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OTTAWA December 11th, 1941.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1133.

Examination of Valentine Tank Track Pins.

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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 December 11th, 1941.

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Origin of Material and Object of Investigation:

On November 28th, 1941, Mr. G. N. Wedlake, of the Cockshutt Plow Company Limited, Brantford, Ontario, sent in twenty-nine Valentine Tank track pins for examination.

Six of these were pack-carburized S.A.E. 2115 steel from the Canadian Pacific Railway, Montreal, Quebec; of these six, five had broken in service at approximately the same place. An examination of these pins was requested

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

in order to determine, if possible, the reason for failure.

The remaining pins were from the Cockshutt Plow Company Limited, Brantford, Ontario. All but four were of S.A.E. 1045 steel, the others being of S.A.E. X1335 steel. Some of these pins had been hardened by the Tocco induction method, whilst some had been quenched after being liquid-carburized. Both types of pins had been given a variety of heat treatments after being hardened. An examination of all pins was requested, in order to determine which treatment conferred the most satisfactory properties.

In order to readily identify the variety of pins examined, the pin types were designated by letters as indicated in the following table:

Table I.

C.P.R. pins, pack-carburized S.A.E.2115 steel:

Type		
A.	-	Unbroken after 292 miles.
B.	-	Broken, no mileage given.
C.	-	" , 255 miles.
D.	-	" , 410 "
E.	-	" , no mileage given.
F.	-	" , 410 miles.

Cockshutt Plow pins:

G.	-	Liquid-carburized S.A.E.1045	-	250° F. draw; no mi.given.
H.	-	" " " "	-	400° F. " ; " " "
I.	-	" " " "	-	600° F. " ; 327 miles.
J.	-	Tocco-hardened S.A.E.X1335	-	250° F. draw; 935 miles.
K.	-	" " S.A.E.1045	-	250° F. " ; 935 "
L.	-	" " " "	-	400° F. " ; no mi.given.
M.	-	" " " "	-	600° F. " ; 327 miles.
N.	-	" " S.A.E.X1335	-	250° F. draw.
O.	-	" " " "	-	250° F. "
P.	-	" " " "	-	250° F. "

-

Specification:

The specification governing the manufacture of these pins states that they should be case-hardened to a depth which is not to exceed 0.035 inch. This case is required to have a minimum Vickers hardness of 700 and the pin is required to show an 8° bend without fracture when bent on a 12-inch radius.

Macroscopic Examination:

No obvious defects, apart from the breaks on five of the C. P. R. pins submitted, could be seen on visual examination. Breaks in the C. P. R. pins occurred in the same place, i.e., at about three-quarters of the pin length as measured from the head, as Figure 1 shows. This would be just before the edge of the outside eye on the three-eye side of the link. It was reported that all failures were of this type.

Figure 1.

Fracture on C. P. R. Pins.

In order to obtain some measurement of the wear, (Macroscopic Examination, cont'd) -

diameter measurements were made on Pins A, I, M, and H at the point on the pin where failure usually occurs. The results obtained are reported in the following table, the values given being an average of at least seven readings:

Pin		Diameter, in inches
A.	-	0.871
I.	-	0.869
M.	-	0.870
H.	-	0.862

-

Magnaflux Tests:

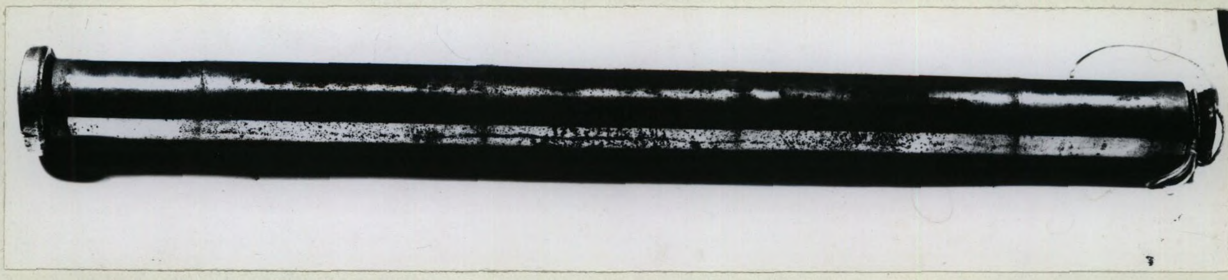
All the pins were magnafluxed, both circularly and longitudinally, using the residual powder method. 2,000 amperes was used for circular and 1500 amperes for longitudinal magnetization.

