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O T T A W A September 7th, 1943.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1498.

Examination of Headed SAE 9255 Track Pins made from Centreless-Ground Bar Stock.

(Copy No. 10.)

Abstract

This report discusses an examination of headed track pins made from centreless-ground SAE 9255 bar stock. It describes surface and core hardness surveys made on the pins and includes results of bend and drop impact tests and metallographic examination.

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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Investigation No. 1498.

Examination of Headed SAE 9255 Track Pins
made from Centreless-Ground Bar Stock.

Origin of Material and Object of Investigation:

On August 27th, 1943, Professor J. U. MacEwan, Consultant to Director of Metallurgy, Army Engineering Design Branch, Department of Munitions and Supply, Ottawa, Ontario, submitted Requisition No. 583, AEDB, Lot No. 371, Report No. 23 5C Div. 2, covering twelve headed SAE 9255 track pins which had been received at these Laboratories (six on August 25th and six on August 26th). The pins had been made from centreless-ground stock by the Cockshutt Plow Company, Brantford, Ontario.

It was requested that the surface hardness and core hardness of the pins be carefully checked to discover if the pin ends were excessively soft due to the heading operation and the softening of the rivetting end.

It was reported that the pins had received the following heat treatment: 19 minutes in 28 per cent cyanide at 1600° F. and oil quenched, then tempered for 1 hour in a Homocarb furnace at 800° F. The tips are softened by heating for a short time in a salt bath.

Specifications

Surface Hardness (with exception of headed and rivetted end) -

Surface hardness shall be 48 Rockwell 'C' ± 3.

Core Hardness (with exception of rivetted end) -

Core hardness shall be 42-51 Rockwell 'C'.

Bend Test -

When supported on 12-inch centres and loaded centrally through a 12-inch radius the pin shall take a 0.7-inch deflection without breaking or cracking.

Impact Test -

When supported on 8-inch centres the pin shall withstand a blow of 350 foot-pounds.

Headed End -

Full surface hardness shall be reached within 1¼ inches of the headed end. The core hardness shall be as specified above.

Rivetted End -

(a) The tip shall have a maximum of Rockwell 'C' 24.

(b) When measured along the full diameter of the pin, full surface hardness shall be reached within one inch of the end of the pin.

Surface Hardness:

A hardness survey of the surfaces of the pins was made, starting from the end and taking readings one-quarter of an inch apart until full pin hardness was reached. Tables I and II record the results obtained, starting from the tip and from the head respectively. In the survey starting from the tip, measurements were made on the full diameter of the pin. Figure 1 illustrates the points where hardness measurements were taken on the pins.

(Figure 1 follows, on page 3. Tables I and II are on Pages 4 and 5.)

Figure 1.

