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OTTAWA June 6, 1945.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1885.

Metallurgical Examination of Fractured End Stud from Bogie Spring Rebound Chain Assembly (Armoured Snowmobile).

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(Copy No. 10.)

Bureau of Mines
Division of Metallic Minerals
-
Physical Metallurgy
Research Laboratories

CANADA
DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

OTTAWA June 6, 1945.

REPORT

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Origin of Material and Object of Investigation:

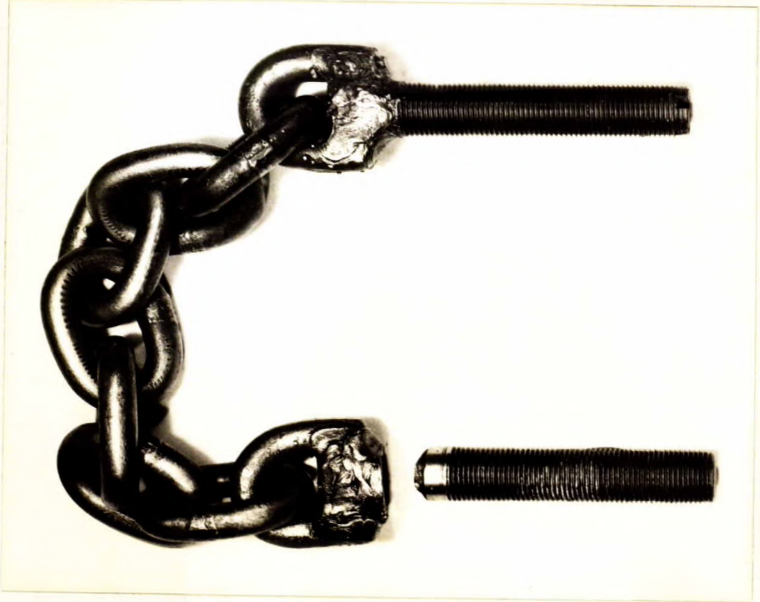
On May 17, 1945, a broken upper bogie spring rebound chain assembly was received from Mr. W. J. Washburn, of the Army Engineering Design Branch, Department of Munitions and Supply, Montreal, Quebec. The end stud from the assembly had failed after having been installed but without seeing service. The accompanying letter (File 141-FU21) requested a metallurgical examination of the failed end stud to determine the cause of fracture and to ascertain whether the material in the stud was as specified.

The material specified for the end stud was Atlas Impacto Steel quenched and drawn to a Brinell hardness of 207 to 220 before welding. The assembly was to be quenched in water from the welding temperature.

Description of Material:

A general view of the broken assembly received is shown in Figure 1.

Figure 1.

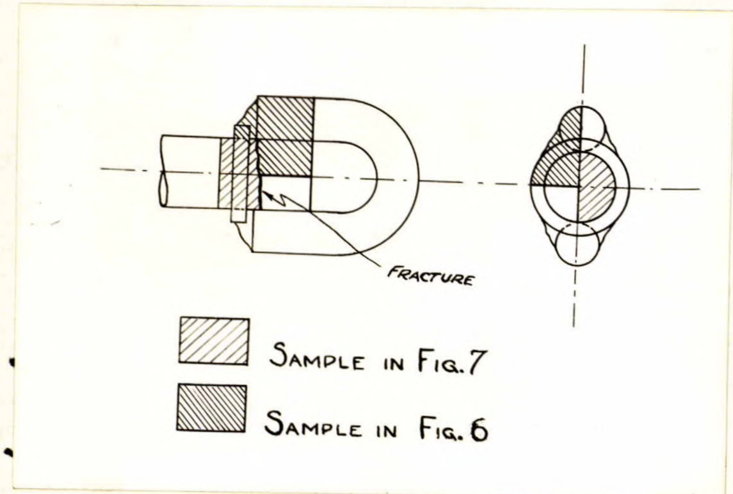


VIEW OF BROKEN REBOUND CHAIN ASSEMBLY.
(Approximately half actual size).

