BUREAU OF MINES
DIVISION OF METALLIC MINERALS

ORE DRESSING AND
METALLURGICAL LABORATORIES

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
MINES AND GEOLOGY BRANCH

O T T A W A June 20th, 1942.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1244.

Investigation into Cause of Failure of Pinion and Shaft from 4.5/5.5 Carriage.

Origin of Material and Object of Investigation:

On June 1st, 1942, Mr. M. W. Hollands, of the Inspection Board of the United Kingdom and Canada, 58 Lyon Street, Ottawa, Ontario, submitted a broken pinion and shaft which failed during firing proof on a 4.5/5.5 gun carriage at Valcartier, Quebec. It was requested that the cause of the defect should be investigated. This work is covered by Analysis Requisition No. O.T. 3017 and by Mr. Holland's letter

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

of May 30th, 1942, File No. 7/4/22.

The following is an excerpt from Mr. Holland's letter, containing information pertinent to this investigation:

"Pertinent information regarding this part which may be useful to you in your investigation is as follows:

(a) Part No. is MM271.

(b) Part is specified from three per cent nickel steel, to Specification BSS-5005/401.

(c) The piece failed during actual firing.

In the operation of this pinion and shaft no direct impact load is placed on it inasmuch as it is a part of the hand operated mechanism of the elevating gear--the pinion drives on a 40:1 ratio. No load whatsoever was on this part at the actual time of firing and the failure was due entirely to the general recoil shock in the equipment."

Visual and Macroscopic Examination:

Figure 1 is a photograph of the broken parts of the pinion and shaft, showing the location of the failure.

Figure 2 is a photograph of the fractured surface.

The pinion and shaft was then sectioned and the cross-section was macro-etched in 38% HCl, 12% H_2SO_4. The resulting structure is shown in Figure 3.

Chemical Analysis:

The chemical analysis obtained is compared with the specified analysis in Table I.

(Continued on next page)

(Chemical Analysis, cont'd) -

Table I. - Chemical Analysis.

	Specified BSS-5005/401 - Per cent -	Obtained
Carbon	0.25 - 0.35	0.32
Manganese	0.35 - 0.75	0.61
Silicon	0.3 max.	0.06
Sulphur	0.05 max.	0.022
Phosphorus	0.05 max.	0.030
Nickel	2.75 - 3.5	3.35
Chromium	0.3 max.	Trace

Physical Tests:

Izod impact bars were obtained from the gear teeth. A tensile test bar 0.282" in diameter was obtained from the body of the shaft. The results obtained from these tests are compared with BSS-5005/401 in Table II.

Table II. - Physical Properties.

	BSS-5005/401	Obtained
Ultimate tensile, p.s.i.	100,800	120,000
Yield strength, p.s.i.	71,680	108,000
Elongation, per cent	22	28
Reduction in area, per cent	50	66.3
Izod impact, foot pounds	40 min.	72

Microscopic Examination:

Figure 4 is a photomicrograph, at a magnification of 500 diameters, showing the structure of the steel present in this pinion and shaft. The etchant used was 4 per cent picral.

Discussion of Results:

Physical and chemical tests showed the steel to be of a good quality, in compliance with Specification BSS-5005/401. The photomicrograph, Figure 4, reveals a fine structure that would indicate that the heat treating practice was good.

(Discussion of Results, cont'd) -

Microscopic examination before etching showed no undue amount of inclusions.

The appearance of the fracture (Figure 2) is characteristic of a failure due to fatigue. There is every indication that, in machining, no effort was made to avoid a sharp corner where the diameter was reduced to the keyed portion of the shaft. Any sharp change in dimension or direction gives rise to a high concentration of stresses. Such stresses may be great enough to cause failure of a part even though it be properly designed and the material be of good quality.

Conclusion:

The failure of the pinion and shaft submitted for examination is a characteristic fatigue failure.

There are indications that the fatigue limit of the steel was exceeded at the location of this failure owing to a concentration of stresses brought about by an exceedingly sharp change in shape of the part.

The material, from a metallurgical aspect, is in compliance with BSS-5005/401.

Recommendations:

It is recommended that, wherever possible, all shapes to be machined should be so designed that it is possible to machine all corners so as to leave a slight fillet. Even a radius of as little as 0.05" in corners is helpful in avoiding a concentration of stresses great enough to cause fatigue failure. This is a factor in the workmanship of any machined shape that cannot be too strongly emphasized if such failures are to be minimized.

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HVK:GHB.

Figure 1.

Photograph, 2/5 actual size, showing broken pinion and shaft, as received.

Figure 2.

Photograph, approximately twice normal size, showing fractured surface.

Figure 3.

Photograph of macro-etched section,
$\frac{1}{2}$ actual size,
showing forging lines.

Figure 4.

Photomicrograph, X500,
picral etch.

HVX:GHB.