Title Copy.

FILE COPY

O T T A W A March 27th, 1942.

# R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1191.

Examination of a Steel Bar which Failed by Fatigue.

(Copy No. 10.)

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     March 27th, 1942.

# REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1191.

## Examination of a Steel Bar which Failed by Fatigue.

==========

### Source of Material and Object of Investigation:

On March 15th, 1942, Lieut. Comm. C. E. Olive, of the Department of National Defence (Naval Services), Ottawa, Ontario, submitted for examination a portion of a steel bar which had failed in service. It was stated that the bar was from a special mechanism used by the Navy. The part consisted of two 8-foot lengths of $1\frac{1}{4}$" O.D. "merchant iron" bars, separated at each end by a metal plate and bolted together with a rubber-lined split steel collar. The bars of this device

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

are in contact with sea water and are said to fail after 55 hours' service, while the bolts last only 35 hours.

Request was made for an examination of the failed bar and also for suggestions as to the best means of overcoming or minimizing these failures.

The selection of "merchant iron" bars was due to their availability in naval stores. The rust and scale was left on the bars and as a protection against corrosion they were covered with grease.

Macro-Examination:

The outside diameter was 1-3/8" and there was some rust and scale on the outer surface. The fracture shown in Figure 1 is a typical fatigue fracture.

Microscopic Examination:

A cross-section of the steel through the fracture was given a metallographic polish and examined under the microscope. Figure 2 is a photomicrograph at X100 magnification of the unetched material and shows corrosion fatigue cracks radiating from the outer surface towards the centre of the bar.

Figure 3 shows the structure of the steel (at X100 magnification) after an etch in a solution of 2 per cent nitric acid in alcohol. The light areas within the grains are ferrite and the dark etching material is pearlite (the iron-iron carbide constituent). There are also some manganese sulphide inclusions present.

-

Discussion of Results:

The presence of an oxide scale on the bar does not offer any protection from corrosion as the oxide is porous. When further oxidation takes place, minute pits and grooves are formed which act as "stress raisers". Under these conditions the fatigue strength of the steel is lowered as much as 12 per cent. However, it has been shown that if the bar is subjected to corrosion and repeated stresses simultaneously the fatigue limit is reduced as much as 65 per cent. Failures of this nature are known as "corrosion fatigue" failures. Figure 2 shows the progress of one of these corrosion fatigue cracks which accelerated the failure of this bar.

The material was a low-carbon steel with a fairly high inclusion content. The Brinell hardness of the steel, 107, indicates that its endurance limit is approximately 25,000 p.s.i. The observed inclusion content in Figure 3 would lower this value somewhat.

The clamps used on each end of these bars may possibly lower the fatigue strength due to the unequal distribution of local stresses. Overstraining of these bolts above their elastic limit will damage the bolts and lower their fatigue strength.

In order to minimize the above difficulties, one can replace the "merchant iron" with stainless steel or apply suitable protective coatings.

---

Conclusions and Remarks:

This investigation has shown that this steel failed by corrosion fatigue.

Recommendations which might increase the present

(Conclusions and Remarks, cont'd) -

life of the steel used are either:

(1) Machining the bars to obtain a smooth surface, or

(2) By shot blasting,

with the latter possibly being more easily accomplished.

Whether or not a smooth surface is obtained on the bars they should be given a protective coating.

The following methods are suggested:

1. Metal Coating; zinc or cadmium plate; zinc hot dip galvanizing.

2. Chemical Coatings; perkerizing.

3. Metal Spray Coatings; zinc or aluminium.

4. Grease on all coatings or on unprotected metal.

It may be possible to increase the present service life of this apparatus by the use of a better quality steel, such as plain carbon or medium alloy steel.

The bolts require special attention as they are highly susceptible to notch sensitivity. In addition, they can be easily strained beyond their elastic limit during assembly.

It is recommended that the bolts also be given a metallic protective coating.

oooooooooooo
oooooo
oo

NBB:GHB.

Figure 1.

FATIGUE FRACTURE

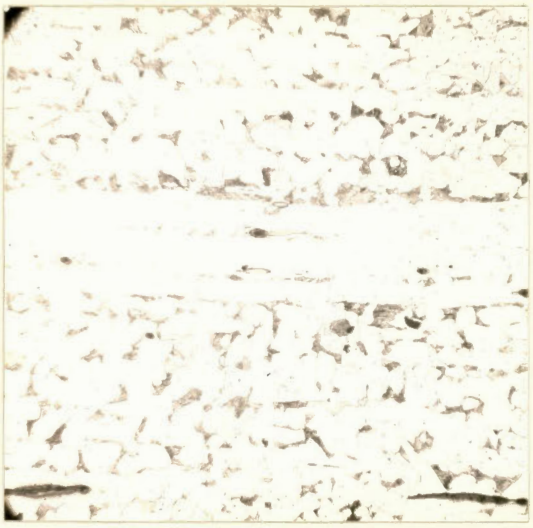
(Approximately to size).

Figure 2.

X100, unetched.

CORROSION FATIGUE CRACK.

Figure 3.



X100, etched in 2 per cent nital.

GRAIN STRUCTURE OF STEEL.

NBB:GHB.