No transverse cracks were found. Figure 2 shows a longitudinal defect found in a Tocco-hardened S.A.E. 1045 pin which had been drawn at 250° F. and had been in service for 935 miles. Figures 3 and 4 show a series of radial cracks or strains on the head of a pin, as revealed by the magnaflux method. These were present on two liquid-carburized pins drawn at different temperatures, namely 250° F. and 400° F., but having gone the same mileage, 935.

(Figures 2, 3, and 4 are shown on next page)

(Magnaflux Tests, cont'd) -

Figure 2.



Magnafluxed pin showing longitudinal defect.

Figure 3.

Figure 4.

Magnafluxed pins showing defects in pin-head.

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Depth of Case:

Samples were polished and etched and the depth of case was measured microscopically to an accuracy of one-thousandths of an inch. Depths varied from 0.021 to 0.075 inch (case depth being taken from the outside edge to the middle of the transition zone). The results are

(Continued on next page)

(Depth of Case, cont'd) -

shown below:

Type of Pin	Treatment	Depth of Case, in inches
A.	C.P.R., Pack Carb.	0.035
B.	" " "	0.066
C.	" " "	0.040
D.	" " "	0.040
E.	" " "	0.051
F.	" " "	0.054
G.	Cockshutt, Liquid Carb.	0.021
H.	" " "	0.040
I.	" " "	0.021
J.	Cockshutt, Tocco X1335	0.035-0.055
K.	Cockshutt, Tocco 1045	0.058
L.	" " "	0.043-0.065
M.	" " "	0.062-0.075
N.	Cockshutt, Tocco X1335	0.036-0.055
O.	" " "	0.041-0.048
P.	" " "	0.022-0.062

Figure 5 shows, respectively at Positions 1 to 4, polished and etched specimens cut from Pins I, A, O, and L, the dark etching nature of case serving to reveal its thickness.

Figure 5.

1 2 3 4

PHOTOGRAPH SHOWING DIFFERENT
CASE DEPTHS.

Hardness Tests:

Using the Vickers method and a 10-kilogram load, hardnesses were taken of the etched samples at varying distances from the surface. Depth-to-hardness relationships are shown in Table II.

Table II.

SAMPLE NO.	VICKERS HARDNESS NUMBERS At surface	At Depths, in inches from surface 0.012	0.025	0.050	0.075	0.10	0.125	0.150
A.	803	635	483	310	240	168	158	153
B.	882	793	708	600	407	304	227	190
C.	803	742	627	275	250	213	187	175
D.	882	688	628	295	212	190	187	185
E.	813	767	672	455	332	250	202	200
F.	933	815	660	428	216	167	167	167
G.	579	612	482	350	270	233	220	218
H.	672	633	525	385	285	263	250	245
I.	634	455	370	256	240	230	225	220
J.	690	647	570	270	247	243	240	230
K.	833	795	735	375	298	291	278	270
L.	690	648	600	410	240	230	228	217
M.	530	530	516	446	377	310	238	223
N.	702	645	580	455	345	240	235	228
O.	892	692	620	385	263	257	252	247
P.	690	626	553	305	229	220	212	204

Microscopic Examination:

Polished sections from all pins were examined under the microscope, both in the unetched condition and after an etch in a solution of 2 per cent nitric acid in alcohol. Examination of the unetched specimens showed that the steel was quite clean. Figures 6 to 14, which appear at the end of this report, are photomicrographs, at X1000 magnification, obtained from representative structures revealed by the nital etch. Captions under the figures indicate the locations from which the photomicrographs were taken.

(See photomicrographs at end of this report.)

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Bend Tests:

Bend tests of the unbroken pins were carried out in an Amsler Universal testing machine, using 12-inch radii and 9-inch centres.

The results obtained are listed in Table III.

Table III.

