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OTTAWA December 20th, 1944.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1766.

Metallurgical Examination of Three Snowmobile Track Cross Links.

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(Copy No. 10.)

Bureau of Mines
Division of Metallic
Minerals

Physical Metallurgy
Research Laboratories

DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

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Origin of Request and Purpose of Investigation:

On December 2nd, 1944, under Analysis Requisition No. O.T. 4309, Mr. J. M. Gilmartin, I.O.M., for Inspector of Materials, Inspection Board of United Kingdom and Canada, Ottawa, Ontario, submitted one broken and two unbroken Snowmobile track cross links for examination. Tags attached to the links indicated that the failed link and one unbroken link were from a lot produced using a new die. The other unbroken link was from an old die.

Accompanying the requisition was a copy of a letter (November 27th; File No. 4/10/41/SNOW/8) from Mr. R. A. Miller of the Tanks Inspection office of the I.E.U.K. & C. at Hamilton, Ontario. This letter stated that no trouble had been encountered while using the old die. Since using the new die, however, a number of breakages were

(Origin of Request and Purpose of Investigation, cont'd) -

being found after the rubber curing operation and one hundred per cent visual inspection was necessary in order to screen out all the broken links. It was suggested that the dies were possibly different and that the dimensions of the radii were not of the same order. It was requested, however, that a complete investigation be carried out to determine whether there was any difference in the metallurgical aspects of the three links which might account for the breakages.

General Note:

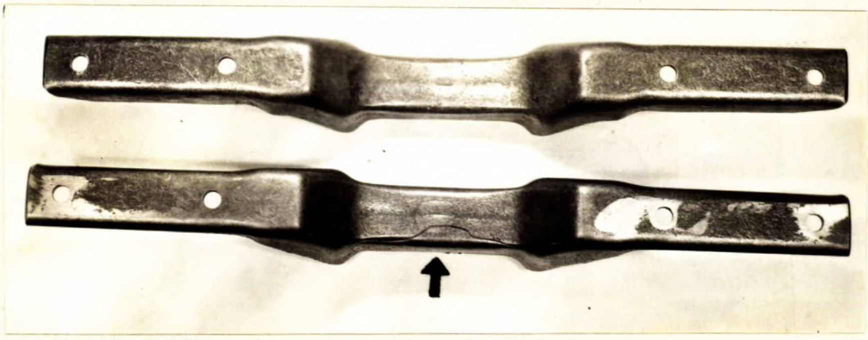
For purposes of clarity in this report:

Link A refers to the cracked link, new die.
" B " " " unbroken link, new die.
" C " " " unbroken link, old die.

Macro-Examination:

Figure 1 shows one unbroken link alongside the cracked link. The crack was opened up and the fractured surface was found to be free from any noticeable staining. It was not possible to establish the exact point where the crack started.

Figure 1.



Note the crack on the surface of the bottom link.

Chemical Analysis:

Drillings were taken from the three links and analysed. The results were:

(Continued on next page)

(Chemical Analysis, cont'd) -

		Link A	Link B	Link C	Specification, SAE 4340
			- Per Cent -		
Carbon	-	0.42	0.42	0.43	0.38-0.43
Manganese	-	0.73	0.77	0.73	0.60-0.80
Silicon	-	0.28	0.25	0.26	0.20-0.35
Nickel	-	1.75	1.75	1.68	1.65-2.00
Chromium	-	0.87	0.89	0.88	0.70-0.90
Molybdenum	-	0.24	0.24	0.24	0.20-0.30
Phosphorus	-	0.018	0.017	0.017	0.040 max.
Sulphur	-	0.021	0.023	0.020	0.040 max.

Grain Size:

The grain sizes of the three links were determined by using Vilella's etch.

Link		A.S.T.M. Grain Size
A	-	6-7 (approximately 80 per cent 7).
B	-	1-4 (approximately 50 per cent 4).
C	-	9-10

Hardness:

Vickers hardness readings were taken on the centre of the face of transverse microspecimens cut from the links. A 10-kilogram load was used. 42-47 Rockwell 'C' is required by the specification.

Link		Vickers Pyramid Number	Converted to Rockwell 'C'*
A	-	514	49.5
B	-	488	47.5
C	-	498	48.5

Transverse hardness surveys were made on the transverse microspecimens, using the Tukon hardness tester and a 100-gram load. Table I lists the results obtained.

(Continued on next page)

* Scott-Gray conversion chart used.

(Hardness, cont'd) -

TABLE I.

