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OTTAWA November 1st, 1944.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1727.

Examination of an S.A. Cam for 4-Inch Twin Mk. XIX Gun Mounting.

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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 November 1st, 1944.

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Origin of Material and Object of Investigation:

On September 18th, 1944, Lieut. Commander (E) G. Taylor, R.N.V.R., of the British Admiralty Technical Mission, 58 Lyon Street, Ottawa, Ontario, submitted for examination an S.A. Cam for a 4-inch Twin Mk. XIX Gun Mounting. An accompanying letter, dated September 15th, from Mr. A. H. Dobson of the British Admiralty Stores, Toronto, stated that "on one or two occasions, it has been noted that small cracks have been observed on the face of the cam after the flame-hardening process has been completed, while the hardness obtained is not even across the face and length of the cam." It was requested that an investigation be carried out with a view to establishing certain stable conditions necessary for successful flame-hardening.

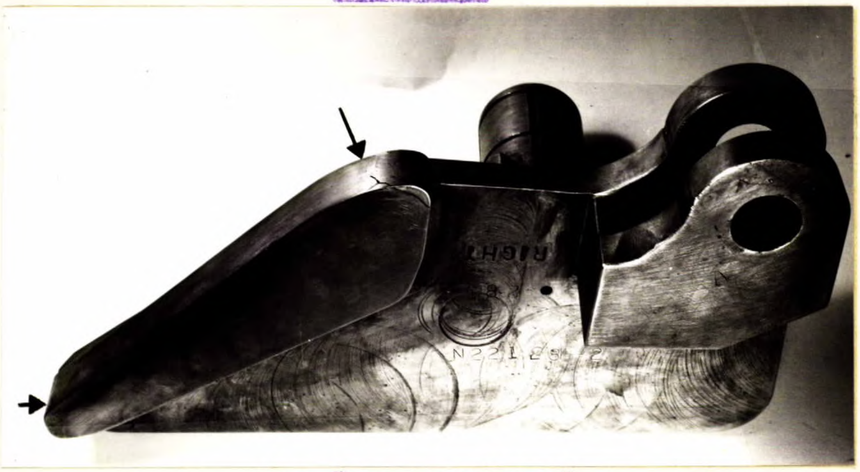
Description of Flame-Hardening Process:

A description of the flame-hardening process employed by Trenton Industries Limited, Trenton, Nova Scotia, the firm carrying out this operation, is given in a second enclosure, from Mr. Robt. C. Logan, the general superintendent of the Trenton plant. Mr. Logan states that the torch passes along the face of the cam at a fixed speed of 3 inches per minute. The torch body has a special head. This head has two rows of holes, one row emitting flame and the other row emitting water. The rows are ½ inch apart; the five holes in each row are approximately 0.015 inch in diameter. The face of the torch is set 3/8 inch away from the surface to be hardened. The flow of water used for quenching is regulated so that its force is just insufficient to blow out the flame. The temperature of the water is considered a variable factor, depending on the time of year. It is stated that it changes from about 46° F. in January to 70° F. in August.

Macro-Examination:

Figure 1 illustrates the cracks (arrows in picture) on the cam face as it was received. Figure 2 is a close-up view of a crack on the flame-hardened surface.

Figure 1.



CAM "AS RECEIVED".

Arrows point to cracks.

(Macro-Examination, cont'd) -

Figure 2.

CLOSE-UP OF A CRACK
ON FLAME-HARDENED SURFACE.

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Chemical Analysis:

Drillings were taken from the cam for chemical analysis.

	As Found	Atlas Ultimo-4	SAE 4340
		- Per Cent -	
Carbon	- 0.45	0.45	0.38-0.43
Manganese	- 0.55	0.75	0.60-0.80
Silicon	- 0.32	0.20	0.20-0.35
Sulphur	- 0.022	0.030	0.040 max.
Phosphorus	- 0.012	0.030	0.040 max.
Chromium	- 0.73	0.75	0.70-0.90
Nickel	- 2.11	1.75	1.65-2.00
Molybdenum	- 0.33	0.35	0.20-0.30

Hardness:

A series of hardness readings was made across the face of the cam, approximately one inch apart longitudinally. Figure 3 shows the relative spacing of the impressions.

(Continued on next page)

(Hardness, cont'd) -

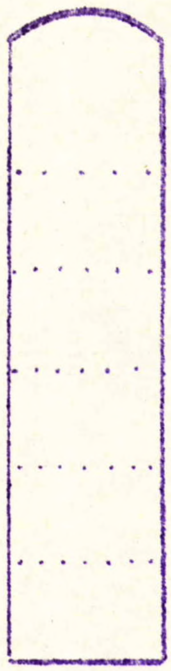


Figure 3.

Hardness, Rockwell 'C'.

