O T T A W A October 18th, 1943.

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of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1517.

Investigation of SAE 9255 Austempered Steel Universal Carrier Track Pins.

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Origin of Material and Object of Investigation:

On September 21st, 1943, the Commercial Steel Treating Corporation, Detroit, Michigan, per R. J. Hoensheid, President, submitted forty-eight (48) SAE 9255 homogeneous steel universal carrier pins for examination. On October 6th, after having received a favourable report on the experimental pins, the corporation forwarded nineteen (19) pins taken from a batch treated on a production scale. It was reported that the bar stock was centreless-ground prior to heat treatment, in order to remove the decarburization, and that after grinding the pins were hardened by carrying out an isothermal transformation in salt.

This report discusses the investigation results obtained in these Laboratories for both the experimental and the production pins.

Heat Treatment:

Four different treatments were used. The experimental pins were given the first three treatments and the 19 production pins the fourth.

Lot 1. Sixteen pins were heated to 1600° F. in neutral salt, kept at heat for 15 minutes, transferred to a salt bath (KNO_3+$NaNO_2$) at a temperature of 480° F. and held for 30 minutes, then air cooled.

Lot 2. Sixteen were heated to 1600° F. in neutral salt. No soak. Quenched in oil 10 seconds to approximate temperature of 500° F. Transferred to austempering salt bath, temperature 480° F. Held for 30 minutes, then air cooled.

Lot 3. Sixteen pins were heated to 1600° F. in neutral salt. No soak. Quenched in oil for 20 seconds to approximately temperature of 250° F., transferred to austempering salt bath at a temperature of 480° F., held at this temperature for 30 minutes and then air cooled.

Lot 4. Nineteen production pins. It was reported that these were in the austempering bath for a somewhat longer time.

In all tables listed in this report, the heat treatment numbers correspond with lot numbers shown above.

Bend Tests:

Bend tests were carried out, using both the standard inspection bend test machine and the Amsler Universal testing machine. A 12-inch radius and 8-inch centres were used on both machines. The Amsler machine applies a controlled continuous load.

Table I lists the results obtained.

(Continued on next page)

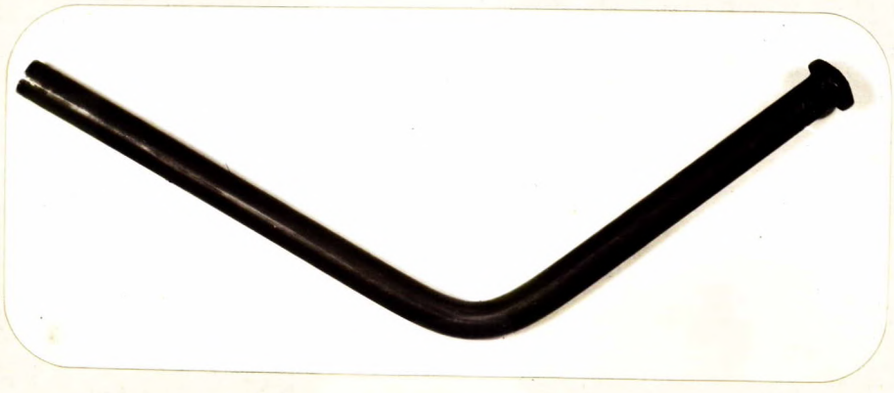
(Bend Tests, cont'd) -

TABLE I.

Treatment No.	Surface Hardness, Rockwell 'C'	Core Hardness, Rockwell 'C'	Load in pounds	Deflection, in inches
Lot 1	51-53	55	-	1.15, unbroken.
"	52-53	55	-	1.15, unbroken.
"	52	55	2,650	1.80, broke.
Lot 2	53-54	55	-	1.15, unbroken.
"	53-54	55	-	1.15, unbroken.
"	53	54	2,650	1.90, broke.
Lot 3	53-54	54	-	1.15, unbroken.
"	52	54	2,700	1.60, broke.
Lot 4	49-51	47.5	2,260	1.90, unbroken.
"	49-51	49	2,320	2.00, unbroken.
"	49-51	50	2,270	2.00, unbroken.
"	49-51	49	2,260	1.95, unbroken.
"	49-51	49	2,270	1.98, unbroken.
"	50-52	50	2,400	1.75, unbroken.

One pin was bent on the Amsler Universal machine, using 6-inch centres and a 1-inch radius block. An angle of 68° was obtained for this pin without breaking. The surface hardness was 52 and the core 54 Rockwell 'C'. Figure 1 illustrates the bent pin.