LINK A Distance from the surface (inches)	LINK A Knoop hardness	LINK B Distance from the surface (inches)	LINK B Knoop hardness	LINK C Distance from the surface (inches)	LINK C Knoop hardness
0.004	462	0.004	363	0.004	448
0.008	502	0.008	396	0.008	523
0.012	523	0.012	428	0.012	562
0.016	511	0.016	523	0.016	562
0.020	502	0.020	422	0.020	523
0.024	523	0.024	523	0.024	502
0.032	511	0.032	396	0.028	519
Centre of link -	547	-	478	-	528

Microscopic Examination:

Transverse microspecimens were cut from the links and then polished. When examined under the microscope in the unetched state, the specimens were all found to contain some elongated sulphide inclusions. Re-examination after etching in 2 per cent nital solution revealed the structures shown in Figures 2, 4 and 6, all taken at X500. Figure 2 illustrates the tempered martensitic structure of the failed link A. Figure 4, taken of Link B, shows a coarser acicular martensite. Figure 6, of Link C, shows nodular martensite combined with a spheroidal carbide structure. An attempt was made to duplicate all three structures by varying the heat treatment. Figures 3, 5 and 7 are photomicrographs of the structures which ressemble most closely the structures shown in Figures 2, 4 and 6 respectively (the captions give the heat treatments used to produce the structures).

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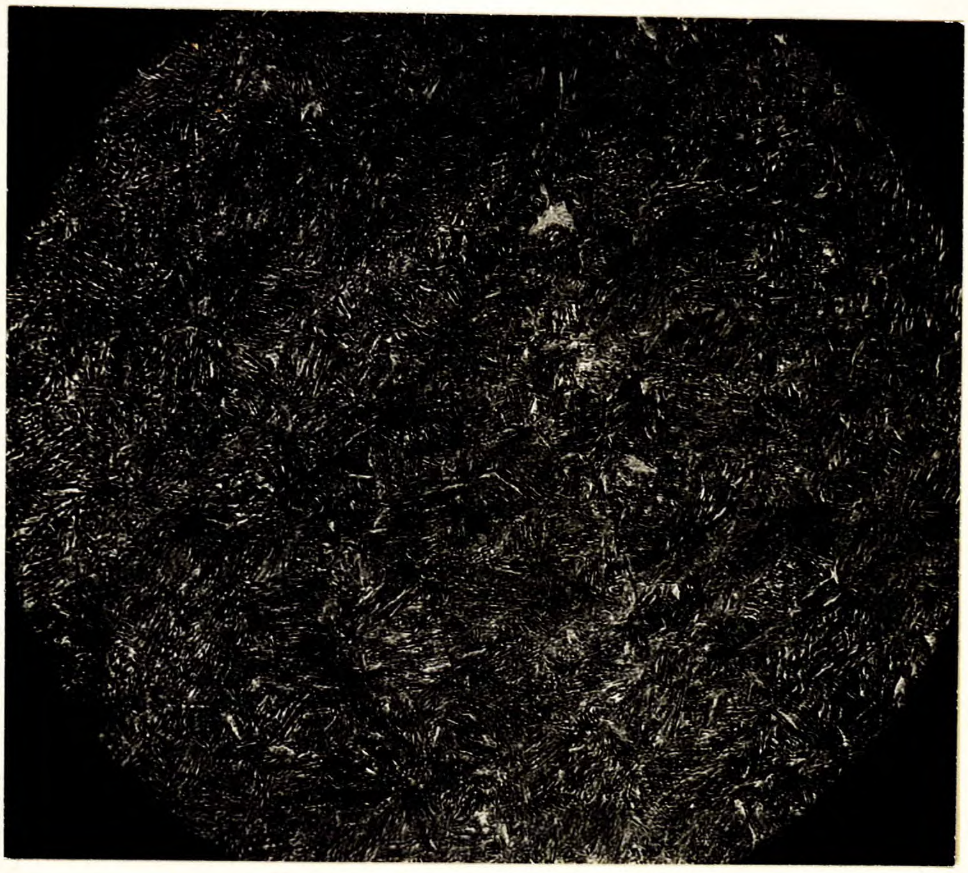
(Microscopic Examination, cont'd) -

Figure 2.



X500, nital etch.

STRUCTURE OF CRACKED LINK A.

