malleable links. The pins which made up this assembly and which were not broken after this mileage have also been examined.**

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### Origin of Material and Object of Investigation:

On November 22nd, 1943, Dr. C. W. Drury, Director of Metallurgy, Army Engineering Design Branch, Department of Munitions and Supply, Toronto, Ontario, submitted eight (8) broken Universal Carrier links and eleven (11) unbroken pins for examination. It was reported that these had gone 4,913 miles in a field test at Windsor, Ontario.

Six of the broken links were of blackheart malleable cast at International Harvester Co. of Canada, Hamilton, Ontario, and specially heat treated in these Laboratories, the treatment

(Origin of Material and Object of Investigation, cont'd) -

involving a heating to above the critical and a quench into a molten salt bath.

The two other broken links were the standard blackheart malleable links produced and heat treated in the regular production manner at the International Harvester plant.

Ten of the pins were from the Canadian Acme Screw and Gear Company, Toronto, Ontario. The remaining pin was produced by Allied Products Corporation, Detroit, Michigan.

A complete metallurgical examination on both the links and pins was requested by Dr. Drury, under Requisitions Nos. 615 and 616, AEDB Lots Nos. 502 and 503, received on November 29th, 1943, Report No. 9B, Test No. 2 and Report No. 9A, Test No. 26.

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## TRACK LINKS.

### Heat Treatment:

#### Specially Treated Links -

Annealed in the regular blackheart cycle but not decarburized; were cyanided at 1500° F. for 30 minutes, then quenched in caustic soda at 590° F. to 680° F. for 45 minutes.

#### Blackheart Malleable Link -

Annealed in regular blackheart cycle but with some iron ore in packing (iron ore added of high-silicon type and in amounts just sufficient to make up for dust loss). The castings are preheated to approximately 1500° F. then heated in a cyanide salt bath at 1620° F. for 34 minutes, air-cooled for 20 minutes, heated in hardening salt bath at 1450° F. for 2 minutes, and quenched in oil at 120° F. to 180° F. A 0.015- to 0.030-inch decarburized zone was aimed for in the annealing

