File.

FILE COPY

OTTAWA July 3rd, 1944.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1674.

Metallurgical Examination of Cam Shaft and Injector Rolls from Cummins Diesel Engine.

==========

(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 July 3rd, 1944.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1674.

Metallurgical Examination of Cam Shaft and Injector Rolls from Cummins Diesel Engine.

Origin of Request and Object of Investigation:

On June 2nd, 1944, under Analysis Requisition No. O.T. 4223, two cam shafts and twelve injector rolls from a Cummins diesel engine supplied by Research Enterprises Limited, Toronto, Ontario, were received from the Inspection Board of United Kingdom and Canada, Ottawa, Ontario, for examination.

The accompanying request letter, dated June 1st, 1944, File No. 12/4/20, stated that the cam shafts had failed after a relatively small number of operating hours. A metallurgical examination was requested for both cam shafts and rollers, to determine the cause of failure. It was pointed

(Origin of Request and Object of Investigation, cont'd) -

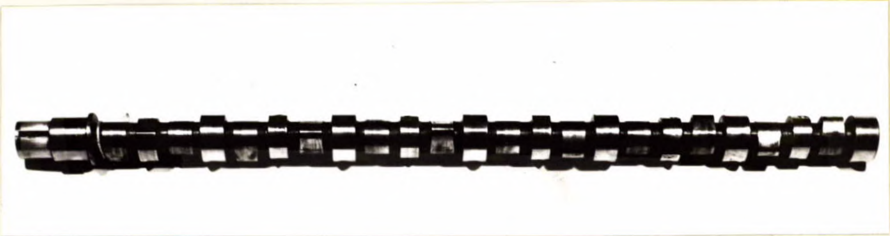
out that there were areas (see Figure 3) in which the case had broken away from the core. The following tests were desired:

Complete chemical analysis of the steel.
Surface hardness of the material.
Measurement of the case depth.
Micrographic examination of the structure of the core and case.

It was requested that the cam shafts and rollers be returned after the examination.

As the two cam shafts are considered identical, for the purpose of economy only one was sectioned for examination in this investigation. The two injector rolls used were representative of the twelve received. (See Figures 1 and 2).

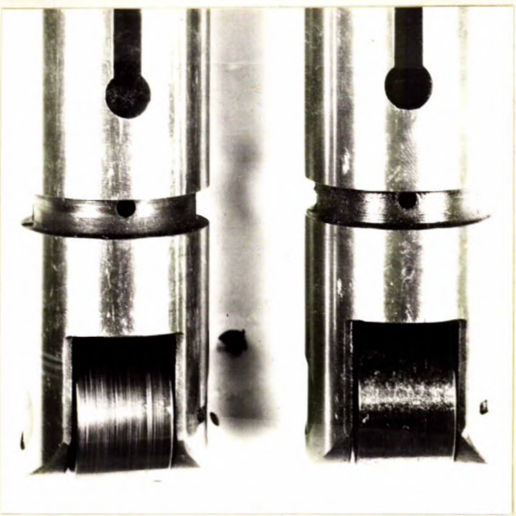
Figure 1.



GENERAL VIEW OF CAM SHAFT.
(Approximately 1/8 actual size).

-

Figure 2.



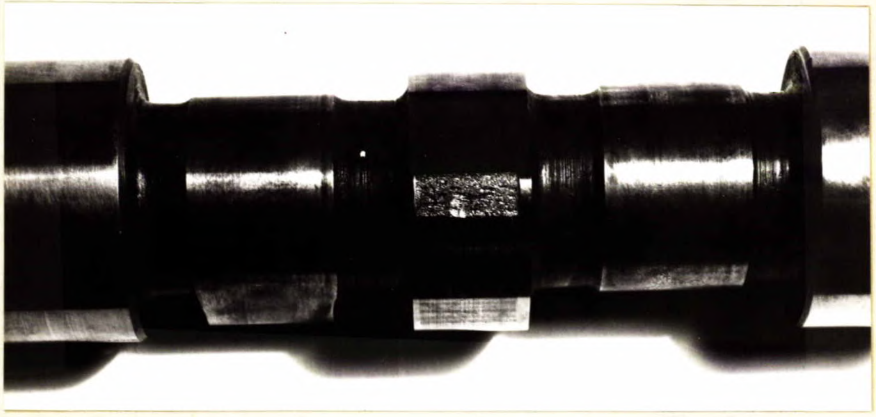
INJECTOR ROLLS FROM DIESEL ENGINE.
(Approximately 3/4 actual size).