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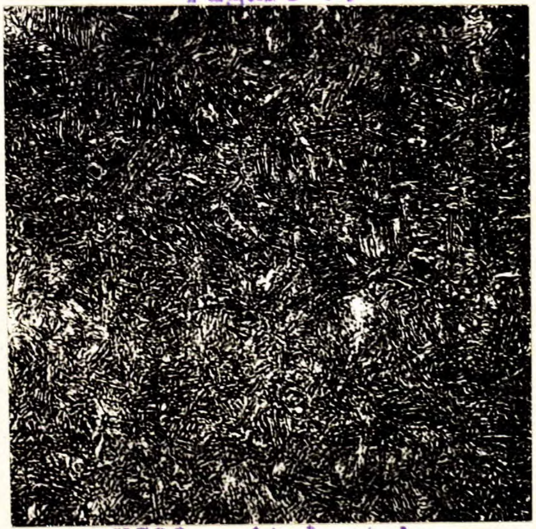
Figure 3.



X500, nital etch.

Note: Structure obtained after tempered martensitic bar stock is heated to 2000° F. for 30 minutes, quenched in salt at 650° F. for 15 minutes, transferred to salt at 1500° F. for 30 minutes, oil-quenched, and drawn at 700° F. for 30 minutes.

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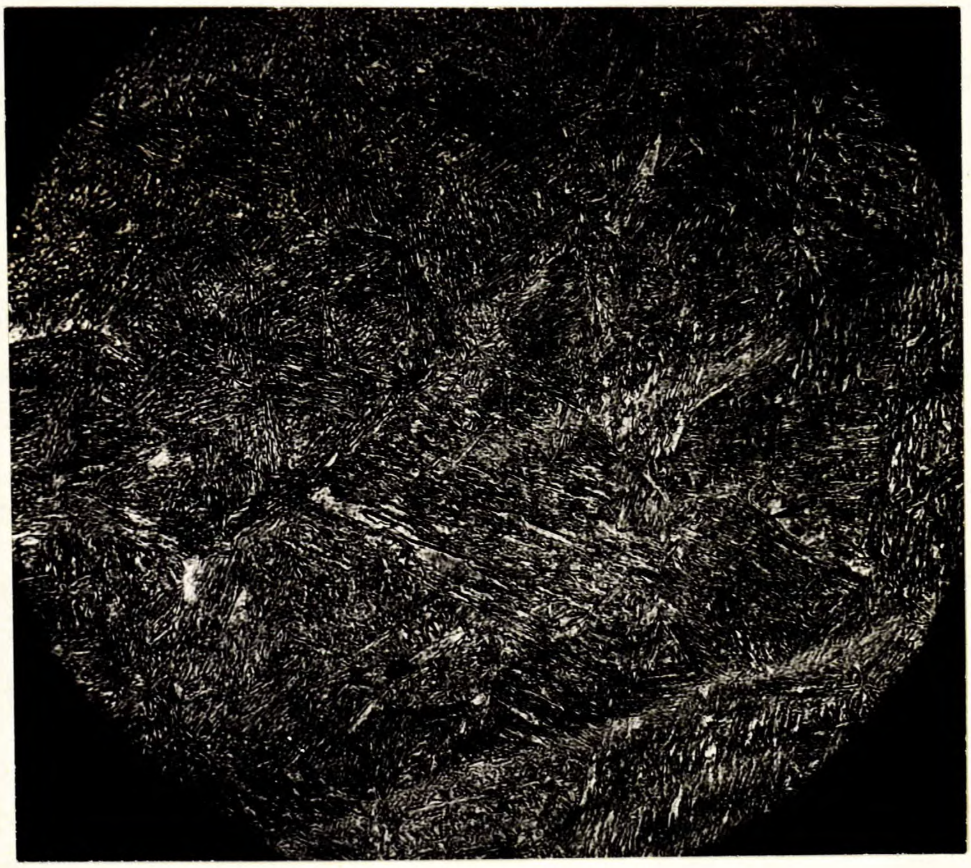
(Microscopic Examination, cont'd) -

Figure 4.



X500, nital etch.

COARSE MARTENSITE STRUCTURE OF UNBROKEN LINK B.

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Figure 5.

X500, nital etch.

Note: Structure obtained after heating tempered martensitic bar stock to 2000° F., holding for 30 minutes, then transferring to salt at 1500° F., holding for 30 minutes, then quenching in oil and drawing at 700° F. for 30 minutes.

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(Microscopic Examination, cont'd) -

Figure 6.

X500, nital etch.

LINK C.

Heterogenous structure of nodular martensite and spheroidal carbides.

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Figure 7.

