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R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1392.

Examination of Ship's Plate Which Cracked During Riveting.

(Copy No. 13.)

BUREAU OF MINES
DIVISION OF METALLIC MINERALS

ORE DRESSING AND
METALLURGICAL LABORATORIES

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
MINES AND GEOLOGY BRANCH

OTTAWA April 26th, 1943.

REPORT

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Origin of Samples:

The following extract from a letter received on April 3rd, 1943 (File No. NS 29-59-4/1 FD2115), from A/Lt. Cdr. J. R. Millard, Senior Technician, Technical Division, Department of National Defence, Naval Service, Ottawa, Ontario, explains the origin of the samples investigated:

> "There have been forwarded to your laboratory sample Mild Steel Coupons which were cut from defective ship's Plate, D.O.S.C.O. Heat No. C565-072-2, and which were incorporated in plates marked O.F.B.-6 and O.F.B.-7.
>
> The plates showed no visible signs of fracture until riveting had commenced. The main crack in O.F.B.-7 extended 3'0" in length, and in O.F.B.-6 extended 1'6" in length. The fractures occurred in severe weather, the temperature being in the neighbourhood of -20° F.
>
> All sample coupons forwarded to you are marked with plate number as well as coupon number, with the exception of one, which is marked 'XX'. 'XX' is a plate which exhibited no signs of failure, and was forwarded for purposes of comparison."

Object of Study:

It was requested that a report on possible reasons for failure be prepared.

Chemical Analysis:

Drillings from two of the plates were chemically analysed, with the following results:

		Plate No. XX	Plate No. O.F.B.-7-A3
		-Per cent -	
Carbon	-	0.34	0.33
Manganese	-	0.52	0.52
Silicon	-	Trace.	Trace.
Phosphorus	-	0.020	0.037
Sulphur	-	0.035	0.055
Nickel	-	0.027	0.023
Chromium	-	Trace.	Trace.
Aluminium	-	0.008	0.008

Physical Examination:

The hardness of the plates was determined by the Vickers method. These readings, taken through the thickness of the plates, showed that the Plate O.F.B.-6 varied in hardness slightly from face to face, Plate O.F.B.-7 was uniform, and Plate XX had a centre region harder than the material near the two faces.

Plate		V.H.N.
O.F.B.-6	-	140 to 153.
O.F.B.-7	-	157
XX	-	158 edges, 187 centre.

Material from Plates O.F.B.-6 and O.F.B.-7 (which were respectively 0.320 and 0.332 inch thick) passed a bend test conducted in accordance with Clause 4, Page 12, of "Specification for a Destroyer 'Tribal Class'." In this case a $1\frac{1}{2}$-inch strip from each plate was bent double, in an Amsler Universal testing machine, over an 0.958-inch-diameter bar.

Since the plate was not thick enough to permit removal of full-sized Charpy-type bars, substandard specimens

(Physical Examination, cont'd) -

10 mm. wide and 0.300 inch thick, with V notches 0.060 inch deep parallel to the 10 mm. face, were machined. In order to get some information on how values obtained with similar bars compared with values obtained from a standard Charpy bar (10 mm. square with notch 2 mm. deep), a bar of each type was machined from a mild steel rod containing 0.27 per cent carbon, 0.71 per cent manganese and 0.25 per cent silicon. These specimens gave the following values on test:

		Breaking Load, Foot Pounds
Substandard Charpy	-	18.5
Standard Charpy	-	23

The following results were obtained on substandard specimens machined along and across the direction of rolling from Plate XX and the A-3 section of Plate O.F.B.-7. In all cold-temperature tests the bars were held at temperature for 30 minutes:

		Breaking Load, Foot Pounds			
		Plate No. XX		Plate No. O.F.B.-7.	
Temperature at which tested		Along Rolling	Across Rolling	Along Rolling	Across Rolling
Room	-	15	15	21	13
30° Fahrenheit	-	4	6	15.5	10
-5° "	-	2	2	4	4
-20° "	-		1	4	3

Bars 10 mm. wide and 20 mm. wide, 0.300 inch thick, with notches 0.060 inch deep parallel to the 0.300 inch face, were machined lengthwise from each plate and broken at room temperature.

(Continued on next page)

(Physical Examination, cont'd) -

	Breaking Load, Foot Pounds Plate No. XX	Plate No. O.F.B.-7
10 mm. wide -	12	21
20 mm. wide -	140	144

In all of the above tests the bars were rested on supports 50 mm. apart (notch facing away from direction of impact) and broken with a blow from a hammer having a V head.

Tests for Ageing Susceptibility:

Samples from Plates XX and O.F.B.-7 were water-quenched from 1255° F. The following hardness results were obtained from these samples:

	Plate No. XX	Plate No. O.F.B.-7
	- Vickers Hardness -	
As quenched -	175 to 192	175
After air ageing for 12 days -	210 to 223	198

Microstructure:

Specimens for the microscope were prepared from Plate XX and from Plate O.F.B.-7. Both plates had a normalized structure that was probably obtained by cooling the plates in air from the hot-rolling operation.

Both plates had ferrite banding present in similar amounts.

Both of Plates XX and O.F.B.-7 were seen to have a grain size of predominantly 1, with some grains 2 to 3 after a McQuaid-Ehn test (pack-carburized 8 hours at 1700° F.; slow-cool).

Discussion of Results:

Chemical analysis results of failed and satisfactory plates showed that apparently there were no differences in composition that could account for variations in service performance.

The bend test showed that the ductility of the two plates which cracked in riveting conformed to specification standards.

Impact tests over a range of temperatures indicated a very marked drop in impact strength at cold or sub-zero temperatures. The low-temperature impact strength of the plate which cracked, however, was slightly better than that of the one which performed satisfactorily (Plate XX). The lower impact strength of Plate XX was probably caused by the comparatively hard zone in the centre of its cross-section.

Tests with single and double width Charpy-type bars indicate that the steel in both the cracked and the satisfactory plates was not notch-sensitive.

The rise in hardness after the 1255° F. quench showed that both plates were susceptible to quench ageing and, by inference, to strain ageing. The chemical contents of the two plates, however, were so similar that strain-ageing propensities of good and bad plates would be expected to be of the same order. For this reason and because of other outstanding trends apparent, the possibility that ageing was a large factor in the failure of Plates O.F.B.-6 and O.F.B.-7 is discounted.

Microscopic examination revealed no great difference between Plate XX and Plate O.F.B.-7. Both plates were rather coarse-grained.

CONCLUSIONS:

It is felt that the low cold-temperature impact strength of Plate O.F.B.-7 caused it to fail when it was riveted at minus 20° F. The fact that Plate XX did not fail would seem to indicate that it was riveted on a warmer day or that the riveting operation was not so severe.

An earlier report (Report of Investigation No. 1373, March 22nd, 1943) covered the examination of a sample of ship's plate which was reported to have cracked during the punching operation. The conclusion in that report was that the punching operation which caused failure must have been unusually severe. It has since been stated that the plate actually had cracked during riveting. In that case, since riveting may have been done outdoors in severe weather, failure also may have resulted because the cold steel lacked sufficient strength to withstand impact stresses imposed on riveting.

Plain carbon steels generally have poor low-temperature impact properties, and allowances must be made for this in fabrication. Low-temperature impact properties of these steels, however, can be improved by controlling steel deoxidation practice so that a fine-grained steel is produced.

Should improved impact properties at low temperature be desired in these steels, a fine-grain-size requirement should be introduced into the specification.

The trouble might be overcome more simply by taking care to avoid fabrication at low temperature.

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