Figure 1.



BENT PIN.

Impact Tests:

Drop impact tests were carried out on the pins. Only one drop was made on each pin. Table II lists the results:

TABLE II.

Treatment	Impact, foot-pounds*	Remarks	Surface Hardness Rockwell 'C'	Core Hardness Rockwell 'C'
Lot 1	45	Passed.	52-53	53
"	45	"	52-53	54
"	300	"	50-53	54
"	400	"	51-54	55
"	400	"	50-53	55
Lot 2	45	"	52-54	55
"	45	"	52-54	56
"	400	"	52-54	54
"	400	"	52-53	56
"	400	"	53-54	56
Lot 3	45	"	53-55	55
"	250	"	53-55	55
"	300	"	53-54	56
"	300	"	51-54	55
"	400	"	52-54	55
Lot 4	400	"	48-50	52
"	400	"	49-51	51
"	400	"	49-51	52
"	400	"	47-49	52
"	400	"	48-50	52
"	400	"	48-50	48-50

* 45 foot-pounds specified "proof" drop for one load. Heavier loads applied for information purposes.

Depth-Hardness Survey:

Transverse sections were cut from two pins taken from each heat treatment. Hardness readings were taken across the face of the section.

Table III shows the results obtained.

(Table III appears on next page.)

(Depth-Hardness Survey, cont'd) -

TABLE III. - TRANSVERSE HARDNESS SURVEY.

(Vickers hardness testing machine, 10-kg. load)

Treatment	Surface	Vickers Hardness Numbers — Distance from the Surface, 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
Lot 1	577	585	627	635	642	635	627	620	613	600	605	610	620
"	570	568	590	642	640	637	633	632	632	635	639	639	639
Lot 2	585	585	627	627	627	627	627	627	627	627	627	640	657
"	577	554	639	639	639	649	649	649	649	649	649	649	649
Lot 3	455	473	613	613	613	613	613	613	618	620	625	627	627
"	571	568	652	649	647	645	642	642	642	640	642	640	640
Lot 4*	526	546	568	590	610	610	610	610	610	613	620	630	630
"	526	524	518	535	549	557	565	572	580	584	584	584	584

* Production.

Carbon Step-Cut Analysis:

The transverse hardness survey indicates decarburization at the surface. To check this, a pin was taken from each of Lots 1, 2, and 3, and sections 0.005-inch thick were ground successively from their surfaces and analysed for carbon. The results were:

Successive Increments, inches from surface	Pin No. 1 (Treatment No. 1)	Pin No. 2 (Treatment No. 2)	Pin No. 3 (Treatment No. 3)
	- Per cent -		
0.005 -	0.53	0.49	0.44
0.010 -	0.55	0.50	0.49
0.015 -	0.57	0.51	0.50
0.020 -	0.57	0.52	0.53
0.025 -	0.61	0.52	0.53
0.030 -	0.59	0.54	0.53

Microscopic Examination:

Transverse specimens were cut from pins taken from each type of heat treatment. These samples were polished and

(Microscopic Examination, cont'd) -

etched in 2 per cent nital. Figures 2, 3, 4 and 5, taken at X1000 magnification, illustrate the structures obtained. Figure 6 shows the structure obtained in these Laboratories by quenching from 1625° F. with salt at 500° F. for one hour. Figure 7 (X1000) is a photomicrograph of an SAE 9255 universal carrier pin, quenched and drawn to 54.5 Rockwell 'C'.

Figure 2.

X1000, nital etch.

LOT NO. 1.

(Continued on next page)

Figure 3.

X1000, nital etch.
LOT NO. 2.

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Figure 4.

X1000, nital etch.
LOT NO. 3.

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Figure 5.

X1000, nital etch.
PRODUCTION LOT NO. 4.