A sketch of the end of the assembly where failure occurred is shown in Figure 2. Micro specimens were cut from the locations shown in this sketch.

The end stud had fractured in a brittle manner about 3/16 inch below the outer edge of the seamless steel tubing (see Figure 3).

Figure 2.



VIEW OF END STUD, U-LINK AND WELD SHOWING FRACTURE.
(Approximately ½ actual size).

Note: Sample designated Fig. 6 represents only right-hand illustration.

Figure 3.

VIEW OF FRACTURE.
(Approximately ½ actual size).

Chemical Analysis:

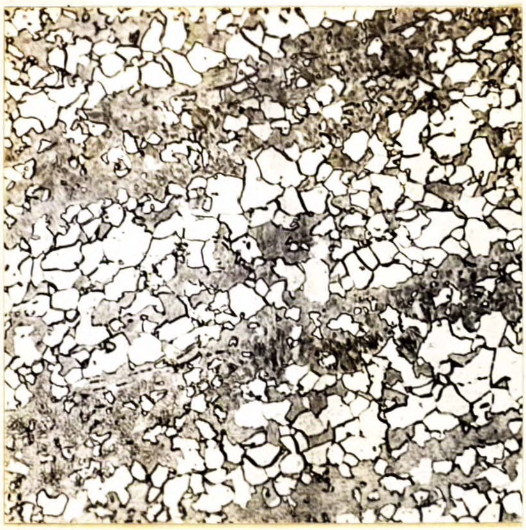
Analysis showed the broken end stud to be essentially as specified although the carbon was high. The analysis is shown below:

		Analysis, per cent	Nominal Composition, per cent
Carbon	-	0.23	0.15
Manganese	-	0.69	0.50
Phosphorus	-	0.010	0.030
Sulphur	-	0.012	0.030
Silicon	-	0.14	0.20
Nickel	-	1.82	1.75
Molybdenum	-	0.28	0.25
Chromium	-	0.09	--

Micro-Examination:

Micro specimens were taken from the locations shown in the sketch in Figure 2. The microstructure in each of the two zones shown in Figure 7 was studied. In the zone marked A in Figure 7, the microstructure had a banded appearance (proeutectoid ferrite and martensite), as shown in Figure 4.

Figure 4.



X500, nital etch.

BANDED STRUCTURE IN END STUD
(ZONE A IN FIGURE 7).

Ferrite and martensite.

(Micro-Examination, cont'd) -

A short distance above the fracture (Zone B in Figure 7), the structure retained its original drawn martensitic appearance. This is shown in Figure 5 below.

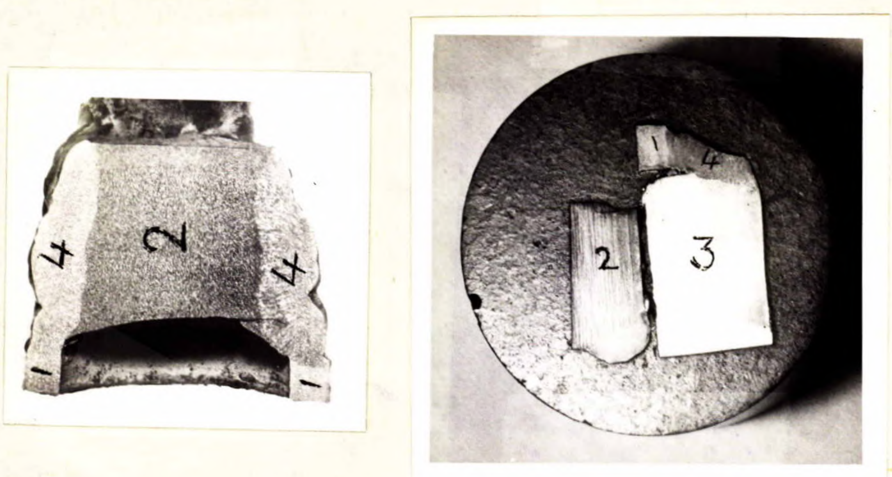
Figure 5.

