FILE COPY

OTTAWA April 24, 1945.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1849.

Metallurgical Examination of Induction-Hardened Snowmobile Sprockets.

==========

(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 April 24, 1945.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1849.

Metallurgical Examination of Induction-Hardened Snowmobile Sprockets.

==========

Origin of Material and Object of Investigation:

On April 10, 1945, the Director of Tanks and M.T., Inspection Board of United Kingdom and Canada, Ottawa, Ontario, submitted two snowmobile sprockets for metallurgical examination. In a covering letter (File 4/10/41/Snow/9), it was explained that the firm of Farand and Delorme, Montreal, was experiencing considerable difficulty in obtaining consistent hardness figures on the induction-hardened surfaces of these sprockets. Specifications require that the bearing surfaces of snowmobile sprockets be hardened to Rockwell "C" 57 ±3 to a depth of 5/32 ±1/32 inch.

It was requested that the metallurgical examination include:

(1) Chemical analysis.

(2) Magnafluxing to check for quenching cracks in the teeth.

(3) Determination of the reason for low and inconsistent hardness.

(4) Reheat treatment of sections of sprocket to determine optimum quenching oil and temperature.

Magnaflux:

Both sprockets were magnafluxed. There were no quenching cracks about the drilled holes in the teeth.

Chemical Analysis:

Chemical analysis of drillings taken from one sprocket is shown below, along with the SAE 1050 specification:

		Sprocket	S.A.E. 1050 Specification
		- Per	cent -
Carbon	-	0.47	0.48-0.55
Manganese	-	0.77	0.60-0.90
Silicon	-	0.23	0.15-0.30
Phosphorus	-	0.020	0.040 max.
Sulphur	-	0.025	0.050 max.

Hardness Survey:

Sections were cut from both sprockets and hardness surveys were made 'as received' and after reheat treatment at these Laboratories. No facilities were readily available to induction-harden the bearing surfaces only; consequently, complete sections were hardened, rather than the zone 5/32 inch from the bearing surface. To reheat-treat, specimens were held at 1575° F. in a neutral atmosphere for 20 minutes and were then oil-quenched.

As shown in Figures 1 and 1a, there is a zone of low and variable hardness at the bearing surface. Readings taken 1/16 inch fron this surface ranged from 28 to 44 Rockwell "C". About 1/10 inch from the bearing surface, the hardness is more uniform.

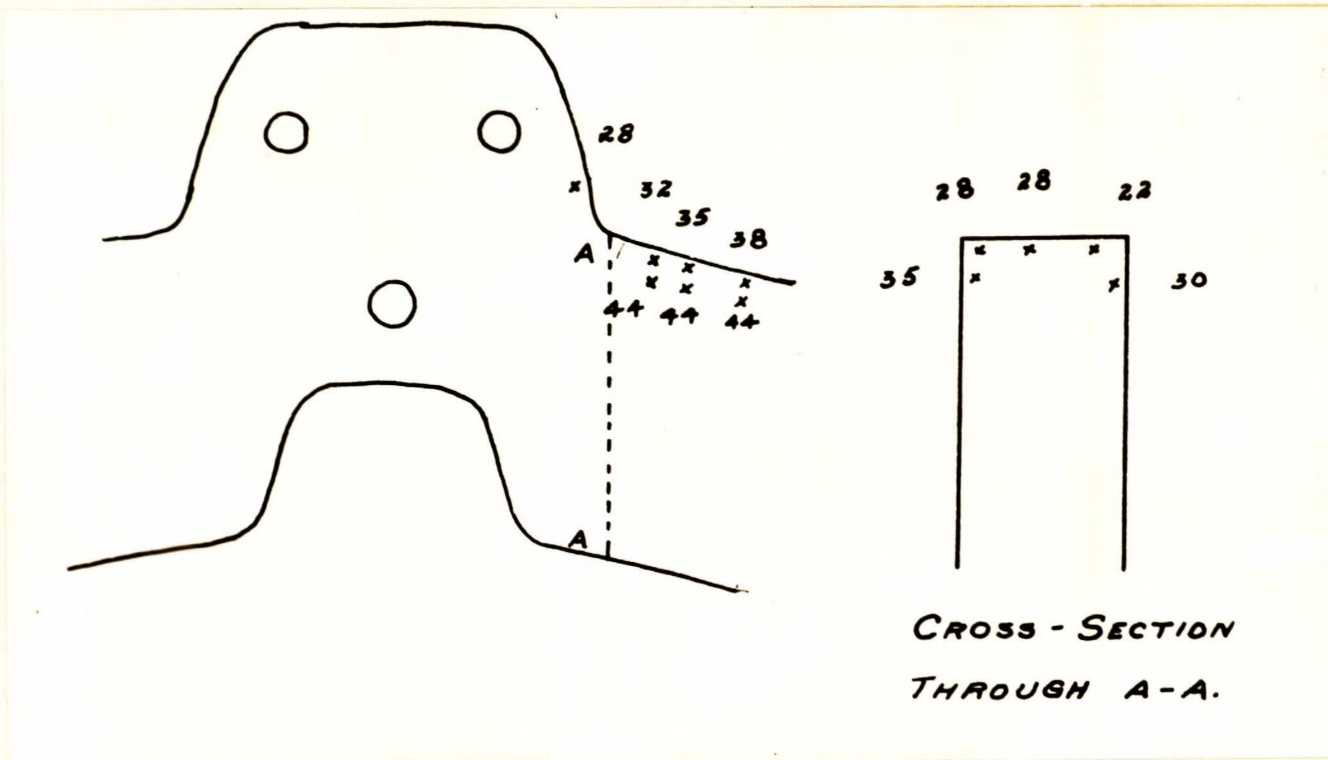
Readings in the cross-section (Figure 1a) were taken with a Vickers machine and converted to Rockwell "C". The low values (22 to 28) were taken approximately 0.040 inch from the bearing surface.