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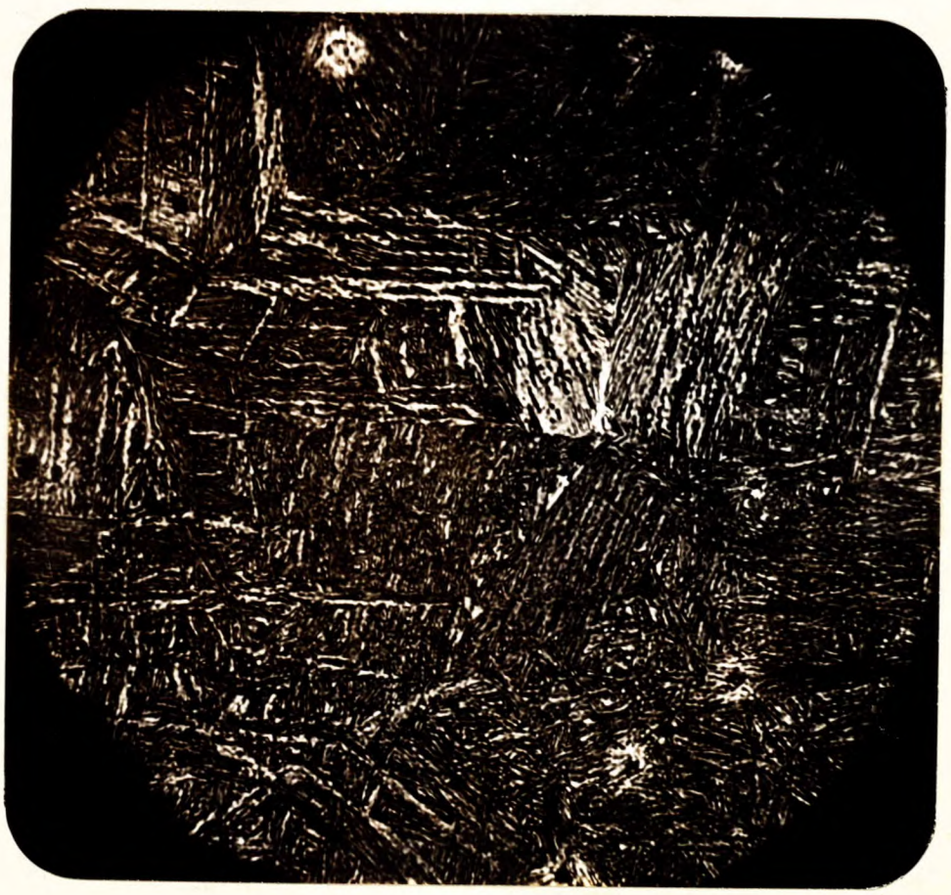
Figure 6.



X1000, nital etch.
BAINITE STRUCTURE OF PIN AUSTEMPERED AT THE O.D.M.L.

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(Microscopic Examination, cont'd) -

Figure 7.

X1000, nital etch.
TEMPERED MARTENSITE.
Oil-quenched and drawn to 54.5 Rockwell 'C'.

Discussion:

The bend and impact results obtained for these pins were excellent. Specification O.A. 214 states that the pins must pass 0.5 inch bend deflection and a 45 ft.-lb. impact. These pins went up to 2 inches deflection and 400 ft.-lb. impact without failing. The hardness values of the experimental treatments are, on the whole, somewhat higher than that produced in the first production batch. It is quite possible that the temperature of the salt bath rose somewhat when the larger mass of metal was introduced. Decarburization is present at the surface of the pins for approximately 0.005 inch. It may be

(Discussion, cont'd) -

that either the bar stock has not been ground enough or the decarburization occurred in the neutral salt bath at the quenching temperature. It must be pointed out that the surface hardness for most of the pins is still over the present upper limit for the homogeneous type, namely, 51 Rockwell 'C'. However, the main point in austempering the pin is to allow for the use of a harder pin without sacrifice of ductility, as the harder pin would be expected to have better resistance to abrasion and higher fatigue performance. For both wear and fatigue properties, the outer surface material is of prime importance. While granting freely that the pins under examination are excellent, it is still felt that every effort should be made to reduce decarburization to a minimum.

The microstructures obtained do not show the bainite structure usually associated with austempering. A fine tempered martensite has been obtained. In view of the excellent strength and ductility obtained, it is felt that the treatment given has been similar to martempering. This type of treatment produces a high strength material. The steel is brought to the same temperature throughout and then martensite is formed. This eliminates the stresses and strains usually produced by quenching from a high temperature to form martensite. A noticeable difference in structure is observed from the normal quenched-and-drawn martensite (Figure 7).

CONCLUSIONS:

1. The core hardnesses of the pins are somewhat higher than those of the surface.

2. A slight decarburization is evident; it is approximately 0.005 inch deep. It is felt that every effort should be made to hold this to a minimum.

3. The surface hardness of the majority of the pins is over the present specified upper limit, Rockwell 'C' 51. This should aid the wear resistance.

4. The hardnesses of the trial production lot are slightly lower, possibly due to an increase in the temperature of the austempering bath.

5. The bend characteristics of the pins are very good.

6. The pins withstood impact blows of 400 foot-pounds without failing. Specification O.A. 214 calls for only 45 foot-pounds resistance.

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