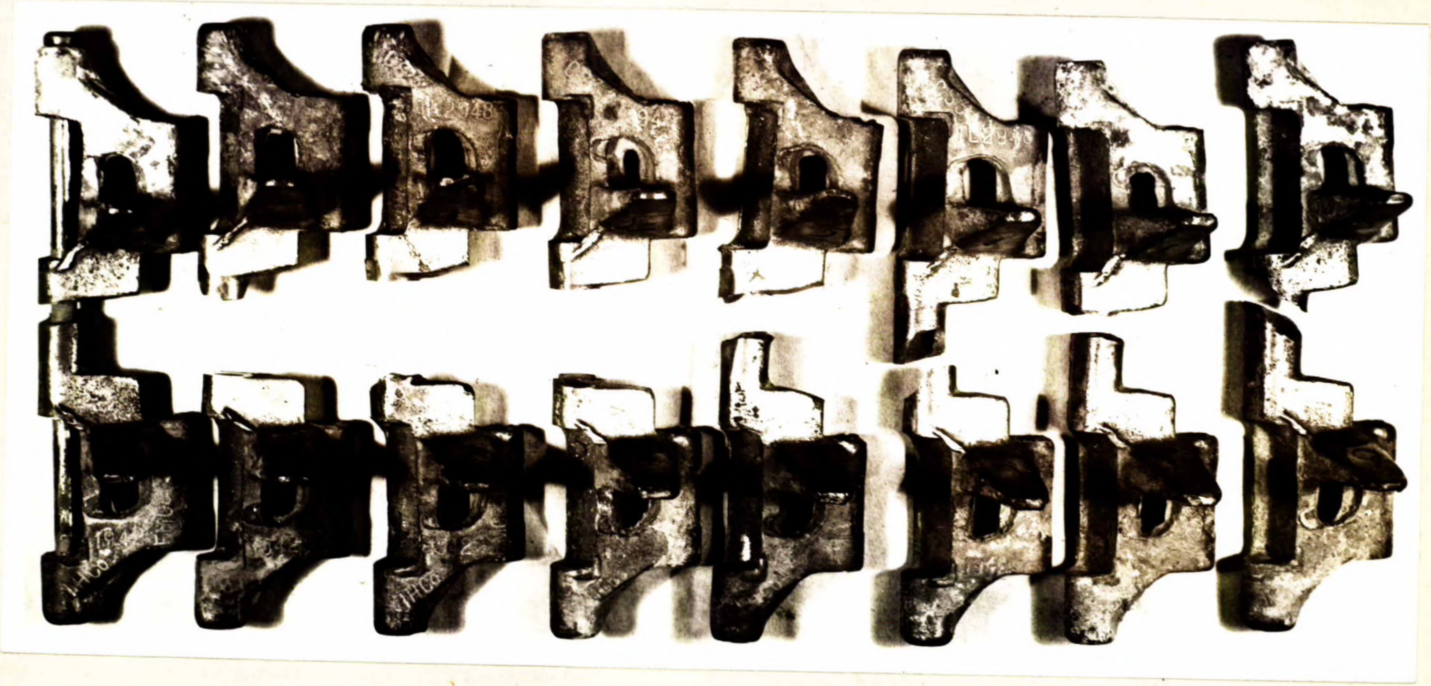
(Heat Treatment, cont'd) -

process and approximately a 0.005-inch cyanided case in the hardening bath.

<u>Macro-Examination:</u>

The links as received are shown in Figure 1.

<u>Figure 1.</u>



LINKS AS RECEIVED.

Both types of links have failed at the same position across the centre of the barrel on the three-eys side. One link, (Macro-Examination, cont'd) -

however, had the centre eye-hole wall worn to approximately 3/32 inch. The fracture of this link was fresh and non-duplex in character. Other link fractures were worn by service operation and showed very little that was of interest.

Hardness Surveys:

Sections were cut through the barrel and grouser of each track link as close as possible to the position of failure, and hardness readings were taken from the centre of the grouser towards the eye-hole surface. The Vickers hardness testing machine was used, with a 10-kg. load. Hardness readings were plotted against the distance from the eye-hole surfaces, and the values at each 0.01 inch from the surface are tabulated below:

TABLE I.

| Link No. | VICKERS HARDNESS NUMBERS Distance from eye-hole surface, in inches | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.01 | 0.02 | 0.03 | 0.04 | 0.05 | 0.06 | 0.07 | 0.08 | 0.09 | 0.10 | 0.15 | 0.20 | 0.25 |
| 1* | 170 | 170 | 204 | 232 | 232 | 232 | 232 | 232 | 232 | 232 | 227 | 220 | 220 |
| 2 | 233 | 233 | 233 | 235 | 238 | 235 | 230 | 225 | 222 | 218 | 205 | 195 | 200 |
| 3 | 102 | 105 | 107 | 108 | 108 | 109 | 113 | 115 | 115 | 115 | 159 | 228 | 255 |
| 4 | 226 | 265 | 292 | 295 | 296 | 298 | 298 | 298 | 298 | 298 | 298 | 298 | 298 |
| 5* | 160 | 166 | 169 | 172 | 175 | 178 | 179 | 180 | 181 | 182 | 187 | 192 | 192 |
| 6 | 205 | 220 | 230 | 245 | 260 | 272 | 272 | 276 | 280 | 282 | 278 | 265 | 265 |
| 7 | 149 | 165 | 190 | 214 | 240 | 255 | 270 | 282 | 298 | 292 | 273 | 273 | 273 |
| 8 | 226 | 210 | 224 | 266 | 268 | 270 | 272 | 275 | 276 | 279 | 285 | 285 | 285 |

* Standard malleable iron links.

