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REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1577.

Examination of Three Types of Universal Carrier Pins.

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(Copy No. 20.)

Abstract

Universal Carrier pins manufactured by Allied Products Corporation, Canadian Acme Screw and Gear Company Limited and a British producer, representative of pins used in Universal Carrier Field Test No. 16, were examined. Bend tests, impact tests at room temperature and -50° F., hardness tests, and microscopic examination of the core and case materials were carried out. When the final results of the field trial have been obtained the results of these tests should be correlated with them.

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

CANADA

DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

OTTAWA January 20th, 1944.

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Origin of Material and Object of Investigation:

On October 21st, 1943, Dr. C. W. Drury, Director of Metallurgy, Army Engineering Design Branch, Department of Munitions and Supply, Toronto, Ontario, submitted Requisition No. 727, AEDB Lots Nos. 810, 811, 812, Report No. 20, Section A, Test 26, covering the examination of the following material, all of which had been received:

Lot No. 810 - 12 Universal Carrier pins of SAE 3115 steel, with normal core hardness, from Allied Products Corporation, Detroit, Michigan.

Lot No. 811 - 12 Universal Carrier pins of SAE 2115 steel, with low core hardness, from Canadian Acme Screw and Gear Company Limited, Weston, Ontario.

Lot No. 812 - 12 Universal Carrier pins of B.S.S. 5005-102 steel, with low core hardness, of British manufacture.

It was requested that the physical properties of the pins be determined to see how they comply with the requirements

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

of Specification O.A. 214. It was reported that these pins are representative of those used in No. 16 Universal Carrier Field Test. It has been reported that this test has gone 2,575 miles but no further information has been given.

Specification O.A. 214:

Case Hardness -

The case hardness shall be of a minimum hardness of 650 V.P.N., or 80 Rockwell 'A'.

Depth of Case -

The depth of case of pins one-half inch in diameter or less shall be between 0.012 and 0.20 inch in thickness. It should be measured from the surface of the pin to the first point of colour change after the pin has been etched and should not include the transition zone.

Core Hardness -

The core hardness shall be within the limits of 24-32 Rockwell 'C', or 250-315 V.P.N.

Angle of Bend -

Pins of 7/16-inch diameter shall give a minimum deflection of 0.25 inch without the case cracking, when freely supported between 8-inch centres and centrally loaded through a bending block with 12-inch-radius cylindrical face.

Impact Resistance -

Pins of 7/16-inch diameter, when freely supported between 8-inch centres, should withstand a blow of 45 foot-pounds. The case may crack but the pin should not break.

Chemical Analysis:

Drillings taken from the core of one of each type of pin were analysed chemically, with the following results:

Allied Products Pins -

		As Found	Specification SAE 3115
		- Per cent -	
Carbon	-	0.17	0.10-0.20
Manganese	-	0.52	0.30-0.60
Chromium	-	0.68	0.45-0.75
Nickel	-	1.27	1.00-1.50

Canadian Acme Screw and Gear Pins -

		As Found	Specification SAE 2115
		- Per cent -	
Carbon	-	0.10	0.10-0.20
Manganese	-	0.41	0.30-0.60
Nickel	-	1.58	1.25-1.75

British Pin -

	As Found	Specification B.S.S. 5005/102
Carbon	0.10	0.15 max.
Manganese	0.52	0.60 max.
Nickel	1.91	1.50-2.25
Chromium	0.09	0.30 max.

-

Physical Properties:

Tensile Tests -

Tensile specimens 0.252 in. in diameter were machined from the cores of each type of pin and tested in a Baldwin-Southwark testing machine.

Table I, on Page 4, lists the tensile properties of the core material:

(Continued on next page)

(Physical Properties, cont'd) -
Tensile Tests, cont'd -

TABLE I.

Test Bar	Ultimate strength, p.s.i.	0.1 per cent proof stress, p.s.i.	Elongation, per cent for a gauge length of 1 inch	Elongation, per cent for a gauge length of 2 inches	Reduction of area, per cent
Allied Products	136,000	94,000	20	13	62
" "	137,600	98,000	Broke outside of gauge marks.		64
Canadian Acme	122,900	*	15	7.5	70.7
" "	124,100	88,600	20	11	61.2
British	91,200	63,000	30	21	70

* Not determined.