Pin		Bend at break, in degrees		Breaking load, in pounds
A.	-	1.5	-	5,000
G.	-	28.9	-	13,300
H.	-	10.5	-	8,650
I.	-	15.0	-	10,000
J.	-	7.0	-	8,200
K.	-	4.5	-	8,000
L.	-	7.3	-	10,000
M.	-	28.5	-	14,750
N.	-	1.8	-	7,000
O.	-	1.8	-	6,700
P.	-	3.2	-	6,200

-

Discussion of Results:

Macroscopic Examination -

It is significant that pin breakage invariably occurs at the same location, which indicates that the pin is most heavily stressed at this point rather than at the eye junctures. This may occur as a result of lack of perfection of the inner surface of the eye holes, a condition that is inevitable in any cast link. It would be interesting to know whether pins used in links made by different manufacturers all failed in the same place. It is also significant that the pins show very little wear, a 935-mile service only causing a reduction in diameter of 0.009 inch. It would seem, then, that the wear resistance of a very hard case is not needed in this service. The fact that breakage invariably occurs at the same location indicates a marked stress concentration. The use of a softer and more ductile material should result in better stress distribution.

Magnaflux Tests -

The magnaflux examination showed no transverse cracks in any of the pins. It is unlikely, then, that quenching cracks are responsible for any of the pin failures encountered and it would seem certain that sound hardened cases can be produced by the Tocco method. Subsequent examination revealed that the indication of a longitudinal defect in one Tocco pin was caused by an area of strain. Markings in the head of the liquid-carburized pin most probably indicate strain areas which form as a result of forging at too low a temperature, since subsequent examination revealed no cracking in these areas.

(Discussion of Results, cont'd) -

Case Depth -

Only Pins A, G, and J met the specification requirements with respect to case depth. It would seem that the pins produced by the liquid-carburizing process, however, would probably be satisfactory on this score, although they are likely to have a case depth of about 60 per cent of the maximum specified. Three of the C. P. R. pins have approximately the required depth of case. The others have considerably thicker cases. It is obvious that the case produced by the Tocco method is liable to be less uniform in thickness than the case on pins treated by pack- or liquid-carburizing methods. The average case thicknesses on these Tocco-hardened pins also exceeds the specified maximum. Tocco-hardened pins, however, have approximately the same case thicknesses as have the more heavily carburized C. P. R. pins.

Hardness Tests -

Only the C. P. R. pins and Pins K, N, and O have cases of the required specified hardness. It is peculiar that Pin G, which has been drawn at 250° F., should have a lower hardness than Pins H and I, which have been drawn respectively at 400° F. and 600° F., since all pins have been given the same hardening treatment. The lower hardness of Pin G may be due to the fact that it was improperly quenched. It is also possible that the pins may have been mixed in tagging. Apparently a 250° F. draw produces very nearly the required hardness in both X1335 and 1045 Tocco-treated pins. The cores of the Tocco-hardened pins have

(Discussion of Results, cont'd) -

(Hardness Tests, cont'd) -

more uniform hardnesses than have the cores of the C. P. R. pins. It is obvicus that the Tocco treatment has little effect on the core material.

Microscopic Examination -

The cleanliness of the steel indicates that satisfactorily made steel was used in every case. The amounts of ferrite in the core are an indication of the temperature from which the core material was quenched. For the pack- and liquid-carburized pins, the core and case material must necessarily have been quenched from the same temperature. The large amount of ferrite in the C. P. R. pins shows that these pins were cooled slowly in the carburizing medium and then reheated to approximately 1400° F. and subsequently quenched. All other pins contain only a small amount of ferrite, so they must have been quenched from just under the upper critical. It would have been better if these pins had been quenched from a slightly higher temperature, as a uniform fine pearlitic (sorbitic) structure is to be preferred. Cases produced by the Tocco method are much finer in structure than are cases produced by pack- or liquid-carburizing. Because of this, it is possible that they might have better properties. All cases, however, had satisfactory structures.

Bend Tests -

Only one C. P. R. pin was available for the bend test and it gave poor values. This should not be taken to indicate that this is the result that might

(Discussion of Results, cont'd) -

(Bend Tests, cont'd) -

normally be expected from C. P. R. pins, as it is quite possible that this pin was not representative. Only Pins G, H, I, and M, i.e., all the liquid-carburized pins and the Tocco pin that had been drawn at 600° F., met the load requirements of the specification. Pins J and L, however, very nearly met the requirements. The cases of all of these pins had hardnesses under the specified minimum and the two pins that gave the best bend test results had the softest cases. Case thickness for the ranges present seems to have little effect on the results, as the two pins that gave the best results had respectively the thinnest and thickest case of any of the pins examined. The liquid-carburizing method, obviously, produces satisfactory pins. If the specified bend test is to be met, however, the Tocco treatment must be followed by a draw of at least 400° F.

