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REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1785.

Metallurgical Examination of a Broken High Speed Steel Mill Cutter.

(Copy No. 6.)

Bureau of Mines
Division of Metallic
Minerals
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Physical Metallurgy
Research Laboratories

CANADA

DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

OTTAWA February 1, 1945.

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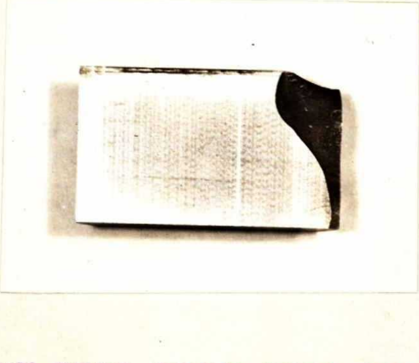
Origin of Material and Object of Investigation:

On January 6, 1944, one broken High Speed Steel mill cutter (see Figure 1) was received for metallurgical examination from Alexander Fleck Limited, Ottawa. This tool, which had failed in service, was one of a batch of eighteen cutters which had been heat-treated in these Laboratories. The remaining seventeen were reported to be satisfactory.

Figure 1.



BROKEN HIGH SPEED MILL CUTTER
AS RECEIVED.

(Approximately $\frac{3}{4}$ size).

Tempering Experiment:

A sample was cut from the tool submitted and tempered in a furnace at 1050° F. for 2½ hours, followed by cooling in the furnace.

Hardness Test:

Hardness tests were made on the specimen as received and after tempering, using the Vickers hardness tester with a 30-kilogram load. The results are given in the following table:

	VICKERS (30-kg. load)	ROCKWELL 'C' (Converted)
Steel as received -	810	64
Steel drawn at 1050° F. -	862	66

Microscopic Examination:

Photomicrographs were taken from specimens in the "as received" condition and after tempering. Figure 2 is a photomicrograph, at X1000 magnification, showing the structure of the steel as received. Figure 3, also taken at X1000 magnification, shows the microstructure after tempering at 1050° F. for 2½ hours.

Figure 4, taken at X500 magnification, shows the banded structure of the steel.

All specimens were etched in 6 per cent nital.

(Continued on next page)

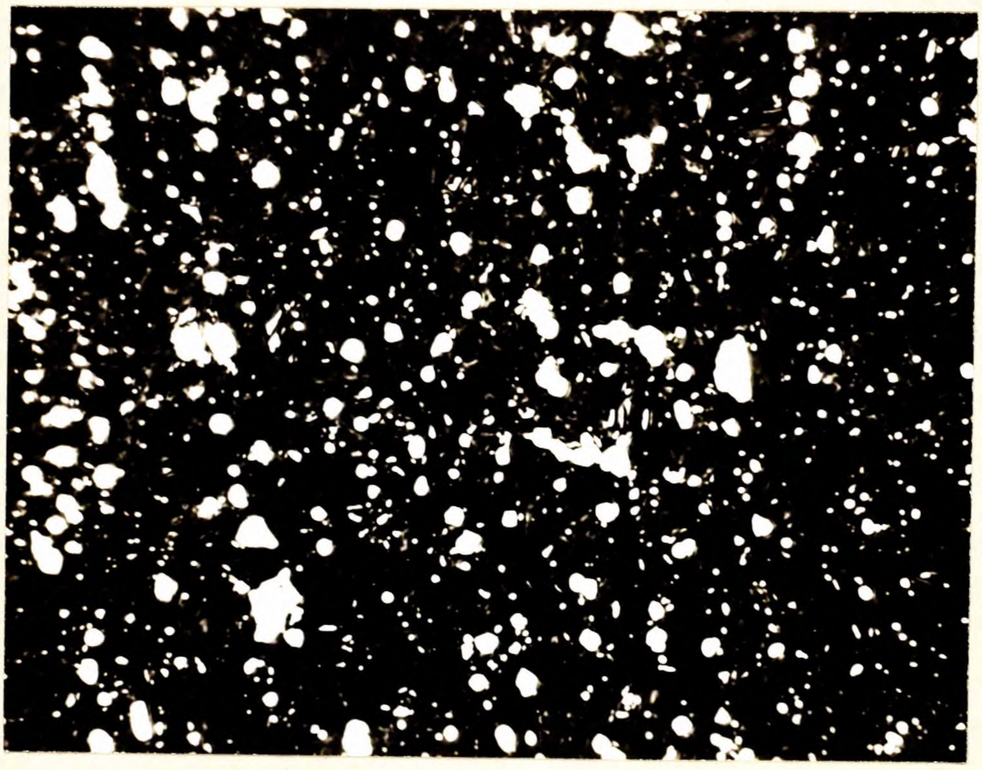
Figure 2.

X1000, etched in 6 per cent nital.

MICROSTRUCTURE OF STEEL "AS RECEIVED".