Bend Tests -

Bend tests were carried out on three pins of each type, using the standard inspection machine which supports the pins on 8-inch centres while the load is applied centrally through a loading block with a 12-inch-radius cylindrical face.

Table II, following, lists the results obtained as well as the surface and core hardnesses and the case depths:

TABLE II.

Pin No.	Surface Hardness Rockwell 'A'	Surface Hardness V.P.N.* equivalent	Core hardness, V.P.N., with 50-kg. load	Case depth, inches	Deflection at first case crack, inches
	Allied Products -				
1	79-81	661	285	0.016	0.32
2	80-82.5	710	310	0.014	0.37
3	79.5-81.5	680	264	0.016	0.50
	Canadian Acme -				
1	84.5-85.5	890	252	0.020	0.22
2	84-85	860	266	0.022	<u>0.21</u>
3	84.5-85	(870)*	<u>221</u>	<u>0.022</u>	<u>0.21</u>
	British -				
1	79-80.5	(746)*	204	0.016	0.31
2	<u>77-78</u>	(817)*	<u>206</u>	0.018	0.39
3	83-84	(772)*	<u>248</u>	0.016	0.26

NOTE: Underlined figures indicate results outside the specified limits.

* Bracketed figures are averages of actual readings taken on the surface with the Vickers machine and the 10-kg. load and are not necessarily equivalent to the Rockwell 'A' readings.

(Physical Properties, cont'd) -

Impact Tests -

Drop impact tests were carried out on pins of each type at room temperature and at -50° F. by subjecting the pin, which is freely supported on 8-inch centres, to a blow of 45 foot-pounds. For the low-temperature tests the pins were kept at -50° F. for 30 minutes prior to testing, to ensure that they reached that temperature throughout. The following table, Table III, lists (1) the results of the tests at room temperature, and (2) the results at -50° F., as well as the surface and core hardness and case depth of all pins tested.

TABLE III.

RESULTS OF TESTS AT ROOM TEMPERATURE.

Pin No.	Surface Hardness: Rockwell 'A'	Surface Hardness: V.P.N.* equivalent	Core hardness, V.P.N., with 50-kg. load	Case depth, inches	Remarks
	Allied Products Pins -				
4	81-81.5	(743)*	318	0.016	Passed.
5	74-77	(585)*	264	0.012	Passed.
6	80-81	680	266	0.018	Passed.
	Canadian Acme Pins -				
4	84-85.5	860	238	0.016	Passed.
5	83-85	(824)*	309	0.014	Passed.
6	84.5-85	870	231	0.020	Passed.
	British Pins -				
4	81-81.5	(796)*	204	0.020	Passed.
5	81-82	(814)*	204	0.018	Passed.
6	81-82	(758)*	228	0.016	Passed.
	RESULTS OF TESTS AT -50° F.				
	Allied Products Pins -				
7	80-82	697	316	0.012	Passed.
8	70-75	(698)*	231	0.010	Passed.
9	84-85.5	840	332	0.018	Failed.
10	82-85	800	341	0.016	Passed.

(Continued on next page)

(Physical Properties, cont'd) -
Impact Tests, cont'd -

TABLE III (Continued)

RESULTS OF TESTS AT -50° F. (continued).

Pin No.	Surface Hardness Rockwell 'A'	V.P.N.® equivalent	Core hardness, V.P.N., with 50-kg. load	Case depth, inches	Remarks
	Canadian Acme Pins -				
7	82.5-83.5	780	234	0.018	Passed.
8	82	738	256	0.018	Passed.
9	80-81	680	253	0.020	Passed.
10	82-85.5	815	204	0.020	Passed.
	British Pins -				
7	81.5-82	(858)®	207	0.018	Passed.
8	77-78	(813)®	195	0.014	Passed.
9	83-84	(824)®	204	0.020	Passed.
10	75.5-79	(907)®	192	0.018	Passed.

® NOTE: Bracketed figures are averages of actual readings taken on the surface with the Vickers machine, using the 10-kg. load.

Average Values:

The following table (Table IV) lists average values for the surface and core hardnesses and case depth of each of the three types of pins:

TABLE IV.

