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OTTAWA May 8th, 1944.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1636.

Metallurgical Examination of C.D.P. Track Pins Which Failed O.A. 227 Impact Test.

(Copy No. 10.)

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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Metallurgical Examination of C.D.P. Track Pins Which Failed O.A. 227 Impact Test.

Origin of Material and Object of Investigation:

On April 13th, 1944, three (3) C.D.P. track pins were submitted by the Inspection Board of United Kingdom and Canada, Electric Steels Limited, Three Rivers, Quebec. A covering requisition (Requisition 804, A.E.D.B. Lot No. 1055, Report 22, Section C) was sent in by Dr. C. W. Drury, Director of Metallurgy, Army Engineering Design Branch, Department of Munitions and Supply, Toronto, Ontario.

It was reported that Pin No. 1 required five blows of 400 foot-pounds to give a 1.2-inch deflection; Pin No. 2 gave a deflection of 1.6-inches after six blows; Pin No. 3 broke after four blows.

It was requested that a metallurgical examination of these pins be carried out to determine the cause of failure to meet impact test specifications.

Chemical Analysis:

The chemical analysis of Pin No. 3 (which broke after four blows) is shown below:

		AS FOUND	SPECIFICATION SAE 9255
		- Per Cent -	
Carbon	-	0.58	0.50-0.60
Manganese	-	0.83	0.70-0.90
Silicon	-	2.20	1.80-2.20
Phosphorus	-	0.007	0.040 max.
Sulphur	-	0.038	0.040 max.
Chromium	-	0.009	--

Hardness:

The surface and core hardness values obtained on Vickers and Rockwell hardness testing machines are shown in Table I.

TABLE I.

Pin No.	SURFACE Rockwell 'C'	SURFACE V.H.N., 10-kg. load	CORE Rockwell 'C'	CORE V.H.N., 10-kg. load
1	44-45	450-488	43-44	483-488
2	45-46	450	43-44	450
3	44-45	450-483	43-44	450

Microscopic Examination:

Microscopic examination of longitudinal specimens in the unetched condition showed:

(1) Inclusions of the oxide type (alumina, iron and manganese) which were grouped together in stringers in the direction of rolling. See Figure 1, a photomicrograph at X500 magnification.

(2) Elongated inclusions of the sulphide-basic silicate type. See Figure 2, photomicrograph at X500.

(3) Acid silicate inclusions which are not elongated in the direction of rolling. See Figure 2.

(4) Titanium cyano nitride inclusions (pink in colour and strongly angular. See Figure 2.

Etching longitudinal sections with 2 per cent nital

(Microscopic Examination, cont'd) -

revealed a tempered martensitic microstructure banded with light etching areas. This banding was more noticeable and extensive than usually found in SAE 9255 pin steel. A typical example of this microstructure is shown in Figure 3, a photomicrograph at X250 magnification. For comparative purposes, the microstructure of a longitudinal section of a C.D.P. track pin in which this banding is not visible is shown in Figure 4, also a photomicrograph at X250.

Longitudinal specimens representative of the three pins, etched with Stead's copper reagent, showed a heavily banded structure, indicating segregation in these banded areas. A typical example of a longitudinal section so etched is shown in Figure 5, a photomicrograph at X250.

<u>Discussion:</u>

The chemical composition of the pins agrees with SAE 9255 specification. The hardness values, substantiated by a tempered martensitic microstructure, indicate that the pins have had the standard quench-and-draw heat treatment.

The extent of banding observed in SAE 9255 pin steel varies. In some pins it is not present in the quenched and drawn microstructure. In the pins at present under consideration it is very evident. There are two generally accepted theories regarding the formation of this banded structure. First, that it is the result of dendritic segregation of phosphorus, carbon, silicon and non-metallic inclusions during cooling of the ingot. As stated by Sauveur,*

> " . . . steel ingots are made up after solidification of closely interlocked heterogeneous dendrites and that while those dendrites probably undergo granulation on further cooling, the dendritic segregation implied by such

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* "The Metallography and Heat Treatment of Iron and Steel," by A. Sauveur. McGraw-Hill Book Co. Inc., 1935.

(Discussion, cont'd) -

> chemical heterogeneity persists. When steel ingots are subjected to work that is forged or rolled, the portions rich in the segregating elements (the fillings of the dendrites), as well as those poor in these elements (the axes), are elongated in the direction of the work, imparting to the hot worked steel the well known laminated appearance readily revealed by macro-etching . . . . Directional properties are in this way imparted to steel by hot working. The tensile strength, elastic limit, and especially the ductility and resistance to shock, will vary much in accordance with the direction of testing, ... Obviously the more pronounced and persistent the dendritic segregation, the more pronounced the directional properties."

The other theory* actually complements the first and suggests that when the metal is cooling during or after rolling, the precipitation of ferrite first occurs about the elongated sulphide inclusions, which act as nuclei. As slow cooling proceeds through the critical range, more and more ferrite is thrown out of solid solution in the austenite, the rate of precipitation being most rapid in these elongated areas, until the typical ferrite-pearlite banded structure is produced in the normalized steel.

It is not possible to entirely eliminate this banding by reaustenizing the steel, because on slow cooling the ferrite reprecipitates in the same manner and about the same nuclei as before. On quenching, the precipitation of ferrite is prevented but a banded formation persists, in the form of light etching areas, which are the result of segregation.

