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OTTAWA April 21st, 1944.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1629.

Examination of Welded Shaft and Coupling Plate.

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(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

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Origin of Material:

On March 17th, 1944, Mr. R. G. Hillier, Chief Engineer, Ontario Steel Products Company Limited, Gananoque, Ontario, submitted a welded shaft and coupling plate assembly for examination. In his covering letter Mr. Hillier gave the following information:

The steels used are "close" to SAE 3140 and the shaft is welded into the coupling plate by the arc welding process. The sequence of operations is stated to be: preheat to 500° F. with an acetylene torch, weld with Lincoln "Shield-Arc 100" electrode, immediately remove to 400° F. paint oven and cool there for an hour, and finally, remove and cool in air.

No information is given as to the type of service required of the assembly.

Object of Investigation:

1. To examine the welding of the assembly to determine its quality.

2. To present recommendations designed to improve the welding technique, should this prove to be desirable.

Procedure:

1. The assembly was subjected to a careful visual examination. Figures 1 and 2 show the assembly in the "as received" condition, and the location of the welds.

2. Chemical analysis samples were machined from the shaft and coupling plates. In the following table are listed the results of these analyses together with the SAE 3140 specification, for the purpose of comparison:

		Shaft Material	Coupling Plate Material	SAE 3140
			- Per cent -	
Carbon	-	0.35	0.35	0.38-0.43
Phosphorus	-	0.014	0.026	0.04 max.
Sulphur	-	0.017	0.028	0.04 max.
Manganese	-	0.66	0.64	0.60-0.80
Silicon	-	0.20	0.20	0.20-0.35
Chromium	-	0.63	0.56	0.55-0.75
Nickel	-	None.	None	1.10-1.40
Molybdenum	-	Trace.	Trace.	None.

3. The assembly was sectioned through the centre and a longitudinal section was removed. Figure 3 shows the section after polishing and etching.

4. The welds were removed from the above section and subjected to a metallographic examination. Figure 4 shows the normal structure of the shaft material; Figure 5, the typical structure of the heat-affected zones of the shaft and coupling plate material; Figure 6, the normal structure of the coupling plate material; Figure 7, the transition zone structure typical of the coupling plate material and shaft material; and Figure 8, the structure typical of the weld metal.

5. Hardness tests, using a Vickers machine with a

(Procedure, cont'd) -

10-kilogram load, were made on the above sections. The following table lists the results obtained (the figures quoted are the averages of four readings in each area):

Area Tested	Vickers Hardness Number
Normal shaft material - - - - -	240
Normal coupling plate material - - -	202
Transition zone, shaft material - - -	249
Transition zone, coupling plate material -	229
Heat-affected zone, shaft material - -	289
" " ", coupling plate material -	247

Weld metal hardness ranges from 240 to 292, depending on whether the area tested is in a single- or double-pass weld.

Discussion:

A visual examination of the assembly reveals some undercutting on the shaft material and some weld metal porosity. Both of these defects are avoidable and should be eliminated.

The chemical analysis of the two materials indicates that they are of almost identical composition. Their analyses differ from that of SAE 3140 in that the carbon content is low and neither steel contains any nickel. This would somewhat reduce the hardenability of these steels below that of SAE 3140 but would improve the weldability. The nickel and molybdenum detected in the analysis are probably residuals from alloy scrap used in the steel making. In summary, it should be pointed out that the composition of these steels is puzzling in that they do not conform to any standard analysis listed in these Laboratories. The composition most closely approaches that of SAE 5140 but the carbon, manganese and chromium contents are all slightly low to fit into this composition.

A longitudinal section of the assembly shows good welding, without any serious flaws. An examination of Figure 3 will reveal that the upper left hand weld has been made, at

(Discussion, cont'd) -

least in part, by two passes. It will be noted, also, that the amount of weld metal deposited on both top and bottom welds on the left hand side is considerably greater than on the welds on the right hand side. This has apparently been necessary as a result of variation in fit-up. It would also appear that the coupling material has been veed out to permit greater penetration.

A metallographic examination of the welds and the welding zones reveals nothing unusual. The thermal cycle of welding has, in the transition zone, produced a spheroidizing action on the pearlite areas, whereas in the heat-affected zone there has been produced a structure consisting of slight amounts of ferrite but mostly bainite and/or other higher transformation products. The normal structures of the shaft and coupling plate are considerably different. That of the coupling plate material is a normalized structure with considerable precipitated ferrite On the other hand, the structure of the shaft material is sorbite and the grain size is comparatively coarse. Of these two structures the latter would be better from the point of view of machinability, and this may be a factor of some importance in this assembly. The weld metal structure is normal, pearlite in a matrix of ferrite.

It is apparent that the preheating has been effective in that the formation of martensite in the heat-affected zone has been avoided. However, the method of preheating (oxy-acetylene torch) is open to criticism in that there is too great a possibility of variations in the preheating temperature obtained from welder to welder and from day to day. It is presumed that the post-welding treatment at 400° F. for one hour is designed to retard the cooling rate and is not intended to provide any stress relief. If this is the case, this

(Discussion, cont'd) -

examination shows that the desired affect is being secured. It should be borne in mind that stress relief requires temperatures in the range of 900-1150° F. in order to be effective.

The hardness values obtained confirm that the formation of martensite has been avoided in those areas close to the welds. The hardness of the two materials is consistent with their analysis and heat treatment. The welding electrode used should prove to be completely satisfactory. The physical properties that it is stated to develop are adequate for the job.

