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EXAMINATION OF CRUST BREAKING TOOLS

by

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PHYSICAL METALLURGY DIVISION

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SUMMARY OF RESULTS

The tools are susceptible to fatigue failure originating at high stress concentration points in the fillet regions.

The life of the tools could be extended by cutting larger fillet radii, or tapering the fillet out completely.

The present material should also be given a strengthening heat treatment or replaced by equivalent grades obtainable commercially in the heat treated condition at a machinable hardness within the range 35 to 40 Rockwell 'C'. Alternative grades were suggested.

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INTRODUCTION

In a letter dated December 13, 1965, Mr. C. Watson, Canadian British Aluminium Company Limited, P.O. Box 1530, Baie Comeau, P.Q., stated that he was forwarding three crust breaking tools to the Ferrous Metals Section, Physical Metallurgy Division, Mines Branch, Department of Mines and Technical Surveys, Ottawa. Two of the tools had broken and the third was unused. It was requested that an examination of the tools be carried out and that suggestions be offered that would help to improve their service life, keeping in mind the necessity to avoid contamination of their product with manganese.

VISUAL EXAMINATION

The three crust breaking tools are shown in Figure 1.

The fractured surfaces of the tools show the typical markings of fatigue failure due to cyclic bending stresses. This is shown in Figure 2. Considerable heating had occurred at the hammer end of the large section. Also, severe upsetting or deformation had occurred in service.

CHEMICAL ANALYSES

Drillings were obtained from the keyway of the fractured tool and analysed. The results, contained in spectrographic analysis report, No. 66-4 and chemical analysis report, No. 66-87, are tabulated below:

Element	Composition, Per Cent Tip	AISI 5046
Carbon	0.45	0.43 to 0.50
Manganese	0.79	0.75 to 1.00
Silicon	0.24	0.20 to 0.35
Sulphur	0.032	0.040 maximum
Phosphorus	0.007	0.040 maximum
Chromium	0.24	0.20 to 0.35
Molybdenum	0.01	—
Vanadium	none	—
Nickel	0.43 *	—

* Spectrographic analysis.

The composition of the crust breaking tool resembles that of an AISI 5046 steel, which is a machinery grade of steel.

METALLOGRAPHIC EXAMINATION

A specimen was cut from the keyway of the fractured tool adjacent to the holes drilled for analysis. The specimen was polished, etched in 2% nital and examined metallographically.

The microstructure of the crust breaking tool consisted of pearlitic grains outlined by ferrite similar to a coarse-grained normalized medium carbon steel. The microstructure is shown in Figure 3.

HARDNESS EXAMINATION

The hardness, taken on the keyways was 89 on the Rockwell 'B' scale.

COMMENTS

The composition of the crust breaking tool closely resembled that of an AISI 5046 steel, which is a machinery grade of steel.

The microstructure indicated that the material had been normalized. This condition was consistent with its hardness.

To strengthen the regions where failure tends to occur, the tools could be quenched and tempered.

The failure was due to fatigue, which resulted from cyclic stressing in the fillet regions. Overstressing at localized points in fillets can occur due to abrupt cross-sectional changes in dimension. Any reduction in the abruptness of these changes by redesign would lessen the degree of overstressing in the fillet region and should give longer life for these tools. This could be accomplished by cutting larger fillet radii or, if possible, tapering the fillet out completely. However, it is doubtful if this type of failure can be completely eliminated when using this material with a fillet and without a strengthening heat treatment. Equivalent grades should be obtainable in the heat treated condition, at machinable hardness within the range 35 to 40 R_C, from commercial outlets.

Other steels more suitable for use would be the shock resisting grades or hot work grades of steel. AISI steels S1 and S2 are shock resisting and require a simple liquid quench and temper treatment. AISI steels H12 and H13 are hot work steels, which require a more elaborate heat treatment at a higher quenching temperature and the proper heat treating facilities.

A higher strength machinery grade steel such as AISI 4340, which will air harden, might be more suitable. This heat treatment would be relatively simple. It consists of heating in the range 816 to 857°C (1500 to 1575°F) allowing to air cool and tempering in the range 427 to 593°C (800 to 1100°F) as required for hardness. AISI can be oil quenched if necessary.