The specimens etched with Stead's copper reagent (see Figure 5) indicate considerable segregation. Although generally considered to show phosphorus segregation, this etch is stated by Hatfield to show heterogeneous distribution of manganese and silicon equally well. The phosphorus content

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* "A Course of Metallurgy for Engineers," by F. C. Thompson. H.F. & G. Witherby, London, 1925.

(Discussion, cont'd) -

of these pins (0.007 per cent) is low; so that it is quite likely the light etching areas are the result of silicon segregation. In either case, the result would be loss of ductility and strength.

Although it is a well known fact that excessive banding results in loss of impact strength, banding occurs frequently and pins made of this type have passed impact requirements.

It should be pointed out that the possibility exists whereby micro cracks (hair line) are produced in the quenching operation of the heat treatment process. No evidence, however, was found during this operation to definitely substantiate this condition. It is felt that banding is the most likely cause of failure.

CONCLUSIONS:

1. The three pins conform to SAE 9255 chemical specifications.

2. Hardness values and microstructure indicate standard quench-and-draw heat treatment.

3. Banding is excessive compared with that normally observed in SAE 9255 pin steel.

4. Loss of ductility due to excessive banding is the most likely cause of failure of the pins to meet impact specifications. However, the possibility of hair-line quenching cracks should not be overlooked.

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Figure 1.

X500, unetched.

OXIDE-TYPE INCLUSIONS.
(Iron, alumina, manganese).

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Figure 2.

X500, unetched.

INCLUSIONS.

2. Sulphide silicate.
3. Acid silicate.
4. Titanium nitride.

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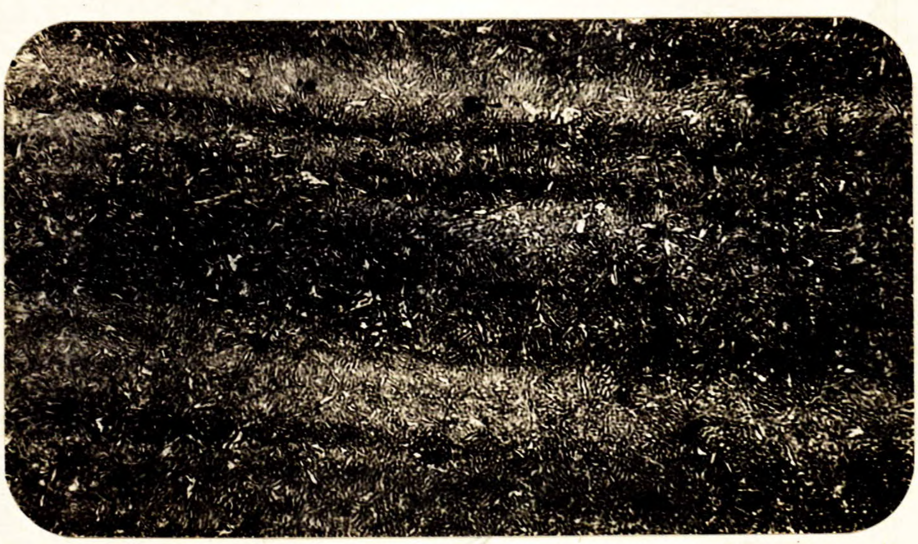
Figure 3.



X250, etched in 2 per cent nital.

TEMPERED MARTENSITE BANDED WITH LIGHT ETCHING AREAS.

Longitudinal Section.

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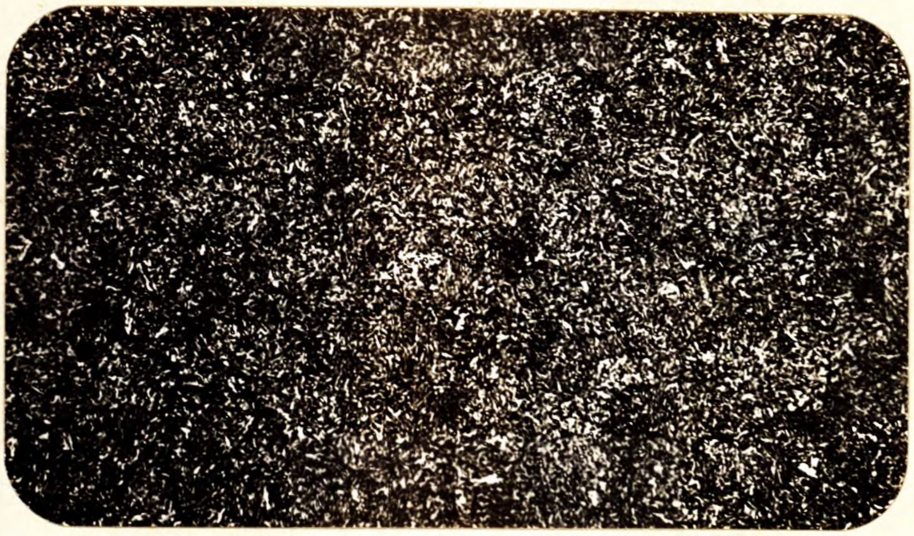
Figure 4.



X250, etched in 2 per cent nital

MICROSTRUCTURE OF A C.D.P. PIN IN WHICH BANDING IS NOT NOTICEABLE.

Longitudinal Section.

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Figure 5.

X250, etched with Stead's reagent.

SEGREGATION IN BANDED STRUCTURE.

Longitudinal Section.

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