Summary:

Since only one whole C. P. R. pin was submitted for examination, it is not felt that any comment can be made on this type of pin. It is obvious, however, that a good percentage of the C. P. R. pins have more than the specified maximum case thickness.

The liquid-carburized pins meet the requirements of the specification and should give satisfactory service.

The Tocco-treated pins examined have cores with non-uniform thicknesses. The average thickness of these cores

(Summary, cont'd) -

exceeds the specified maximum by about the same amount as do the thicknesses of the cores on the more heavily carburized C. P. R. pins. Bend test results indicate that Tocco pins would probably not be satisfactory unless the Tocco treatment were followed by a draw of at least 400° F.

Magnaflux tests indicate that the pins have not been cracked in process of manufacture. Pin diameter measurements show that pin wear is small. It would seem, then, that the minimum allowable case hardness should be reduced.

Conclusions:

Satisfactory pins can be produced by any of the following processes:

(1) Pack carburizing followed by a quench and draw to the required hardness.

(2) Liquid carburizing followed by a quench and draw to the required hardness.

(3) Induction hardening followed by a quench and draw to the required hardness.

(4) A quench and draw of a suitably selected steel to the required hardness.

Previous work has indicated that the Tocco treatment must be preceded by the last-named treatment, because case depth becomes too great if unsorbitized stock is used. This heat treatment, of course, also improves the core properties. It may be that this treatment would not be necessary if an induction equipment operating on the thermonic principles were used, as such equipment

(Conclusions, cont'd) -

operates at high frequency and consequently can produce shallow cases. The Induction Heating Company, of 389 Lafayette Street, New York City, make such equipment for industrial use and are said to sell a 20-kilowatt unit for $5,000. Unsorbitized pins heat-treated by this method, of course, would not have as good core properties.

Excepting induction treatments at very high frequencies, the quench and draw treatment undoubtedly lends itself most readily to economical mass production. If this method were to be followed, the steel selected should have a composition which allowed for the production, in a quenching operation, of an outer hardened zone of the desired thickness and a soft core. Steels are available which react in this fashion in 7/8 inch sections. The literature gives the required data on the subject, one publication, the S.A.E. Journal, July 1941, being particularly valuable. This method of manufacture certainly merits a thorough test.

It should be emphasized that an alloy steel is not essential in this application, for carbon steel should give fairly satisfactory results for all methods of manufacture provided the pins are not heat-treated to too high a hardness.

The results of this investigation would show that full advantage is not being taken of the high wear-resistance of very hard cases and yet the use of pins having such cases seriously impairs pin performance. Consideration

(Conclusions, cont'd) -

should be given, then, to changing the specification to meet the realities of the situation. It is firmly believed that better results would be secured if case hardnesses were held between 500 and 550 Vickers. In this event the maximum thickness allowed for the case could be increased to at least 0.060 inch, as the embrittling effect of too thick a case is not nearly so great when the case hardness is lowered. If these changes were made in the specification, the allowable bend angle on a 12-inch radius could be increased to 12 degrees if this were considered desirable.

It is believed that serious consideration should be given to these suggestions.

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SLG:GSF:PES.

Figure 6.

X250, nital etch.

CORE OF PIN B.
(C.P.R., no mileage)

Figure 7.

X250, nital etch.

CORE OF PIN F.
(C.P.R., 410 miles)

Figure 8.

X1000, nital etch.

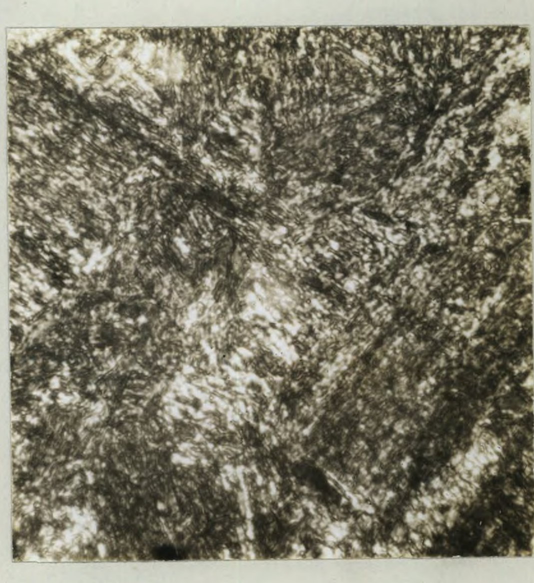
CASE OF PIN B.
(C.P.R., no mileage)

Figure 9.