During heating of tools for heat treatment, where complete facilities are not available, scaling and decarburization can be prevented or minimized by enclosing the work load in boxes made for such a purpose out of a carbonaceous material. Alternatively, the tools might be loosely covered in a metal box with carburizing or spent carburizing compound, with a sand and charcoal mixture, or with cast iron chips.

The cast iron chips tend to stick if temperatures above 927°C (1700°F) are used.

All of the steels discussed contain low manganese quantities and should provide no more contamination hazard than the steel currently being used.

CONCLUSIONS

1. Failure was caused by fatigue resulting from cyclic overload due to stress concentrations in the fillets.

2. The tools had been made of a machinery steel of a grade of steel similar to AISI 5046 that had not been strengthened by a heat treatment.

3. Failures will almost certainly recur frequently unless the fillets can be removed or enlarged, and/or a strengthening heat treatment used.

RECOMMENDATIONS

To improve the service life of these tools the following recommendations should be considered in the order given.

1. Improve the design by either enlarging or removing the fillets if possible.

2. Strengthen the tools by quenching and tempering, or by using material procured in the strengthened condition.

3. Combine recommendation (1) and (2).

4. Use an alternative material such as the air hardening, shock resisting or hot work steels suggested within the text of this report.

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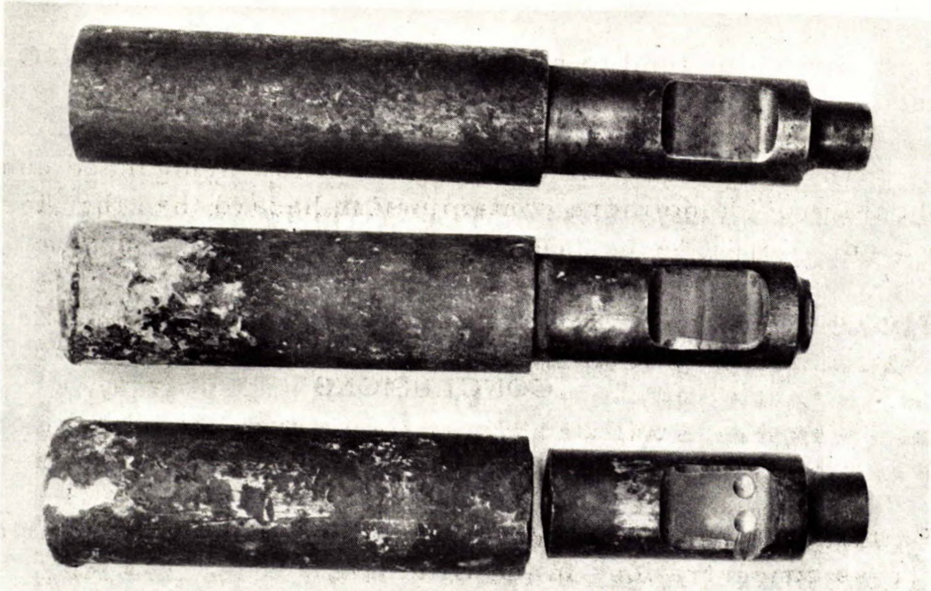

Figure 1. Crust breaking tools showing two broken at fillets and one unused fillet. As Received, X1/4.