Hardness readings were taken at approximately the centre of the eye-hole wall section of each link. The standard malleable links varied from 181 to 249 V.H.N., while readings on the austempered links varied between 242 and 292 V.H.N.

Microscopic Examination:

Transverse sections were cut across the barrel and grouser of one standard malleable and two specially treated links.

(Continued on next page)

(Microscopic Examination, cont'd) -

These were polished and etched in 2 per cent nital. Figures 2, 3, and 4 (X250 magnification) are taken from the centre of the grouser. Figure 5 (X250) is a photomicrograph taken at the eye-hole surface of the standard malleable link.

Figure 2.

X250, nital etch.

CENTRE OF GROUSER,
STANDARD MALLEABLE LINK.

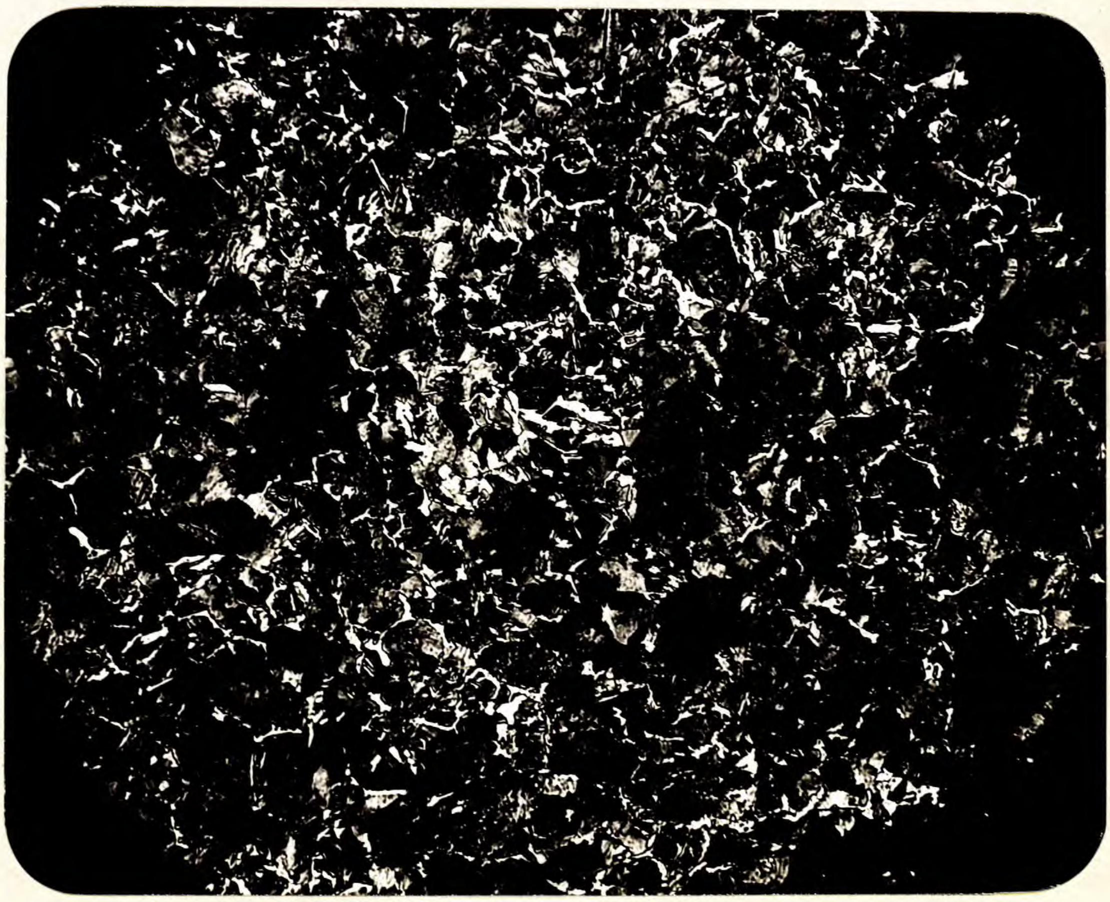
(Continued on next page)

Figure 3.