X1000, nital etch.

CORE OF PIN H.
(Cockshutt liquid-carburized,
400° F. draw)

Figure 10.



X1000, nital etch.

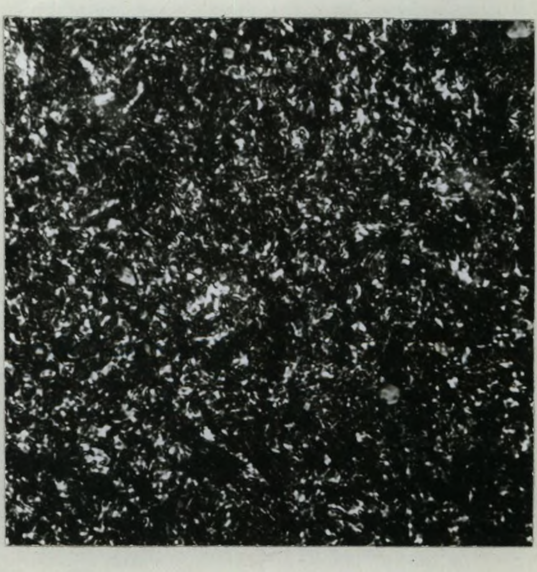
CASE OF PIN H.
(Cockshutt liquid-carburized,
400° F. draw)

Figure 11.

X1000, nital etch.

CORE OF PIN J.
(Cockshutt X1335, Tocco,
250° F. draw)

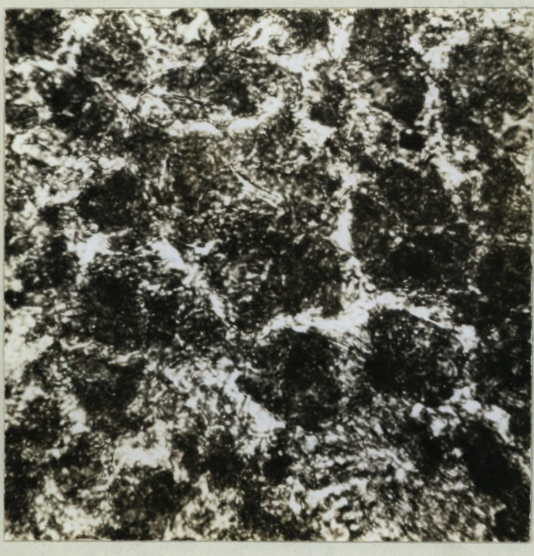
Figure 12.



X1000, nital etch.

CASE OF PIN J.
(Cockshutt X1335, Tocco,
250° F. draw)

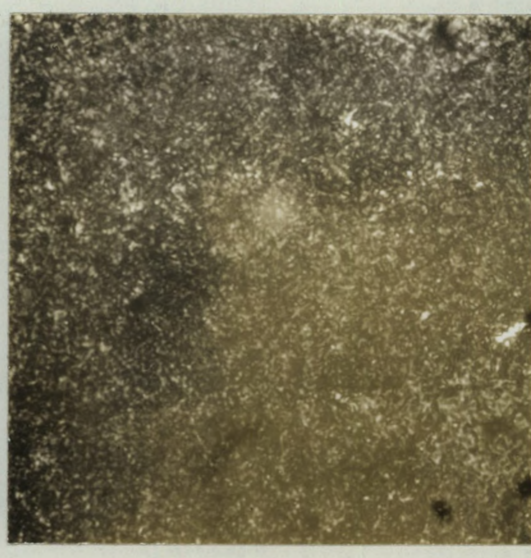
Figure 13.



X1000, nital etch.

CORE OF PIN M.
(Cockshutt 1045, Tocco,
600° F. draw)

Figure 14.



X1000, nital etch.

CASE OF PIN M.
(Cockshutt 1045, Tocco,
600° F. draw)

SLG:GSF:PES.