Note scored roller on right.

-

(Origin of Request and Object of Investigation, cont'd) -

Figure 3.



CAM SHAFT.

(Approximately 8/10 full size).

Note broken case at centre.

—

Chemical Analysis:

Chemical analyses of both cam shaft and injector rolls were made. The results are as follows:

	Per cent	
	Cam Shaft	Injector Rolls
Carbon	0.18	1.01
Manganese	0.78	0.32
Silicon	0.26	0.32
Sulphur	0.028	0.009
Phosphorus	0.011	0.015
Nickel	N.D.	Trace.
Chromium	N.D.	1.15
Molybdenum	Trace.	0.24
Vanadium	Nil.	Nil.

Hardness Test:

The average surface hardness of the cam shaft was found to range from 57 to 60 Rockwell 'C'.

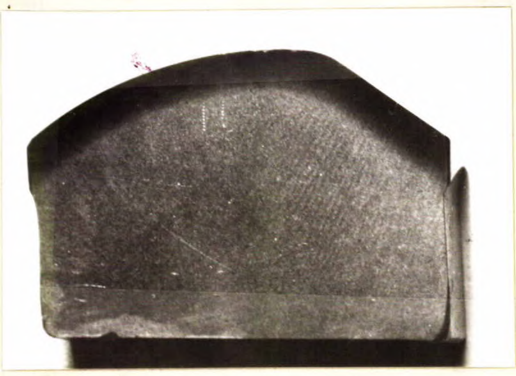
The surface and body hardnesses of the injector rolls were found to average approximately 62 Rockwell 'C'.

Measurement of Case Depth:

A section (Figure 4) was cut from the cam shaft, (Measurement of Case Depth, cont'd) -

polished, etched in nital, and examined for case depth. The case depth measured approximately 0.08 inch.

Figure 4.



X2, nital etch.

SECTION FROM CAM SHAFT,
SHOWING DEPTH OF CASE.

Microscopic Examination:

Sections were cut from a cam shaft and an injector roll, and photomicrographs were taken. Figure 5 shows the microstructure of the camshaft core, etched in nital, at a magnification of X250. Figures 6 and 7 show the microstructure of the camshaft case at magnifications of X250 and X1000 respectively, both etched in nital.

Figures 8, 9 and 10 are microstructures of sections taken from one of the injector rolls, at magnifications of X1000, X2000, and X1000 respectively.

Figures 8 and 9 are the microstructures obtained by etching in nital, whereas Figure 10 shows the carbides against an unetched background.

(Figures 5 to 10 fol-)
(low on Pages 5 and 6.)

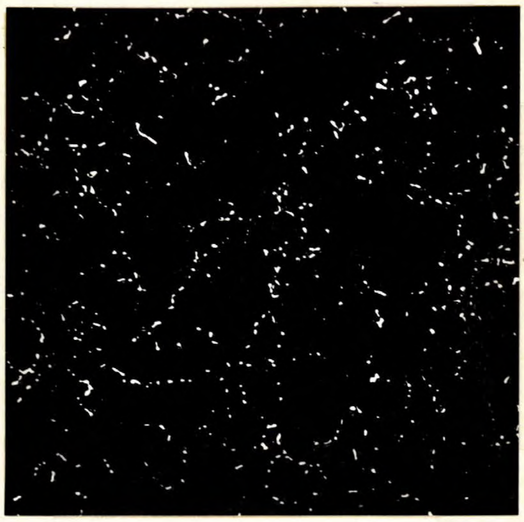
(Microscopic Examination, cont'd) -

Figure 5.

X250, nital etch.

MICROSTRUCTURE OF
CORE OF CAM SHAFT

Figure 6.



X250, nital etch.

MICROSTRUCTURE OF
CAMSHAFT CASE.

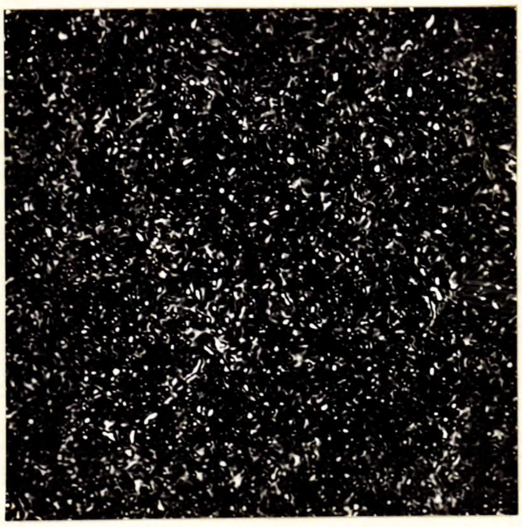
(Note carbides).