(Continued on next page)

(Hardness Survey, cont'd) -

Figure 1.

Figure 1a.

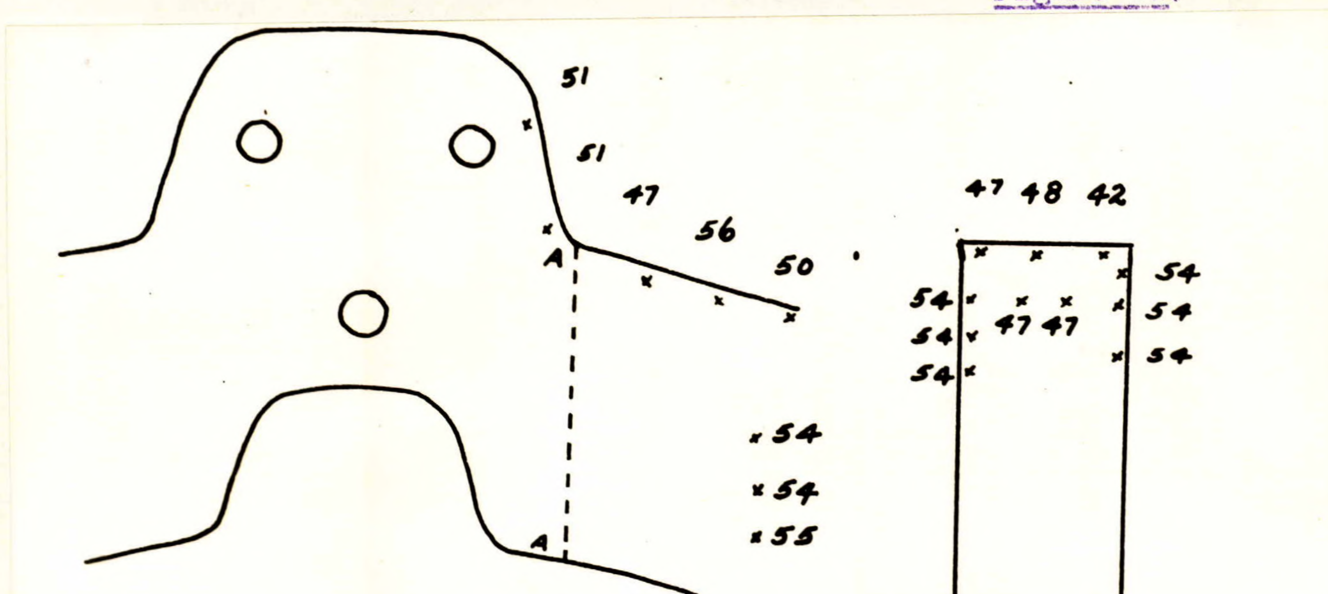


ROCKWELL "C" HARDNESS SURVEY ON SPROCKET "AS RECEIVED".

Hardness surveys on completely hardened sprocket sections substantiate the evidence of lower hardness, in what appears to be a partially decarburized zone at the bearing surface. The location of readings and the hardness values obtained on the reheat treated sample are shown in Figures 2 and 2a.

Figure 2.

Figure 2a.



ROCKWELL "C" HARDNESS SURVEY ON SPROCKET AFTER REHEAT TREATMENT.

(Hardness Survey, cont'd) -

These tests were repeated in three sections from each sprocket with similar results, the only variable being somewhat lower hardness with different quenching oils (see Table I). On all tests the hardness obtained was higher than as received.

TABLE I.

Quenching Oil		Rockwell "C" Hardness (approx. 1/16 in. from bearing surface)
Gulf Super Quench	-	47-56
Houghton G	-	43-49
Houghton #2	-	48-50
Houghton #3	-	43-49
1-4 Water-Oil emulsion	-	30-40)* 50-54)

* Results were not consistent nor conclusive and it was considered that a recommendation for such a quenching practice would only complicate the problem. However, the matter will be further investigated and if satisfactory results are obtained they will be communicated by letter.