Type of Pin	Surface Hardness Rockwell 'A'	V.P.N. equivalent	Core hardness, V.P.N., 50-kg. load	Core depth, inches
Allied Products	80	661	293	0.0148
Canadian Acme	84	828	246	0.0190
British	80.5	(810)®	200	0.0174

® NOTE: Bracketed value is an average of actual readings taken on the surface of pins, using the Vickers machine with a 10-kg. load.

Depth-Hardness Surveys:

Transverse sections were cut from two pins of each type and hardness readings taken across the face of the section, using the Vickers machine with the 10-kilogram load. Table V shows the hardness at various distances from the surface.

TABLE V.

Pin No.	VICKERS HARDNESS NUMBER (10-kilogram load)							
	At surface	At depths, in inches, from the surface						
		0.005	0.01	0.02	0.04	0.06	0.08	0.10
Allied Products No. 4	743	660	575	377	335	330	324	319
" " No. 5	585	507	443	322	312	300	287	253
Canadian Acme No. 3	870	827	725	312	225	210	209	209
" " No. 5	824	737	703	475	393	370	346	327
British No. 4	796	709	600	353	217	210	215	215
" No. 6	758	685	613	383	282	271	264	258

Microscopic Examination:

Transverse sections were cut from two of each type of pin and prepared for metallographic examination. On examining the unetched specimens with the microscope, the steel was seen to be clean. The samples were then etched in 2 per cent nital. Figures 1 and 2 show typical core and case structures, respectively, of the Allied Products pins, Figures 3 and 4 those of Canadian Acme pins, and Figures 5 and 6 those of the British pins. All photomicrographs are at 500 magnifications.

Since the presence of free carbides was suspected in the case of the Canadian Acme pins, two more samples were prepared for metallographic examination and then etched in Murakami's reagent. The presence of a few free carbides in the case was confirmed.

(Figures 1 to 6 follow,)
(on Pages 8, 9, and 10.)

Figure 1.

X500, nital etch.

TYPICAL CORE STRUCTURE OF
ALLIED PRODUCTS PIN.

Low-carbon martensite

Figure 2.

X500, nital etch.

TYPICAL CASE STRUCTURE OF
ALLIED PRODUCTS PIN.

Tempered martensite.

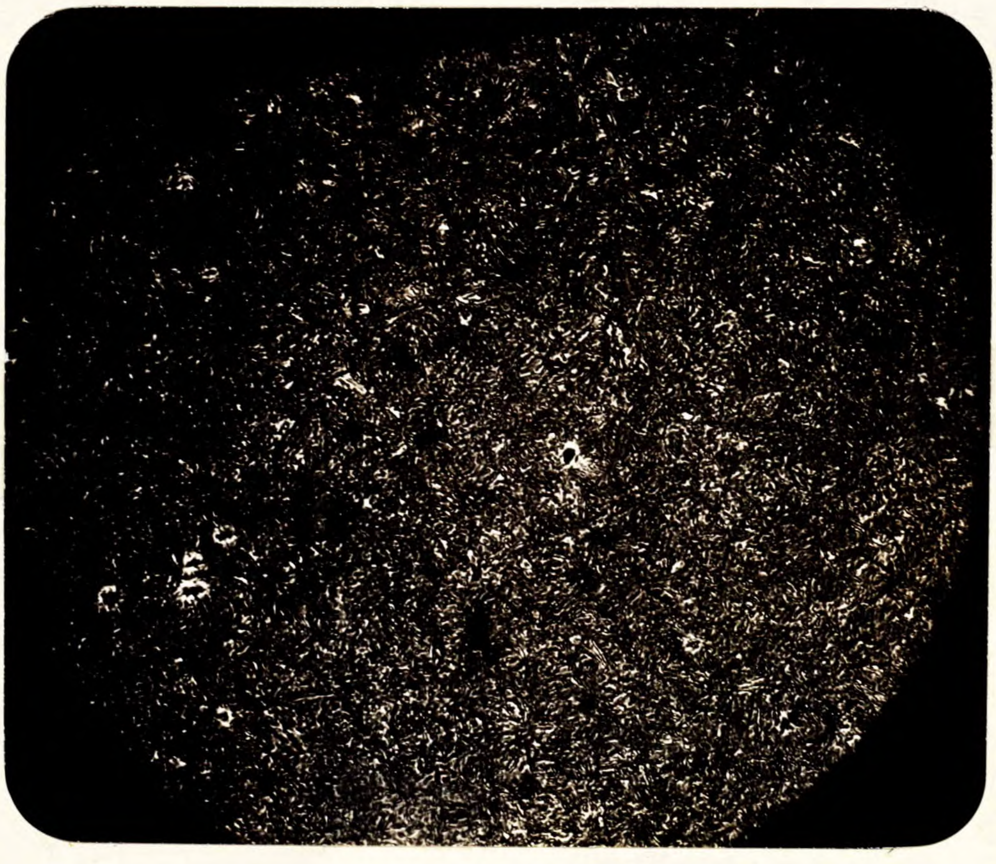
Figure 3.