X250, nital etch.
CENTRE OF GROUSER, SPECIALLY
TREATED MALLEABLE LINK.

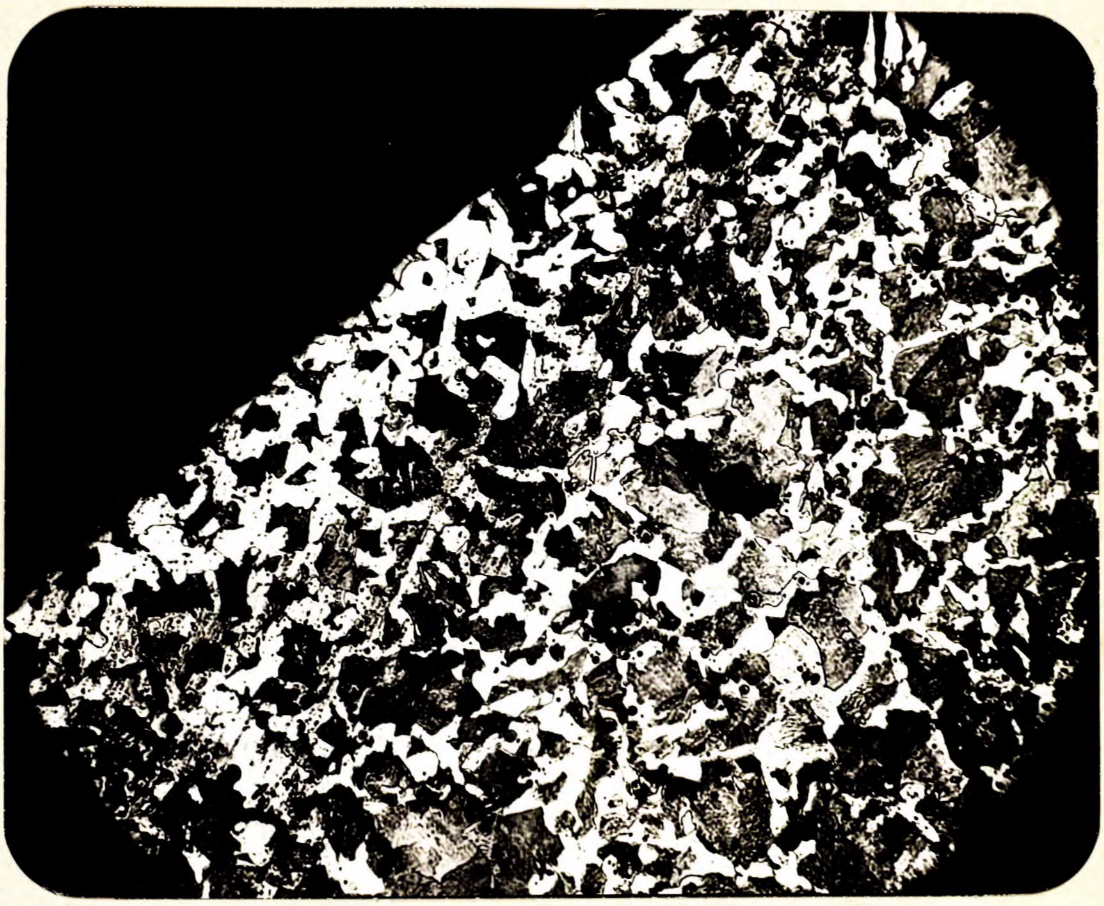
Figure 4.



X250, nital etch.
CENTRE OF GROUSER, SPECIALLY
TREATED MALLEABLE LINK.

(Microscopic Examination, cont'd) -

Figure 5.