X500, nital etch.

NORMAL STRUCTURE OF END STUD.

The banding in the end stud can be seen quite clearly in Figure 6.

Figure 6.



TWO VIEWS OF STUD AND LINK WELDMENT.

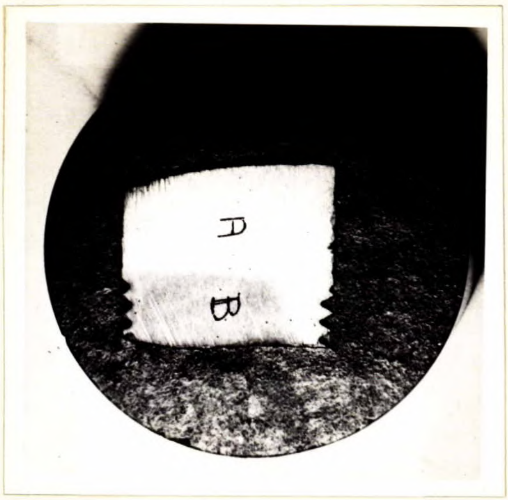
1. Seamless steel tubing.
2. End stud.
3. U-link.
4. Weld metal.

(Approximately twice actual size).

Note: The two surfaces shown are at right angles to each other, the right-hand section being bisected longitudinally.

(Micro-Examination, cont'd) -

Figure 7.



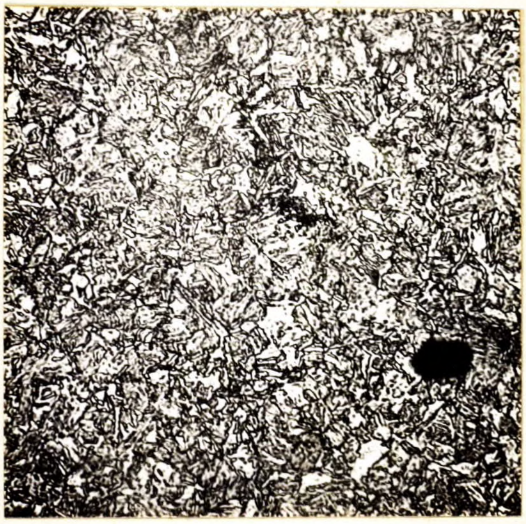
SECTION THROUGH FRACTURE IN END STUD.

A. = Banded zone - nearest fracture.
B. = Normal zone.

(Approximately twice actual size).

For purposes of comparison the microstructure of the stud at the end farthest from the weld was examined. It was essentially the same as that shown in Figure 5, that is, drawn martensite with some ferrite showing around the primary grain boundaries (see Figure 8).

Figure 8.



X500, nital etch.

NORMAL STRUCTURE OF STUD
AT END FARTHEST FROM WELD.

Note presence of ferrite.

Hardness Readings:

A hardness survey was made across that part of the stud shown in Figure 7, using the Vickers hardness tester with a 5-kilogram load. Results are shown below:

V.P.N. (5-kg. load)		Distance from fracture, mm.	
268	-	1)	
252	-	2)	
251	-	3)	
244	-	4)	Impressions in Zone A (Figure 7).
239	-	5)	
244	-	7)	
221	-	8	Boundary line.
249	-	9.5)	
257	-	12)	Impressions in Zone B (Figure 7).
271	-	13)	

Hardness readings taken on the same portion of the stud as shown in the photomicrograph in Figure 8 gave values ranging from 229 to 332 Vickers (5-kilogram load). These agreed with values obtained on that part of the stud still in place in the weldment (Figure 6), which ranged from 296 to 306 V.P.N. The end stud from the other end of the chain assembly had a Brinell hardness of 285 (301 Vickers by conversion).

An Izod test specimen made from this stud gave values of 82 and 77 foot-pounds.

Supplementary Tests, on Other Samples of Atlas Impacto Steel:

Two pieces of Atlas Impacto Steel were obtained and given the following heat treatment:

Sample 1. Heated to 1475° F., furnace-cooled to 1350° F., and water-quenched from 1350° F.