X500, nital etch.

TYPICAL CORE STRUCTURE
OF CANADIAN ACME PIN.

White constituent - ferrite.
Grey constituent - low carbon martensite.

Figure 4.



X500, nital etch.

TYPICAL CASE STRUCTURE
OF CANADIAN ACME PIN.

Tempered martensite.
Small white spheroids - free carbides.

Figure 5.

X500, nital etch.

TYPICAL CORE STRUCTURE
OF BRITISH PIN.

White constituent - massive ferrite.
Grey constituent - low carbon martensite.

Figure 6.

X500, nital etch.

TYPICAL CASE STRUCTURE
OF BRITISH PIN.

Tempered martensite.

DISCUSSION:

Allied Products Pins -

The chemical analysis of the pin steel shows that it conforms to the specification for SAE 3115 steel.

The physical properties of the core material, as determined by tensile tests, appear to be normal for the type of steel and the heat treatment given it.

The case depth of the pins is on the low side of the specification and that of one pin is below the lower limit. The effect of the thin case would be to wear through to the soft core at an earlier mileage than would pins having the specified case depth.

The surface hardness as determined by using the Rockwell tester on the 'A' scale is satisfactory on eight out of ten pins. On the two pins with surface hardness below specification, the value was checked using the Vickers machine with the 10-kilogram load. One of the pins was found to be satisfactory, the low Rockwell 'A' reading being due to a thin case which was penetrated by the diamond under the 60-kilogram load used with the Rockwell 'A' scale. The low surface hardness of the other pin was confirmed by the Vickers machine. This might be due to a decreased cooling rate on quenching the pin.

The core hardness of one of ten pins was below the 250 V.P.N. minimum of Specification O.A. 214. Four were above the maximum specified core hardness of 315 V.P.N. However, two of these four were only very slightly above this limit. The remaining five pins had satisfactory core hardnesses.

All pins passed the bend and impact test requirements at room temperature satisfactorily. At -50° F., one of four pins (332 V.P.N. core hardness, 0.018-inch case depth) tested failed the impact test. This would tend to indicate that the pins of high core hardness with case depth toward the upper specified

(Discussion, cont'd) -

limit have marginal impact resistance at this temperature.

The absence of ferrite in the core of the pins, which is normal for SAE 3115 steel containing 0.68 per cent chromium, indicates that they have received a proper quench from above the critical temperature.

The martensitic case structure was probably tempered during the cutting of the sample.

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Canadian Acme Pins -

The chemical analysis of the pin steel shows that it conforms to the specification for SAE 2115 steel.

The physical properties of the core material, as determined by tensile tests, appear to be normal for the type of steel.

The case depths of the pins are on the high side of the specification and those of two pins are above the upper limits of the specification. This would tend to lower the impact resistance of the pins.

Satisfactory surface hardness has been obtained on all pins.

The core hardnesses of the pins vary from 204 to 309 V.P.N. Five pins are below the 250 V.P.N. minimum required by Specification O.A. 214. The average of the core hardnesses of ten pins is 246, which is slightly below the specified minimum. Thus it appears that pins of this analysis tend to have low core hardnesses. It has been recommended that the steel contain 0.13-0.18 per cent carbon and 0.25-0.45 per cent chromium in order to obtain the specified core hardness.

All of the three pins tested failed to take the specified 0.25-inch deflection before the case cracked. The case depths of these three pins varied from 0.020 to 0.022 inch, which is above the specification limits, and the surface

(Discussion, cont'd) -

hardness from 84 to 85.5 Rockwell 'A'. This high hardness on the thick case probably caused the brittleness.