Since nothing is known as to the type of service expected of this assembly it is difficult to estimate to what degree the welded assembly may prove to be satisfactory. Since a torque test was carried out this implies shearing stresses on the two welds. From a point of view of developing adequate strength, the present joint design should be quite adequate to withstand stresses of this type. If, on the other hand, rapid alternations of stresses are encountered the unfused areas between the shaft and coupling materials may act as stress-raisers and lead to premature service failure. In the event that this type of service conditions may be encountered it would be advisable to vee out the coupling material to permit of complete penetration between the two welds.

CONCLUSIONS:

1. Undercutting and porosity were found in both welds. Both are avoidable and every effort should be made to eliminate them.

2. The composition of the two materials are nearly identical. They most closely approach that of SAE 5140 steel.

3. Variations in amounts of weld metal deposited

(Conclusions, cont'd) -

indicate faulty fit-up.

4. Some veeing of the joint has been employed to permit greater penetration.

5. The preheating and post-heating have apparently been devised to prevent the formation of martensite adjacent to the weld. This objective has been accomplished. The post-welding heat treatment is too low in temperature to provide any stress-relieving effect.

6. The welding electrode used should be quite adequate for this assembly.

7. In the event that rapid alternations of stresses are liable to be encountered in the service life of this part, an alteration of joint design to permit complete penetration would be advisable.

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Figure 1.

Figure 2.

WELDED SHAFT AND COUPLING PLATE
ASSEMBLY AS RECEIVED.

Note, in Figure 2, that weld metal is irregular and there is a fairly large arc crater.

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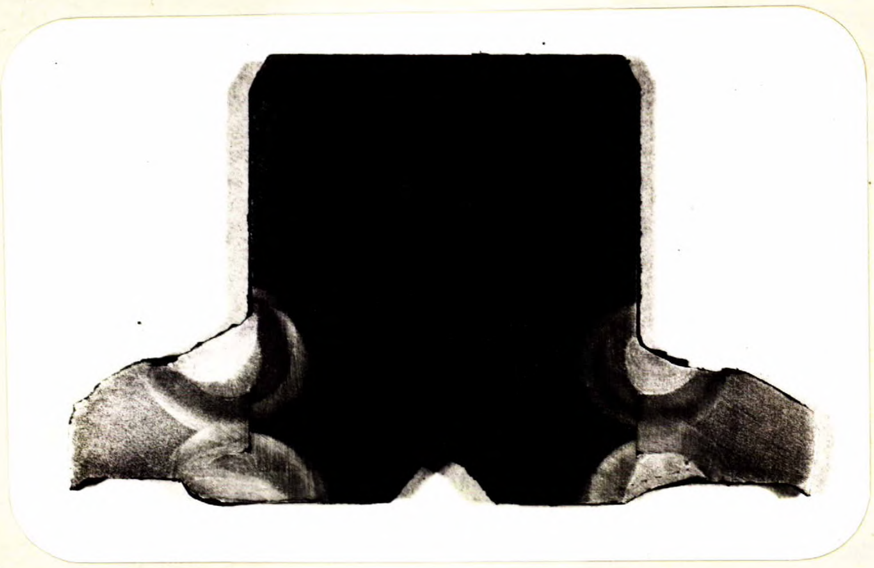
Figure 3.



LONGITUDINAL SECTION OF ASSEMBLY.

Note double pass on upper left hand weld. Note also greater amount of weld metal deposited in both left hand welds.

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Figure 4.

X100, etched in 4 per cent picral.

NORMAL STRUCTURE OF SHAFT MATERIAL.

Coarse-grained sorbite with ferrite at grain boundaries. Good machinability.

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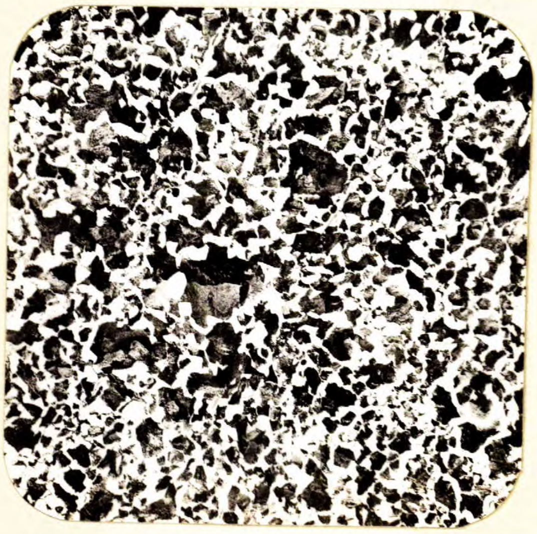
Figure 5.

X100, etched in 4 per cent picral.

TYPICAL STRUCTURE OF HEAT-AFFECTED ZONES.

Some precipitated ferrite - mostly low-carbon bainite and/or upper transformation products.

Figure 6.



X100, etched in 4 per cent picral.

NORMALIZED STRUCTURE OF NORMAL COUPLING MATERIAL.

Pearlite in a matrix of ferrite.

Figure 7.

X100, etched in 4 per cent picral.

TYPICAL STRUCTURE OF TRANSITION ZONE.

Pearlitic areas tending to spheroidize.

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Figure 8.

X100, etched in 4 per cent picral.

STRUCTURE OF WELD METAL.

Dense, fine-grained metal.

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