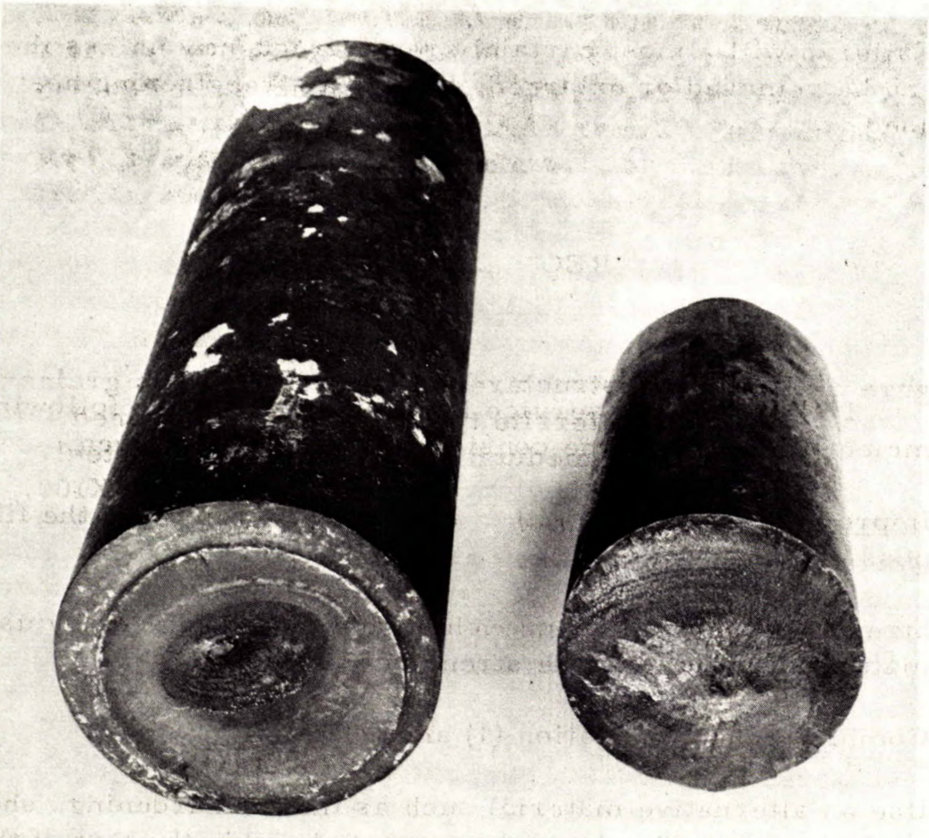

Figure 2. Fractured surface of a broken crust breaking tool. As Received, X2/3.

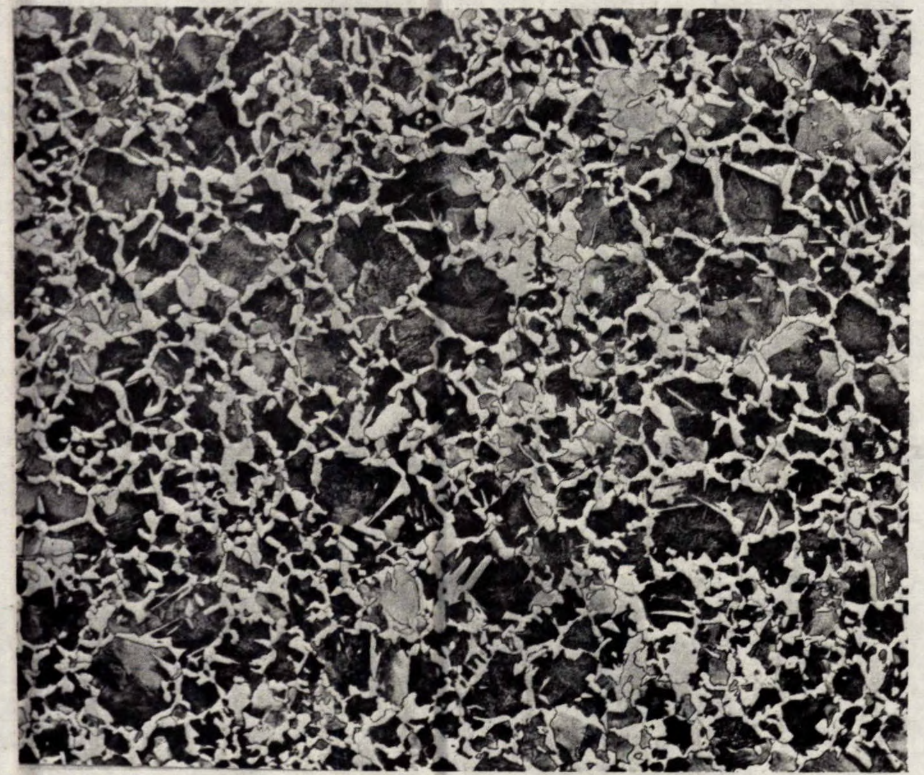

Figure 3. The microstructure consists of pearlitic grains outlined by ferrite typical of coarse-grained normalized medium carbon or low alloy steel.
Etched in 2% nital, X100.