Sample 2. Heated to 1350° F. and quenched from that temperature.

Both samples were then tempered for 1 hour at 1000° F. Photomicrographs are shown in Figures 9 and 10.

(Continued on next page)

(Supplementary Tests, on Other Samples of Atlas Impacto Steel, cont'd) -

Figure 9.

X500, nital etch.
MICROSTRUCTURE OF SAMPLE NO. 1.
Martensite.
(Izod value, 102 ft-lb.).

Figure 10.

X500, nital etch.
MICROSTRUCTURE OF SAMPLE NO. 2.
Ferrite and Martensite.
(Izod value, 104 ft-lb.).

Apparently in Sample No. 1 the upper critical temperature has been depressed on cooling so that at 1350° F. the sample was still above the Ar_3 point. Sample No. 2, although quenched from the same temperature, was between the two critical temperatures, hence the banded structure of ferrite and martensite.

Ordinarily the structure shown in Figure 10 would be expected to give low Izod values. Such was not the case, however, as can be seen from the Izod values under Figures 9 and 10.

Discussion:

A table of the properties of Atlas Impacto Steel, contained in the general catalogue of Atlas Steels Limited, shows that the Izod value decreases from 115 foot-pounds to 23 foot-pounds when the Brinell hardness number is raised from 207 to 277. Some values from this table are shown in Table I.

(Continued on next page)

(Discussion, cont'd) -

Table I.

Izod Impact, ft-lb.	Brinell Hardness No.
35	321
37	311
45	302
47	302
33	302
28	286
23	277
70	277
83	269
91	241
105	212
115	207

The above values are for material quenched from a constant temperature. Quenching from the welding temperature has, as the temperature varies depending on the position of the material relative to the weld, produced four zones in the end stud, namely:

1. A zone quenched from above the upper critical, resulting in full hardening.
2. A zone quenched from a temperature between the two critical temperatures, resulting in the formation of ferrite bands. The banding itself was due to previous inhomogeneity of the microstructure.
3. A zone quenched from below the lower critical which was thus subjected to drawing before quenching.
4. An unaffected zone, which retained its previous hardness.

The Izod values obtained from a test specimen cut from one of the end studs do not agree with the Brinell hardness-Izod relationship shown in Table I. This is due to the higher carbon content, which would result in higher hardness readings for equivalent Izod values. It is apparent, (Discussion, cont'd) -

however, that the material before welding is in a tough condition. The material that has been quenched from above its upper critical and the material that has been merely drawn by the welding operation have much the same structure as the stock material and consequently would appear to be tough. The zone that has been quenched from within the critical range has a totally different structure and one that would be expected to result in brittleness. Failure ordinarily would be attributed to this condition. However, the Izod impact values given under Figures 9 and 10 show that that is not necessarily the case.

It is known that the presence of ferrite results in abnormal lowering of the Izod values at low temperatures, and it may be that failure occurred during cold weather.

Internal stresses, in the stud as a result of welding, may have acted in such a way as to oppose the applied stress and thus result in brittle fracture. The notch effect due to welding may have been higher than would ordinarily be expected.

The possibility of rough handling in assembling and disassembling should not be overlooked.

Conclusions:

1. Quenching from the welding temperature has resulted in the formation of a banded zone in the bar to which ordinarily failure would be attributed.

2. Low temperature conditions, internal stresses due to welding, and rough handling are all possible causes of failure.

Recommendations:

It is recommended that the weldment be normalized from 1600-1650° F. after welding, quenched in water from 1550° F., (Recommendations, cont'd) -

and drawn at 1000° F. This treatment would be expected to produce the following properties in the stud:

Tensile strength, p.s.i.	Yield point, p.s.i.	Elongation in 2 inches, per cent	Reduction of area, per cent	Izod impact, ft-lb.	Brinell hardness
118,000	100,000	25.0	67.0	91	241

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TCH:LB.