X500, nital etch.

Note: Link B was spheroidized at 1225° F. for 40 hours. Above structure was obtained by heating this spheroidized link in neutral salt for 5 minutes at 1650° F., oil quenching, then drawing at 700° F. for 15 minutes.

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Discussion:

The fractured surface of the cracked link revealed no oxidation. This would normally indicate that cracking occurred in the last operation, i.e. during the rubber curing process. Since only one link was examined it is not considered sufficient evidence to definitely establish this fact.

The chemical analyses of the three links are similar. They are within the range which could be expected for different samples taken from one heat of steel. Information, however, could be obtained from the manufacturer as to whether only one heat of steel was being used for the production of the Snowmobile track link.

The hardness of all the links is somewhat higher than the maximum 47 Rockwell 'C' required by specification. The cracked link had the highest hardness, 49.5 Rockwell 'C'. The Tukon hardness tests indicate the presence of decarburization at the surface of all three links. The results in general verify those obtained on the Vickers machine, indicating the same order of hardness for the three links.

The variation in grain size indicates an uncontrolled thermal process. If all the old die links were so fine-grained, e.g. 9-10, it would point to the fact that the thermal treatment had previously been controlled. The two new die links varied from 1-7. A fine-grained link of SAE 4340 would be less apt to crack on quenching than a coarse-grained one.

The microstructures of the three links vary. Some banding was visible in all the structures. The unbroken link B had a coarse tempered martensitic structure. This was duplicated by heating a piece of link (with an original structure of tempered martensite) to 2000° F., then lowering the temperature to 1500° F., which is above the AR_3; this was

(Discussion, cont'd) -

followed by an oil quench and a 700° F. draw. The cracked link A had a finer tempered martensite structure. This structure was achieved in these Laboratories by heating a piece of link (having a tempered martensite structure originally) to 2000° F., then lowering the temperature to 650° F., which is below the AR_1 point. The piece was next placed into neutral salt at 1500° F., oil-quenched, and drawn at 700° F.

The structure of Link C was nodular tempered martensite combined with spheroidal carbides. This structure could only be duplicated by the following treatment:

A link was first spheroidized by heating to 1225° F. and holding for 40 hours. The spheroidized stock was then held in neutral salt at 1650° F. for 5 minutes, oil-quenched, and drawn at 700° F.

This points to the fact that the old die links were in the spheroidized state prior to the heat treatment for the forming operation. The new die links were, in all probability, in the tempered martensitic condition.

Spheroidal carbides are difficult to austenitize. It appears possible that if the manufacturer is using a short time cycle at the austenitizing temperature the spheroids do not get a chance to dissolve. These spheroidal carbides facilitate the forming operation. They also reduce the hardenability of the steel.* On the other hand, a short time cycle on tempered martensitic stock (which originally is harder) would not be as readily formed and, consequently, more internal stress would be

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* "Effect of Time, Temperature and Prior Structure on the Hardenability of Several Alloy Steels," by J. Welchner, E. S. Rowland and J. E. Ubbern. Transactions of A.S.M., Vol. 32, 1944, pp. 521-552.

(Discussion, cont'd) -

produced. The internal stress produced and the greater hardenability of tempered martensitic stock could be important factors in cracking of the links in (a) forming, (b) quenching operation, (c) or during the curing operation.

CONCLUSIONS:

1. No visible oxidation was revealed by the fractured surface of the cracked link.

2. The chemical analyses of the three links are similar. They may all be from the same heat of steel.

3. The hardnesses of the links are above the 47 Rockwell 'C' maximum specified. A higher draw temperature should be used.

4. Some decarburization is present in all three links.

5. The variation in grain size for the new die links suggests an uncontrolled thermal process.

6. The old die link is very fine-grained 9-10 A.S.T.M.

7. The microstructures of the three links vary. Links A and B are tempered martensite, whereas Link C is nodular tempered martensite and spheroidal carbides.

8. The new die links are being formed from a tempered martensitic stock which is heated to the forming temperature. The old die link appears to have been formed from spheroidized stock which was heated up to the high temperature. More internal stress, greater hardenability and therefore greater cracking susceptibility could be expected from the martensitic stock.

Recommendations:

1. A further check on grain size and microstructure should be made on more old die links.

2. Information should be obtained from the manufacturers on whether the "as received" steel is varying in structure.

3. Control of the thermal treatment prior to and after forming is desirable.

4. Consideration should be given to the possibility of using a steel having somewhat less hardenability.

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