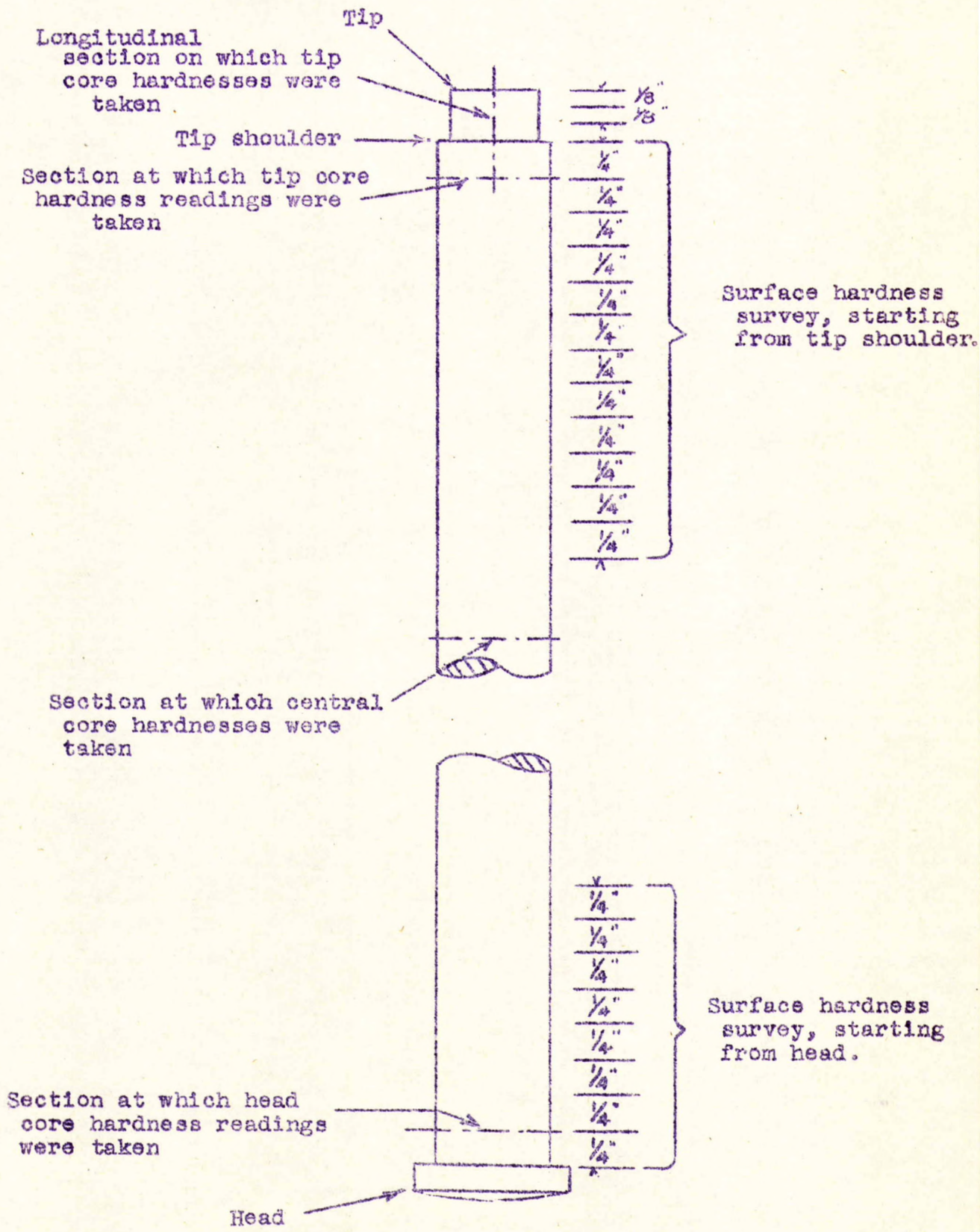

DIAGRAM SHOWING POSITION OF HARDNESS MEASUREMENTS ON PINS. (Full Scale).

TABLE I. - SURFACE HARDNESS SURVEY, STARTING FROM TIP SHOULDER.

PIN NO.	1	2	3	4	5	6	7	8	9	10	11	12
Distance, inches	HARDNESS READINGS, ROCKWELL 'C'											
0.25	23	24.5	23.5	24	25	22	38.5	33	32	32.5	37	34.5
0.50	23	23	23.5	23	24.5	23.5	44.5	40	42	41.5	41	41
0.75	29	25	23.5	24	23	24.5	47	45	43.5	45	45	45.5
1.00	32.5	28.5	29.5	30.5	30	28	48	47.5	46	46	46	48
1.25	34.5	32.5	32.5	32.5	31.5	32	48	48	47	46	46	47.5
1.50	38.5	36	38.5	36.5	36	37			47	46	46.5	
1.75	41	39	38.5	40	38.5	40						
2.00	44	42	42	43	41.5	40						
2.25	45	44	44	46	44.5	43						
2.50	46	45	47	46	46	44.5						
2.75		45	47.5	47.5	46.5	46						
3.00		47	47	47	47.5	46						
Centre of Pin	45-47.5	46-48	46.5-48	46.5-48	47-49	46.5-48	47-48	47-47.5	47-48	46-49	45-47	

TABLE II. - SURFACE HARDNESS SURVEY, STARTING FROM HEAD.

PIN NO.	1	2	3	4	5	6	7	8	9	10	11
Distance, inches	HARDNESS READINGS, ROCKWELL 'C'										
0.25											
0.50	28.5	31	35	34	35	31	31.5	31	30.5	31	32.5
0.75	39.5	40	38	39.5	44.5	37.5	43	38	42	42	39
1.00	44	41.5	44	43	44.5	42	45	43	43	43	44.5
1.25	45	46	45	48	47	44	46	44	44.5	44	45
1.50	46	47	46	47	47	46	46.5	46	45	46	46.5
1.75	47	47.5	46	46	46	47	46	46	45	45	46.5
2.00		47.5	47	47	47.5	47.5	46	46	46	46.5	46
Centre of Pin	45-47.5	46-48	46.5-48	46.5-48	47-49	46.5-48	47-48	47-47.5	47-48	46-49	45-47

Tip Hardness:

Hardness readings were made on the surface of the pin tips which had been turned down for rivetting. Rockwell 'B' and 'C' scales were used and readings were taken at locations 1/8 inch and ¼ inch from the pin end. The results are shown in Table III. (See Figure 1 for position of measurements).