X250, nital etch.
EYE-HOLE SURFACE,
STANDARD MALLEABLE LINK.

-

TRACK PINS.

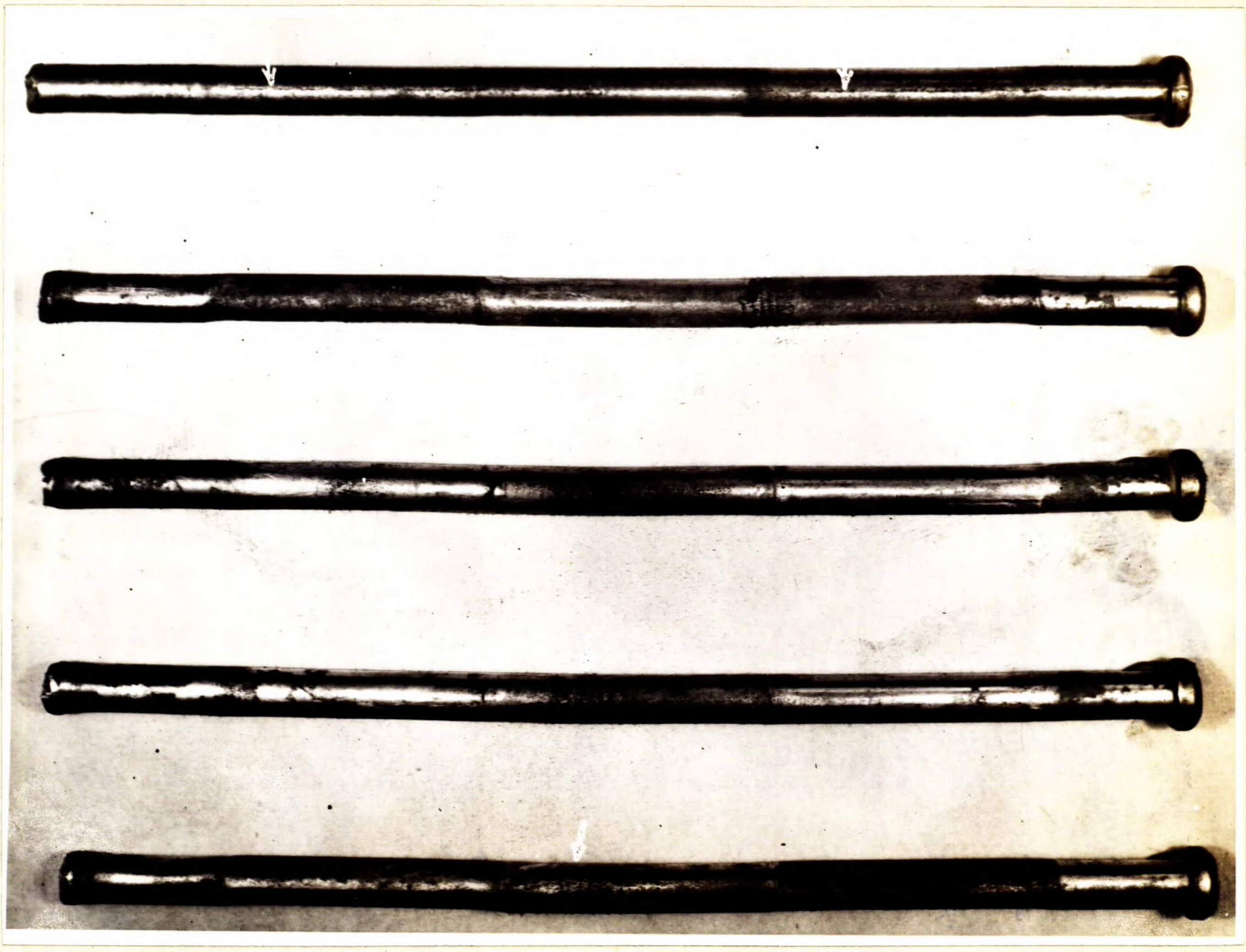
Magnaflux Examination:

The pins were magnetized both longitudinally and transversely, using 1,050 amperes. Transverse surface cracks were observed in four of the pins. One pin had a longitudinal seam. This had been worn down so that it was approximately 0.003 inch in depth. Figure 6 illustrates the magnafluxed pins. The white arrows indicate the points at which cracks are observed.