Figure 7.

X1000, nital etch.

SHOWING EXCESS CARBIDES
IN CAMSHAFT CASE.

Figure 8.



X1000, nital etch.

MICROSTRUCTURE OF
INJECTOR ROLLS.

-

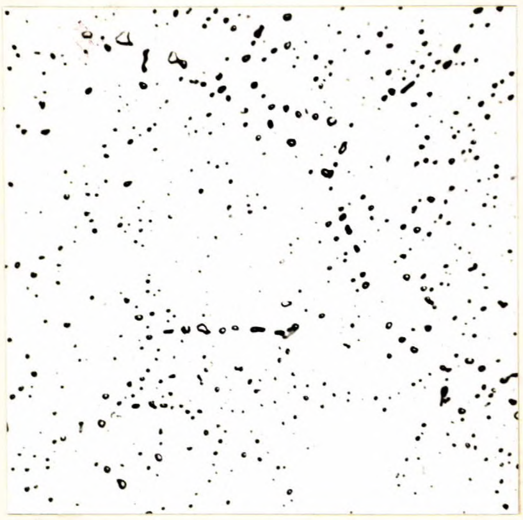
Figure 9.

X2000, nital etch.

MICROSTRUCTURE OF
INJECTOR ROLLS.

-

Figure 10.



X1000, unetched.

SHOWING DISPOSITION OF
IRON-CHROMIUM CARBIDES
IN ROLLS.

-

Discussion of Results; Conclusions:

The chemical analysis shows the cam shaft steel to be SAE 1020 carburizing steel. The injector roll steel is SAE 52100 with an addition of molybdenum. This latter steel is the type most commonly used for ball bearings and roller bearings.

The depth of the case, 0.08 inch, may be considered satisfactory, since the minimum case depth specified for cam shafts is 0.06 inch. The depth of case would indicate that the cam shaft probably has been carburized by the "pack carburizing" method.

The microstructure of the core consists of fine pearlite and ferrite, whereas that of the case is martensite and coarse carbides. Hence it may be concluded that the cam shaft was cooled fairly slowly from the carburizing temperature, probably by removing the boxes from the furnace and permitting the shafts to cool to room temperature in the carburizing boxes. The shafts were next heated to above the critical range of the case and then quenched, resulting in a case the average hardness of which is 59 Rockwell 'C'.

The presence of the large quantities of coarse carbides would indicate that the carbon content of the case is considerably above the eutectoid proportion. This is undoubtedly responsible for the failure of the case. The excess carbon has resulted from the use of a carburizer which is too highly energized.

However, it is possible to eliminate the deleterious effect of the too severe carburization by subjecting the steel to a diffusion treatment after carburizing. The diffusion treatment should be sufficiently long to lower the carbon content of the case approximately to the eutectoid composition.

The fatigue strength of the shaft may be considerably

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

improved by subjecting the part to a shot-peening operation after grinding.

The microstructure of the injector rolls, shown in Figures 8, 9 and 10, i.e., martensite and finely distributed iron-chromium carbides, is normal for a steel of this composition, the distribution of the carbides being very satisfactory. Therefore, it may be concluded that the slight spalling in some of the rolls is due to the irregular wear of the broken portions of the cam shaft on the surface of the rolls.

Recommendations:

1. It is recommended that the cam shafts be given a carburizing treatment which would result in a case whose carbon content is not greater than the eutectoid proportion. This may be accomplished by packing in a carburizer containing less energizer than that in use at present.

2. It is recommended that cam shafts which have thick cases, and particularly those whose cases contain large amounts of free carbides, be subjected to a diffusion treatment after carburizing and before hardening. This may be accomplished by heating in a furnace for two hours under a neutral atmosphere at the carburizing temperature, or by packing the shafts in old, used carburizer and heating for the same period of time. The parts are then cooled in air, and this is followed by the regular hardening operation.

It is suggested that consideration be given to the shotblasting of the shafts after machining, in order to increase their fatigue strength.

ooooooooooo
ooooo
o

AF:LB.