All three pins tested passed satisfactorily the drop impact tests at room temperature and at -50° F. The case depths of these pins were within the specified limits.

The core structure indicates that the pins have probably been quenched in oil from just above the upper critical. The martensite in the case was probably tempered during cutting of the sample. The presence of nodular free carbides has, in other applications, lowered the fatigue strength of the material. It is therefore felt that their presence is not an optimum condition.

British Pins -

The chemical analysis of the pin steel shows it to conform to the specification for B.S.S. 5005/102 steel.

The physical properties of the core material as determined by a tensile test concur with the low core hardness usually obtained.

Satisfactory case depth has been obtained.

Satisfactory surface hardness has been obtained, as is seen by the readings taken with the Vickers machine, using the 10-kilogram load.

The core hardnesses of all pins are below the 250 V.P.N. minimum required by Specification O.A. 214. It has been shown that 95 per cent of pin failures are due to fatigue. The theory has been put forward that fatigue cracks begin in the zone between the hard case and the soft core. If this theory is correct, a very soft core, such as occurs in the British pins, would be expected to lower the fatigue strength of the pin and therefore shorten its service life.

All pins tested passed the bend test requirements

(Discussion, cont'd) -

satisfactorily.

All pins tested passed the drop impact tests at room temperature and at -50° F. This shows the pins are not susceptible to brittleness at low temperatures.

The core structure of the pins is coarser than that of either of the other two types of pins. This indicates a quench from a fairly high temperature. The case structure is also somewhat coarser. Here again the tempering of the martensite probably occurred during cutting.

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General -

Comparing the three types of pins, it is seen that the core hardnesses have the greatest differences of any of the properties. The Allied Products pins have the hardest cores, the hardness tending to be in the upper range and even somewhat above the upper limit of the specification. The Canadian Acme pins have lower core hardnesses, tending to be in the lower range and slightly below the specification limits, while those of the British pins are below the specified Canadian minimum.

The case depths of all pins except those of Canadian Acme are satisfactory. The case depths of those pins tend to be in the upper range and above the upper limit of the specification. In the bend tests the three Canadian Acme pins failed to meet the specified requirements while all other pins were satisfactory.

The cores of the Allied Products pins contained no massive ferrite, while those of the other two types of pins did so. The British pins had coarse core structures, indicating a quench from a fairly high temperature. The case structures of the Canadian Acme and the Allied Products pins were very similar. The Canadian Acme pins, however, had some free carbides in the

(Discussion, cont'd) -

case. This might have been partially responsible for the brittleness observed in the bend tests. The case structure of the British pins was coarser than that of the other two types.

The latest report to date (January 20th, 1944) on Universal Carrier Field Test No. 16 is that it has gone 2,575 miles. No further information as regards breakages is available. When this information is obtained it will be interesting to see how it correlates with the results of the tests described in this report.

It should be noted that, in reporting the results of the tensile tests on the core material, the elongation per cent for gauge lengths of one and two inches is given. From these results it is seen that, when using small-diameter (0.252 inch) test bars, the elongation per cent on a one-inch gauge length should be reported as it correlates with the elongation obtained using larger-diameter test bars (0.505 inch) and a two-inch gauge length.

CONCLUSIONS:

1. The Allied Products pins passed the requirements of the bend tests and impact tests at room temperature satisfactorily. The pins of core hardness above specification have marginal impact properties at -50° F. The core hardness of one pin was below the specified minimum and that of four pins was above the specified maximum. The case depth and surface hardness were satisfactory, with the exception of two pins, one of which had a case depth below specification while the other

(Conclusions, cont'd) -

had surface hardness below the specified minimum.

2. The Canadian Acme pins all passed the drop impact tests, both at room temperature and at -50° F., but all pins tested failed to take the specified 0.25-inch deflection before the case cracked. The case depth is on the high side of the specification limits and that of two pins is above the specified maximum. The surface hardness is satisfactory but the core hardness is variable, tending to be slightly below specification.

3. The British pins were satisfactory with regard to case depth and surface hardness. They all passed the bend tests at room temperature and at -50° F. satisfactorily. However, the core hardness of all pins is below specification. This may shorten their service life.

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