Microscopic Examination:

Transverse sections were cut from both sprockets, polished, and etched with 2 per cent nital. The partially decarburized zone, already indicated by hardness surveys, was visible as a lighter etching area. The depth was measured with a Brinell microscope and found to vary from 0.040 to 0.060 inch

Microscopic examination of these sections further substantiated hardness readings. The microstructure 5/32 inch from the bearing surface of sprockets "as received" contained ferrite, troostite and some martensite (see Figure 3). The same area on reheat-treated sprockets had a microstructure which would be expected to be harder, i.e., be martensite with smaller amounts of troostite and only small particles of ferrite (see Figure 4). At surfaces of the reheat-treated sections other than those which were partially decarburized, the microstructure was largely martensitic (see Figure 5).

(Microscopic Examination, cont'd) -

Figure 3.

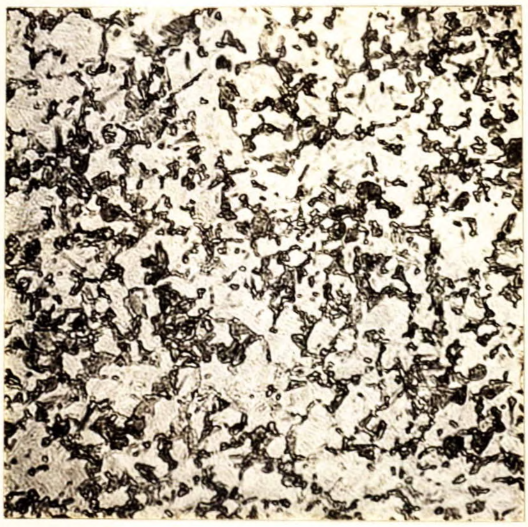
X1000, etched in
2 per cent nital.

INDUCTION HARDENED ZONE
OF SPROCKET AS RECEIVED.

Ferrite, troostite, and martensite.

-

Figure 4.



X500, etched in
2 per cent nital.

SAME ZONE AFTER REHEAT TREATMENT.

Contains more martensite.

-

(Microscopic Examination, cont'd) -

Figure 5.

X500, etched in
2 per cent nital.

REHEAT TREATED SURFACE
FREE FROM DECARBURIZATION.

Largely martensitic.

Discussion:

The chemical composition of the sprockets is in agreement with reported specifications. Magnafluxing did not show any quenching cracks about the drilled holes in the teeth.

Low and inconsistent hardness found in the zone 5/32 inch from the bearing surface is due to:

(1) A quenching practice which is too slow to produce optimum hardness. The source of trouble may be the type of quenching-oil used, lack of agitation in the quenching bath, or delay in quenching the sprocket into the oil.

(2) A partially decarburized zone, 0.040-060 inch in depth, which extends across the bearing surface of the sprocket.

(Continued on next page)

(Discussion, cont'd) -

Reheat-treatment of sprockets at these Laboratories showed that the hardness may be increased by using a more suitable quenching practice. However, it was not found possible to increase the hardness of the partially decarburized zone to within specification limits. The highest hardness obtained on this part of the sprocket was 47-56 Rockwell "C".

It will be noted that the effect of partial decarburization is more pronounced in the improperly quenched sprockets and that with a faster quench the resulting drop in hardness due to decarburization is only 5 to 7 points Rockwell "C". This is quite explainable, since a relatively small decrease in carbon content readily changes the critical cooling rate (i.e., moves the S-curve to the left) of a plain carbon steel and results in greater susceptibility to improper quenching conditions.

In general, it may be stated that faster oil-quenching will result in a surface hardness of 45-50 Rockwell "C" but that it is not considered possible to reach the specified hardness (57 ±3 Rockwell "C") with an oil quench.

If this lot of sprockets is to be reclaimed, there are two alternative methods worthy of consideration:

(1) Lower the hardness specification to 50 ±3 Rockwell "C" and attempt to meet it with a faster quenching practice.

(2) Since the partial decarburization is slight, recarburize the bearing surfaces in a well-controlled carburizing atmosphere, and, with a faster quenching practice, obtain 57 ±3 Rockwell "C".

(Continued on next page)

Conclusions:

1. The low and inconsistent hardness in the induction-hardened zone of the sprockets is due to improper quenching practice and to the occurrence of a partially decarburized zone 0.040-0.060 inch deep on the bearing surface of the sprocket.

(2) Samples of these sprockets were reheat-treated and oil-quenched to give a hardness of Rockwell "C" 47-56 in the zone 5/32 inch from the bearing surface.

oooooooooo
oooooo
oo

IHM:LB.