56, 59, 58, 55, 54.5

51, 58, 57, 57, 55, 50

54, 59, 59.5, 59.5, 57.5, 57

57, 58, 58, 58, 56, 54.5, 52

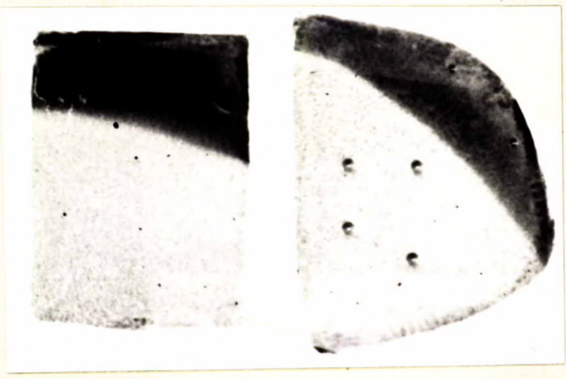
45, 56, 57, 56, 57, 53, 51

The hardness of the unhardened part of the cam was 19 Rockwell 'C'.

Depth of Hardened Zone:

Figure 4 illustrates the variation in depth of the hardened zone. It varies from 0.12 to 0.30 inch.

Figure 4.



DEPTH OF HARDENED ZONE.

(Approximately 2½ times actual size).

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Microscopic Examination:

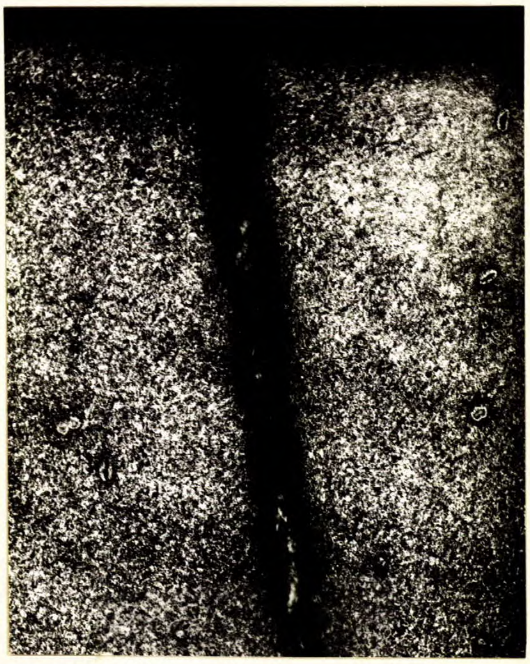
Microsections were cut from the cam. These were polished and etched in 2 per cent nital. Figure 5, a photomicrograph taken at X250 magnification, shows the sorbite and ferrite microstructure of the unhardened zones. Figure 6 (X150) shows one of the cracks at the surface and the martensitic structure of the hardened zone. The samples were then drawn at 600° F. for ½ hour, repolished, and etched in Vilella's reagent. This reagent is used to show the austenitic grain size. Figure 7 (X100) illustrates the fine grain of the hardened zone at a point below the surface. Figure 8 (X100) shows the coarser grains obtained at the surface in the vicinity of a crack.

Figure 5.

X250, nital etch.

SORBITE AND FERRITE STRUCTURE OF THE UNHARDENED CAM.

Figure 6.



X150, nital etch.

Note crack and martensitic structure.

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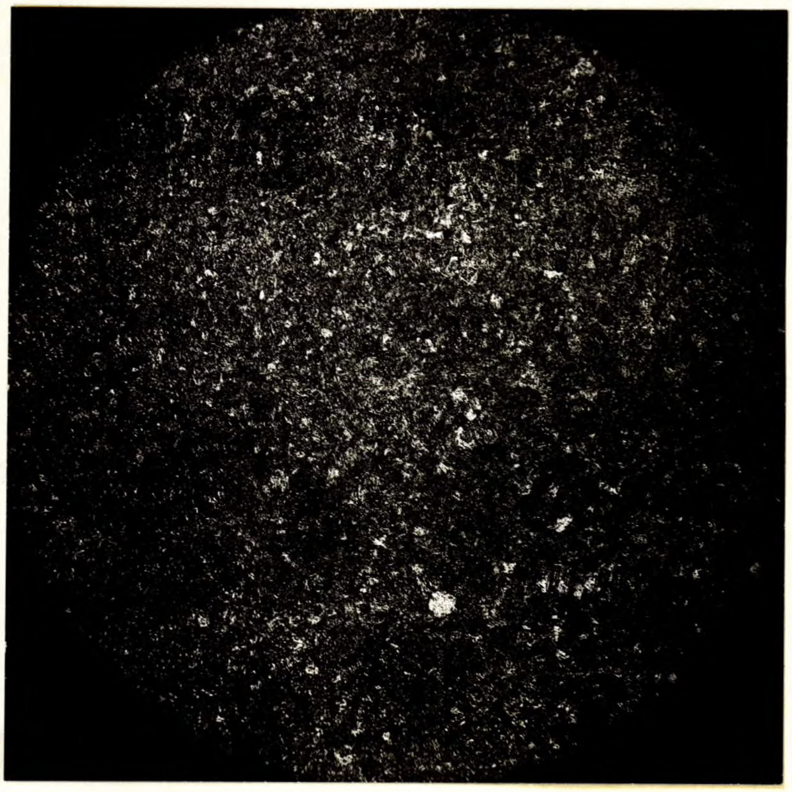
(Microscopic Examination, cont'd) -