TABLE III. - TIP HARDNESS.

Pin No.		Distance From End 1/8 inch	Distance From End ¼ inch
		- Hardness, Rockwell 'C' -	
1	-	17-18	14.5-17.5
7	-	15-19.5	19-22.5
8	-	18-22	15-21
9	-	20-23.5	18-25
10	-	17-21	17-20.5
11	-	17-24	17-22
		- Hardness, Rockwell 'B' -	
2	-	94-95	95-98
3	-	96-97	96
4	-	95.5-96	94.5-96
5	-	95-96	94-95.5
6	-	83-95	93.5-94

Core Hardness:

Transverse sections were cut from the pins in three places, namely, at the centre, at ¼ inch from the head, and at ¼ inch from the tip (measured along the full pin diameter). Hardness readings were taken on the central and tip portions, using the Rockwell 'C' scale, and also on the head portion, using the Vickers machine with the 50-kilogram load. The results appear in Table IV. (See Figure 1 for position of measurements).

(Continued on next page)

(Core Hardness, cont'd) -

TABLE IV. - CORE HARDNESS.

PIN NO.	PIN CENTRE	¼ INCH FROM TIP SHOULDER	¼ INCH FROM HEAD	
	Rockwell 'C'	Rockwell 'C'	V.P.N.	Rockwell 'C' (converted)
1	49-51	28	496	48.5
2	45-47	24-26	396	40
3	45-46	23-24		
4	45-47	24-25	396	40
5	45-46	24-25	471	47
6	47-48.5	28-29	509	49
7	48.5-49	39-40	521	50
8	47-48.5	37	506	49
9	46-46.5	39.5-40.5	468	46.5
10	48-49	35.5-37.5	510	49
11	47.5-49	38.5-39	513	49.5

The tips of Pins 7, 8 and 9 were sectioned longitudinally and hardness readings taken on the longitudinal core of each tip. The readings ranged from 25 to 28.5 Rockwell 'C'.

Bend Tests:

Bend tests were carried out on five of the pins, using twelve-inch centres and a twelve-inch radius block. The loads and deflections at pin failure, as well as the surface and core hardnesses, are recorded in Table V.

TABLE V.

Pin No.	Surface hardness, Rockwell 'C'	Core hardness, Rockwell 'C'	Load, pounds	Deflection, inches
1	45-47.5	49-51	9000	1.093
2	46-48	45-47	9200	1.490
3	46.5-48	45-46	9500	1.524
10	46-48	48-49	9400	1.657
11	45-47	47.5-49	9350	1.566

Impact Tests:

Six pins were subjected to the drop impact test. Three withstood a 350-foot-pound blow and three a 400-foot-pound

(Impact Tests, cont'd) -

blow. Table VI shows the surface and core hardnesses of these pins.

TABLE VI.

Pin No.	Surface Hardness, Rockwell 'C'	Core Hardness, Rockwell 'C'	Remarks
4	46.5-48	45-47	Passed 350 ft.-lb.
5	47-49	45-46	" " "
6	46.5-48	47-48.5	" " "
7	47-48	48.5-49	Passed 400 ft.-lb.
8	47 -47.5	47-48.5	" " "
9	47-48	46-46.5	" " "

Depth-Hardness Relationship:

Transverse sections were cut from the centre of the pins, and hardness readings were taken across the faces, using the Vickers machine and a 10-kilogram load. Table VII shows the hardnesses at various distances from the surface.

TABLE VII.

PIN NO.	VICKERS HARDNESS NUMBER (10-kilogram weight) At depths in inches from the surface.							
	At Surface.	0.005	0.01	0.02	0.05	0.10	0.20	0.30
2	542	518	504	509	514	494	486	464
4	514	507	505	514	514	500	511	483
5	535	526	517	514	514	499	459	446
6	525	514	503	494	493	495	493	493
7	566	534	518	512	526	528	525	530
8	560	540	525	525	529	532	532	536
9	542	525	514	517	515	514	505	485

Microstructure:

Transverse sections were cut from the pins, polished, etched in nital, and examined under the microscope. Figure 2, at 500 diameters, shows the structure at the surface of one of the pins. Note that surface decarburization has been eliminated.

(Continued on next page)

(Microstructure, cont'd) -

Figure 2.

X500, nital etch.

TYPICAL STRUCTURE AT SURFACE OF PIN.