Note large quantities of untempered martensite (white).

Figure 3.

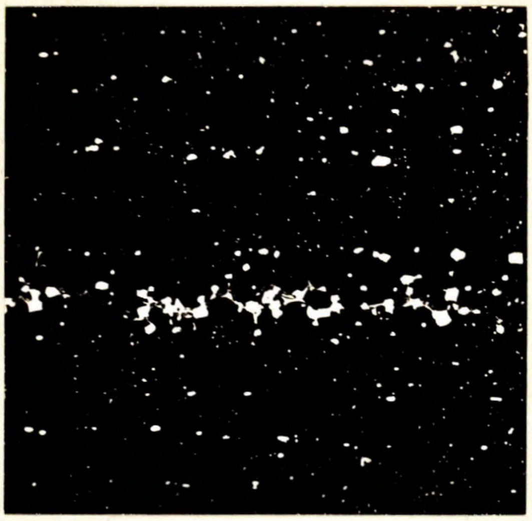


X1000, etched in 6 per cent nital.

MICROSTRUCTURE OF STEEL AFTER TEMPERING
AT 1050° F. FOR 2½ HOURS.

Note carbides in a dark mass of tempered martensite.

Figure 4.



X500, etched in 6 per cent nital.

SHOWING BANDING.

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Discussion of Results; Conclusions:

The mill cutter under examination was fabricated from Rex AA steel, produced by the Crucible Steel Company. This steel is a variety of the 18-4-1 type, and on this assumption, no analysis was made.

Microscopic examination of the steel, as received, revealed considerable areas of white, untempered martensite and retained austenite (Figure 2). Such a structure can result from an arrested quench by either of two methods;

(a) Quenching into warm or hot oil, followed by tempering; or

(b) Quenching into oil at room temperature, but transferring the steel into the tempering furnace while it is still hot.

When a high speed steel is given an arrested quench a considerable quantity of retained austenite results. Most of this austenite transforms to white-etching, untempered martensite in the first drawing operation, which takes place at 1050° F. A second draw would then be necessary to convert the white-etching untempered martensite to the dark-etching tempered martensite shown in Figure 3.

A piece of the cutter was therefore drawn at 1050° F. for

(Discussion of Results; Conclusions, cont'd) -

2½ hours, and cooled in the furnace. (The steel does not have to be cooled in the furnace after drawing, but may be cooled in air with equally good results). Microscopic examination revealed that the white, untempered martensite had been transformed into dark-etching, tempered martensite as shown in Figure 3. This is the normal structure of a properly hardened and heat-treated high speed steel.

The change in the micro constituents resulting from the second draw was also manifested by an increase in the hardness, from 810 to 862 Vickers (64 to 66 Rockwell 'C'). This increased hardness, which results from the transformation of retained austenite to martensite, proves that there must have been present some retained austenite even after the first draw. It also indicates that the increase of hardness resulting from the transformation of retained austenite to untempered martensite was greater than the decrease of hardness resulting from the tempering of the martensite already formed.

The complete elimination of the austenite and untempered martensite by means of the second draw (or third, if necessary) results in a steel which has very considerably improved mechanical properties, such as freedom from brittleness, and greater transverse strength.

Arrested quenching is considered good practice in the heat-treating of high speed tool steels, particularly with intricate designs, in order to prevent the hazard of cracking which might result from quenching down to room temperature. This procedure is perfectly satisfactory provided the quenching is followed by at least two separate draws at 1050° F. for 2½ hours. Multiple draws would ensure complete transformation of the austenite and eliminate the presence of untempered

(Discussion of Results; Conclusions, cont'd) -

martensite.

The photomicrograph shown in Figure 4 indicates that there is considerable segregation or banding in the steel. This banding may or may not have deleterious effects upon the mechanical properties of the steel.

These conclusions may be summarized as follows:

1. Failure of the mill cutter was due to improper heat treatment.

2. The steel must have been given an arrested quench, i.e., it was transferred to the tempering or drawing furnace while still hot.

3. Only one draw was given the steel following the arrested quench. This was insufficient to completely transform all of the retained austenite to tempered martensite.

Recommendations:

1. It is recommended that high speed tool steels which have been heat-treated in a similar manner, that is, quenching to a temperature above room temperature, followed by a single draw, should be given at least one more draw at 1050° F. for 2½ hours, in order that optimum mechanical properties be obtained.

2. High speed tools of simple design should be quenched down to room temperature, followed by two separate draws.

3. High speed tools of intricate design should be quenched at some temperature above room temperature, and must be followed by two or more separate draws.

4. Cooling after drawing may be done in air.

Acknowledgment:

The observations and conclusions for this report were drawn largely from the following paper:

"The Effect of Quenching Bath Temperature on Tempering of High Speed Steel." P. Gordon, M. Cohen, and R. S. Rose, in Trans. A.S.M., Vol. 33, 1944, p. 411.

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