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EXAMINATION OF FRACTURE OF SAE 4140 TEST BAR

by

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SUMMARY

Approximately one-third of the fracture area had a dark, rough appearance, and the remainder showed many shiny facets. Microscopic examination revealed many normal sulphide inclusions and several large inclusions which were identified by etching tests as being silicates, probably with a high manganese content. It is likely that they originated in the slag. Failure originated at one of these entrapped inclusions, causing the first part of the fracture to be mainly intergranular. The remainder of the fracture was shown to have occurred mainly by transcrystalline cleavage. This difference in the mode of fracture is the reason for the difference in the fracture appearance.

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CONTENTS

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INTRODUCTION

A fractured tensile test bar of SAE 4140 steel was submitted for examination on October 6, 1958, by Mr. Gordon J. Pride, Metallurgist, Canadian Unitcast Steels, Ltd., Sherbrooke, Quebec. The furnace log, mechanical properties, and chemical analysis of the heat corresponding to the test bar were also forwarded. The fracture surface, as illustrated in Figure 1, had two distinct areas. Approximately one-third of the surface was rough and dark, and the remainder exhibited many shiny facets. An opinion was requested regarding the nature and cause of the appearance of the fracture.

(Macrograph of fracture surface; X3)

Fig. 1. - Area at the bottom of the picture appeared dark and rough, and the remainder showed many shiny facets.

The following are the chemical and spectrographic analyses and mechanical properties of the steel as supplied by Canadian Unitcast Steels Limited.

Chemical Analysis %

C	Mn	Si	S	P	Cr	Mo	N
0.39	0.80	0.58	0.039	0.029	0.80	0.19	0.006

Semi-Quantitative Spectrographic Analysis %

Cu	Ni	Al	Sn	V	Co
.2	.25	.07	.007	.006	.005

Mechanical Properties

Ultimate Strength psi	Yield Strength psi	Percent Elongation in 2"	Percent Reduction in Area
105,700	63,000	18	25.4

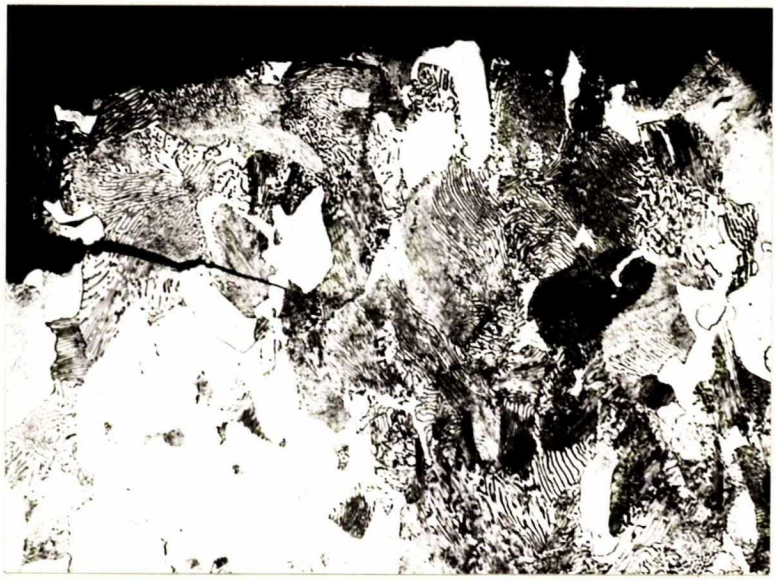
RESULTS OF METALLURGICAL EXAMINATION

Macroscopic Examination

Macroscopic examination of the fracture revealed traces of material which had the appearance of entrapped slag or deoxidation product. Most of this material was found at the edge of the bar, and considerably more was present at the edge of the dark fracture than adjacent to the bright fracture. Material with a similar appearance was observed in surface ruptures near the fracture which were formed when the bar was broken. Most of the fracture surface did not show any of this non-metallic component.

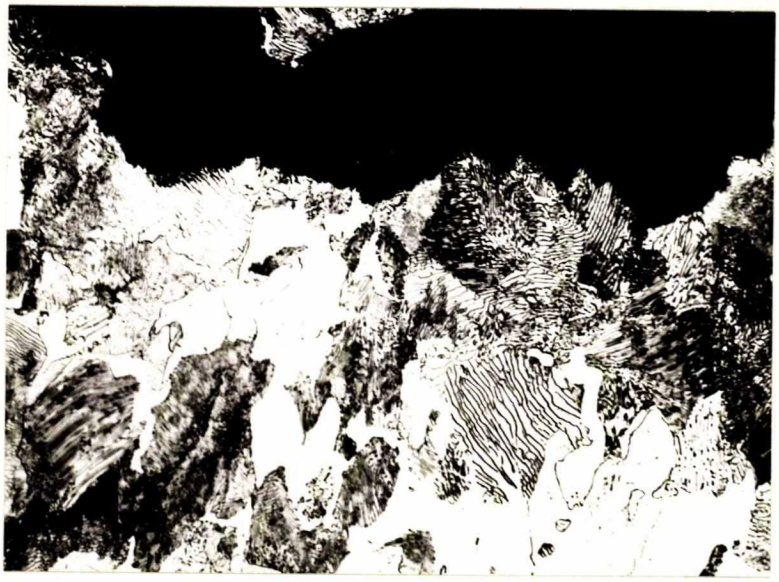
Microscopic Examination

A longitudinal section was cut from the bar to show a cross-section through both fracture types. Photomicrographs of cross-sections at both dark and bright fractures are shown in Figures 2 and 3 respectively.