Discussion:

The two lots of pins were similar except in the hardness of the tips. Judging from their core hardness at the tip shoulder, the first lot (Nos. 1 to 6, received August 25th) had soft enough tips but the softening continued too far up the pin, minimum specified surface hardness being reached 2¼ to 2½ inches from the tip when measured on the full pin diameter.

The excessive softening of the body of the pins near the tips was probably caused by dipping the pins too far into the salt bath or by holding them in the salt bath too long when drawing the tips to rivetting hardness.

The second lot of pins (Nos. 7 to 12, received

(Discussion, cont'd) -

August 26th) had satisfactory surface hardnesses on the tips, but when core hardnesses were taken on longitudinal sections of the tips the results obtained were slightly high for riveting. There is a good possibility that the metal would crack when the tips were rivetted. The soft surfaces and hard cores on the tips were probably caused either by not holding the pins long enough in the salt bath to allow the heat to soak completely through the tips, or by surface decarburization in the salt bath.

Very careful control must be exercised in this drawing operation, as excessive softening of the pin body may well shorten the service life of the pin. It is believed that a point three inches from the pin tip is subject to abnormally high stresses in service, as many pins have failed at this point. Consequently, low hardness at this point would be a serious defect as it would lower the endurance limit (and, it follows, the service life) of the pin materially. On the other hand, if the tips are not softened sufficiently the metal will crack on rivetting, rendering the pin useless.

It is realized that it is very difficult to meet the specified maximum of 24 Rockwell 'C' using steel of this composition. Physical property charts show that a draw of 1300° F. produces a hardness of Rockwell 'C' 26. Therefore, it is believed that 24 Rockwell 'C' is about the minimum hardness that can be reached with this steel.

The hardness gradients taken on the headed end of the pins show the surface to have low hardnesses. However, minimum specified hardness is reached within 1¼ inches from the end in seven out of eleven pins. In the remaining four pins the hardness at the 1¼-inch point was only one point Rockwell 'C' below the specified minimum, and so the pins may

(Discussion, cont'd) -

be considered satisfactory. This softening effect is caused by decarburization of the bar stock during the heading operation. It could be eliminated by heading the pin before it is centreless-ground, but, as this would entail grinding each pin individually, such heading would not be applicable to production. In all but two instances, the core hardness at the headed end was satisfactory. This indicates that the decarburization has not been excessive and also that the head of the pin has been cooled sufficiently fast in quenching to produce full pin hardness.

In the centre of the pin, satisfactory core and surface hardnesses have been obtained.

The bend and drop impact tests gave very satisfactory results. In the bend tests all deflections were over an inch at the point of failure. In the drop impact tests three pins passed the specified 350-foot-pound blow while three passed a 400-foot-pound blow.

The depth-hardness surveys and the microscopic examination show that the decarburization has been successfully eliminated by centreless grinding. A slight carburization has been effected in the heat treatment in the salt bath, shown by the rise in hardness at the surface noted in the depth-hardness surveys. Fatigue tests performed by Dr. Lessells at M.I.T.* indicate that this hard skin increases the life of the pin considerably. The value obtained at the surface, using the Vickers machine with the 10-kilogram load, is higher than that obtained with the Rockwell tester 'C' scale. This is explained by the difference in the depths of penetration of the two machines, the Rockwell machine passing through the thin, harder case.

There is some evidence of the presence of globules

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* Massachusetts Institute of Technology, Boston, Massachusetts.

(Discussion, cont'd) -

of carbides near the surface of the pin (see Figure 2). However, in the light of the excellent results of the bend and drop impact tests, it is felt that this is not serious.

CONCLUSIONS:

1. A satisfactory hardness for rivetting has not been obtained in the tips of the pins. In one lot the tips are of the required hardness but the bodies of the pins have been excessively softened. In the remaining pins the tips are too hard to be rivetted without cracking the metal.

2. Very careful control must be exercised in softening the tips, as excessive softening may well be deleterious as regards wear and fatigue, while insufficient softening makes rivetting impossible. It is believed, however, that 24 Rockwell 'C' is about the minimum hardness that can be obtained with this type of steel.

3. Some decarburization occurs during the heading operation, but, as it only affects the first 1¼ inches of the surface of the pin, this condition is not considered serious.

4. Satisfactory surface and core hardnesses were obtained in the body of the pin.

5. All pins passed the bend test requirements satisfactorily.

6. All pins passed the drop impact tests satisfactorily.

7. Surface decarburization in the bar stock has been eliminated by the centreless grinding.

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