(Continued on next page)

(Magnaflux Examination, cont'd) -

Figure 6.



MAGNAFLUXED PINS.

(Approximately 2/3 natural size).

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Chemical Analysis:

Drillings were taken, for chemical analysis, from the core of a Canadian Acme pin and from the core of the Allied Products pin. The results were:

| | | Canadian Acme Pin | Allied Products Pin |
|---|---|---|---|
| | | - Per cent - | |
| Carbon | - | 0.13 | 0.17 |
| Manganese | - | 0.45 | 0.53 |
| Nickel | - | 1.60 | 1.01 |
| Chromium | - | 0.02 | 0.68 |
| Silicon | - | 0.33 | - |
| Sulphur | - | 0.018 | - |
| Phorphorus | - | 0.009 | - |

-

Physical Properties:

Tensile test specimens were machined from the cores of four Acme pins and the one Allied Products pin. An 0.252-inch-diameter specimen was used. Elongation was measured on 1-inch gauge length.

TABLE II.

| | Allied | No. 9 Acme | No. 7 Acme | No. 2 Acme | No. 8 Acme |
|---|---|---|---|---|---|
| Tensile, p.s.i. | 132,600 | 124,000 | 128,800 | 108,100 | 129,200 |
| 0.1 per cent proof, p.s.i. | 90,600 | 88,000 | 92,400 | 85,300 | 101,000 |
| Elongation, per cent | 22 | --* | 18 | --* | 19 |
| Reduction of area, per cent | 61.2 | 64 | 58 | 71.8 | 60 |

* Broke outside the gauge length.

Bend and Impact Tests:

Two Acme pins which showed no surface cracks on magnafluxing were tested for bend and impact. The standard inspection test machines were used. The results were:

| Pin No. | Surface Hardness, V.P.N. (10-kg.) | Core hardness, Rockwell 'C' | Bend deflection, in inches | 45 ft-lb. impact |
|---|---|---|---|---|
| 4 | 642-707 | 25-26 | - | Passed |
| 3 | --* | 20 | 0.25 | -- |

* Not taken.

Depth of Case:

Transverse sections were cut from five pins. They were etched in nital and the depth of case was then measured using the Brinell microscope.

| | Depth of case, inches |
|---|---|
| Acme Pin No. 8 - | 0.008-0.018 |
| " " " 2 | 0-0.012 |
| " " " 4 | 0-0.008 |
| " " " 9 | 0.008-0.014 |
| Allied Pin | 0-0.010 |

Hardness:

Transverse sections were cut from the pins, and Vickers hardness readings were made across the face, using a 10-kg. load. Table III indicates the results obtained. Because of crankshaft, results of hardness tests on the pin surfaces have been rendered of academic interest only; consequently, only five pins were tested.

TABLE III.

| Sample No. | At the surface | VICKERS HARDNESS NUMBERS At depths, in inches from the surface 0.005 | 0.010 | 0.025 | 0.050 | 0.075 | 0.10 | 0.20 |
|---|---|---|---|---|---|---|---|---|
| 2 | 251-613 | 490 | 366 | 270 | 241 | 227 | 206 | 206 |
| 4 | 503-613 | 465 | 352 | 262 | 262 | 264 | 276 | 263 |
| 8 | 498-514 | 438 | 366 | 297 | 245 | 228 | 227 | 242 |
| 9 | 478-525 | 460 | 448 | 332 | 270 | 232 | 220 | 230 |
| Allied | 317-752 | 587 | 425 | 305 | 281 | 279 | 277 | 277 |