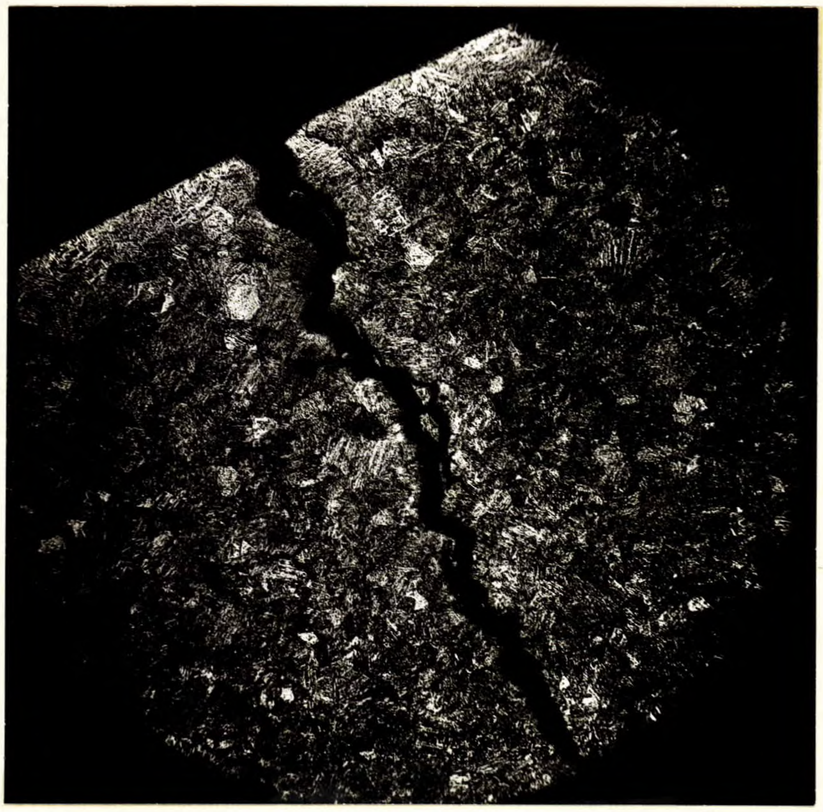
Figure 7.



X100, Vilella's etch.

Note the very fine grain size.

Figure 8.



X100, Vilella's etch.

Note coarser grain size at the surface.

Discussion:

Cracking in a flame-hardening operation is usually caused by heating the work to a high temperature prior to quenching and/or subjecting the heated zone to too severe a quench. Figures 7 and 8 indicate that the grain-coarsening has taken place at the surface. This is caused by overheating, and can be corrected by:

(1) Raising the flame torch slightly higher.

(2) Reducing the length of the heating cycle somewhat.

(3) Reducing the orifice diameter of the burners.

Experimentation by "trial and error" would have to be undertaken at the plant to produce the proper conditions, having all the specified requirements in mind. The heating temperature for this steel should be 1500-1550° F. After heating to 1500-1550° F. for carbide solution, it can be quenched from 1275° F. and still get the required hardness. If a less severe quench were used it would make the problem of overheating somewhat less critical. It is of interest that an experiment carried out in these Laboratories showed that a hardness of 57-58 Rockwell 'C' could be obtained by cooling a piece of the cam with an air blast after flame heating. It is felt that in production, air cooling may present difficulties. Emulsions such as Houghton's Permasol K have been successfully used in flame-hardening operations. These are less severe than water quenches and do not present the fire hazard which ordinary oil introduces.

If the occurrence of cracks in the process is rare, as Mr. Dobson's letter indicates, it is felt that radical changes in the flame-hardening method should not be resorted to. Careful control of the flame, and, possibly, lower water pressure in the operation, would keep to a minimum the danger of cracking. Should the

(Discussion, cont'd) -

cracking become costly, due to a large number of rejects, then both flame control and quenching media should be investigated.

Some softer spots appear to be present at the outside of the hardened cam surface examined. This, along with the report that uneven hardness has been observed on other cams which have been flame-hardened, indicates the necessity for investigating the heating part of the operation.

CONCLUSIONS:

1. Grain coarsening due to overheating accentuates cracking susceptibility. Some coarsening has been observed in the cam examined.

2. This type of steel should be heated to 1500-1550° F., and may be quenched from a temperature as low as 1275° F., the Ar_3 point being approximately 1225° F.

3. The steel can be hardened by an air blast to 57-58 Rockwell 'C'; therefore a less severe quench than a water spray can safely be used to get the required hardness.

4. Softer spots are present on the surface. This points to uneven hardening. Adjustment of the burners may be necessary.

5. The depth of hardening varies from 0.12 to 0.30 inch.

Recommendations:

1. If cracking is an unusual occurrence slight adjustment of the burners, and possibly a lower water spray pressure, might eliminate the trouble.

2. If cracking becomes more serious a check should be made on grain size and depth of hardening by the method given

(Recommendations, cont'd) -

in this report. If the grain size and depth of hardening are satisfactory it would indicate that the heating operation is satisfactory. A less severe quenching medium would then have to be employed.

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