(Etched in 2% Nital; X500)

Fig. 2. - Cross-section through bright fracture showing transcrystalline cleavage.



(Etched in 2% Nital; X500)

Fig. 3. - Cross-section through dark fracture showing evidence of intergranular failure and no transcrystalline cleavage.

Examination of microspecimens showed a large number of sulphide inclusions and several large inclusions such as those in Figures 4 and 5. Etching tests, as outlined below, revealed these to be silicates, probably with a high manganese content.

Etching 10 seconds in a 10% nital solution made no difference in the appearance of the inclusions. Etching 5 minutes in a 10% aqueous solution of chromic acid did not change the appearance of the large inclusions but did remove the sulphide inclusions. A 5 minute etch in boiling alkaline sodium picrate darkened the large inclusions and 10 minutes in a saturated solution of stannous chloride in ethyl alcohol did not produce a further change. The inclusions were removed with a 10 minute etch in a 20% aqueous solution of hydrofluoric acid.

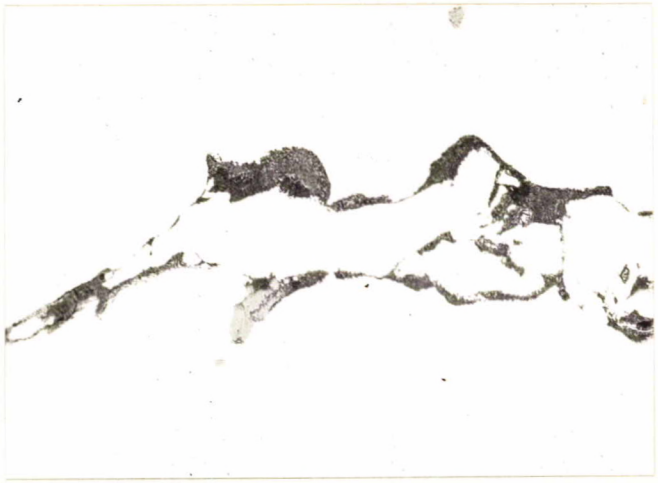
Figures 6, 7, 8 and 9 show the progress in the attack of one of these inclusions after some of the stages of the etching tests.

(As polished; X200)

Fig. 4. - One of several large inclusions observed.

(As polished; X200)

Fig. 5. - One of several areas containing large non-metallic impurities observed near the portion of the fracture which had the dark appearance.



(As polished; X500)

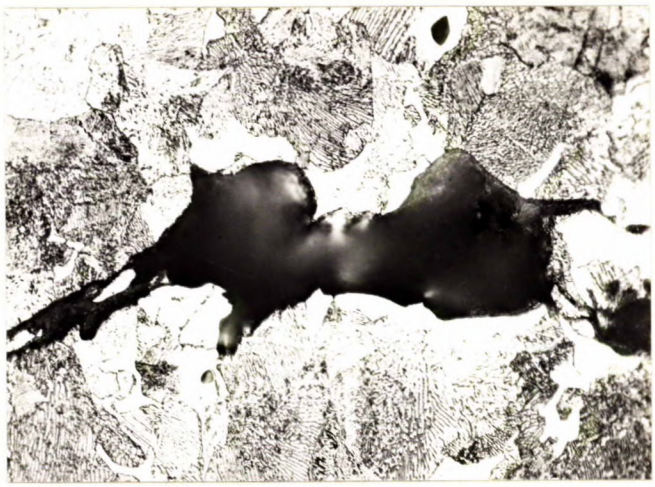
Fig. 6. - As polished inclusion.

(Etched 10 sec in 10% Nital and 5 min in 10% aqueous chromic acid; X500)

Fig. 7. - Sulphide removed.

(Etched 5 min in boiling alkaline sodium picrate; X500)

Fig. 8. - Inclusion darkened.



(Etched 10 min in saturated solution of stannous chloride in ethyl alcohol and 10 min in 20% aqueous hydrofluoric acid; X500)

Fig. 9. - Inclusion removed

DISCUSSION

The large number of sulphide inclusions observed is in agreement with the relatively high sulphur content reported. These inclusions were of the non-deleterious ASTM Type 3 classification. Analyses revealed a silicon content slightly higher than the range specified for A.I.S.I. 4140. There is little doubt that failure initiated at an area containing one or more of the large inclusions. The initial fracture followed the intergranular configuration of these particles, and the remaining metal failed by transcrystalline cleavage. The heavy inclusion content accounted for the low ductility of the metal.

CONCLUSIONS

The two distinct fracture appearances were due to differences in the mode of failure. The dark, rough appearance of one section of the fracture was due to the intercrystalline failure promoted by the presence of large silicate inclusions. The remainder

of the fracture showed bright facets due to transcrystalline cleavage failure.

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