Core hardnesses were taken on the other pins, using the Rockwell 'C' scale.

| Pin No. | Hardness |
|---|---|
| 5 | 20-21 |
| 1 | 22-23 |
| 6 | 16 |
| 10 | 13-16 |
| 3 | 20 |
| 7 | 26-28 |

Microscopic Examination:

Transverse sections were cut from the same set of pins as were used for core physical properties. The specimens were polished and etched in 2 per cent nital. Figures 7, 8, 9 and 10, taken at X500, are of Acme Pins Nos. 2, 8, and 9 and the Allied pin. Figure 11 (X500) is taken at the surface of Acme Pin No. 9.

(Continued on next page)

Figure 7.

X500, nital etch.
CORE OF PIN NO. 2.

Figure 8.

X500, nital etch.
CORE OF PIN NO. 8.

Figure 9.

X500, nital etch.
CORE OF PIN NO. 9.

Figure 10.

X500, nital etch.
CORE OF ALLIED PRODUCTS PIN.

Figure 11.

X500, nital etch.
CASE OF PIN NO. 9.

DISCUSSION:

LINKS

The non-duplex nature of the fracture on one of the specially treated links pointed to an impact failure. The condition of the other link fractures made it impossible to form any definite conclusions as to the mechanism of failure. These links apparently had been held together by pins and so operated after failure, this operation destroying any evidence that might be supplied by the fracture condition.

Most of the decarburization was worn off the standard malleable links. The specially treated links were supposed to have been annealed under controlled conditions so that they would be free from decarburization. This was not achieved, as Table I indicates the presence of decarburized surfaces in some of the links. This decarburization was especially deep in Link 3.

For the standard malleable the absence of ferrite indicates that the soaking time in the cyanide bath was sufficient. The presence of cementite is due either to too long a soak in the cyanide bath or, more probably, to too fast a cooling in the final stages of the malleabilizing process.

However, for the specially treated links no slow cooling, similar to the "dog-house" cooling of the standard malleable, follows the resoaking procedure. In the specially treated link, then, the presence of carbide definitely shows too fast cooling in the final stages of the anneal. Also, the absence of slow cooling of the core of the link accounts for the greater fineness of pearlite in the specially treated product (the final quenching of the standard malleable link only affecting the outer material).

In all three of the links examined, the thin case

(Discussion, cont'd) -

had been well worn off. Figure 5 indicates that for the standard malleable link, most of the ferrite layer (usually 0.015-0.030 inch) had also been eliminated.

The fact that six specially treated links, two standard malleable links and no steel links broke in the field tests indicates that the links as listed are in their reverse order of serviceability. Test results, however, indicated that the specially treated malleable links had the best wear resistance in the eye-holes. It might be that the greater durability of the standard malleable and the better wear resistance of the specially treated link might be combined by retreating the eye-hole portion only of the standard malleable by the special process, heating being effected by induction or lead bath. Indeed, the product might be further improved in ductility should the standard procedure for malleable be altered so as to include a quench other than an air cool from the cyanide operations.

The presence of ferrite in the specially treated link definitely means that the material was given too short a soaking time in the final heat treatment.

It should be pointed out that the whole object of the special heat treatment was to produce a harder eye-hole of the same ductility, the object being to increase wear resistance at no sacrifice in toughness. The decarburized material, of course, will not respond to heat treatment; therefore, in the case of heavily decarburized links there was no chance of effecting improvement by special heat treatment.

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(Discussion, cont'd) -

PINS

Four of the ten Acme pins examined by magnaflux showed cracks in the surface. These have been caused by bends in the pins, some well over 0.25 inch deflection. These pins were bent either by the blow which finally broke the links or by having to carry the whole load after the links failed.

The Allied Products pin showed evidence of a longitudinal seam. It is of extreme interest that this pin lasted for 4,913 miles without breaking. It would appear that seamy stock is not critical, so long as the seam does not penetrate too deeply. If more pins can be found which show the existence of longitudinal seams, conclusions may be reached as to the depth of seam permissible in the bar stock used as carrier pins. The above-mentioned pin is the first of the seamed type that has come to our attention after having been in service.

The chemical analyses indicate that these pins have been produced prior to the order establishing the chromium limits at 0.25-0.45 per cent. The Acme pins having only 0.02 per cent chromium whereas the Allied pin has 0.68 per cent. This chromium addition aids the hardenability considerably. The specified core hardness of 24-32 Rockwell 'C', however, can be met more readily with the chromium content between 0.25 and 0.45 per cent, taking into consideration the variation in the plant conditions of the numerous pin producers.

Of the ten Acme pins examined, two had core hardnesses below 20 Rockwell 'C'. Only two were within the specified range. The pins were mainly 20-23 Rockwell 'C'. More pins should be taken and checked for core hardness to establish the range which gave satisfactory service. It is believed that after the

(Discussion, cont'd) -

present tests at Windsor, Ontario, are concluded enough evidence will be available to definitely establish the most suitable core hardness range, especially in view of the excellent service shown in the present test by the standard-cased pins.

The average physical properties of the cores of the Acme pins were:

| | | |
|---|---|---|
| Tensile | - | 122,500 p.s.i. |
| Yield | - | 96,600 " |
| Elongation | - | 18.5 per cent. |
| Reduction of area | - | 63.4 " |

Although the pins tested for bend and impact were worn to a considerable extent they still passed the specification requirements.

The cores consisted of low-carbon martensite and ferrite. The cases have been worn away considerably. The photomicrograph, however, taken at the surface of one of the Acme pins, reveals a tempered martensitic structure, tempering probably occurring in the preparation of the specimen.

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CONCLUSIONS:

LINKS

1. One specially treated link apparently broke in impact. There was not sufficient evidence to indicate the mechanism of the other link failures.

2. The "specially treated" links were not free from decarburization, as was specified from the manufacturer. Indeed, one link was very badly decarburized. This latter link, especially, would not be expected to show to advantage the special heat treatment which is designed to increase the wear resistance of the eye-hole with no sacrifice in ductility. For this link

(Conclusions, cont'd) -

the eye-hole metal was practically free from carbon to a fair depth.

4. Free carbides are present, indicating, most probably, insufficient time in the final stages of the annealing operations.

5. A reheat treatment of the eye-hole portion only of the standard malleable by special method is suggested as a possible means of producing a link with the ductility of the standard malleable and the wear resistance of the specially treated link.

PINS

1. Magnafluxing shows transverse cracks on the surface for four out of ten Acme pins tested.

2. Evidence of a longitudinal seam on the Allied pin indicates the probability that seamy bar stock is not critical. More evidence, however, is needed for confirmation.

3. Chemical analysis of Acme and Allied pins shows two extremes in chromium content; the former has 0.02 per cent and the latter has 0.68 per cent. For the present specified core hardness of Rockwell 'C' 24-32, a chromium content of 0.25-0.45 is desirable.

4. Of the pins examined,

two (2) were within specified core hardness range,

three (3) were below 20 Rockwell 'C', and

five (5) were 20-23 Rockwell 'C'.

(Continued on next page)

(Conclusions, cont'd) -

5. Core physical ranges were:

Tensile, 108,100-132,600 p.s.i.
Yield, 85,300-101,000 p.s.i.
Elongation in 1 inch, 18-22 per cent.
Reduction of area, 58-71.8 per cent.

6. Core structures consisted of low carbon martensite and ferrite in varying amounts.

7. Case structures were tempered martensite.

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RECOMMENDATIONS:

Since the standard cased pins have given excellent service, a large number should be sectioned and checked for core hardness. This would give excellent information as to the desirable core hardness range.

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SLG:GHB.