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METALLURGICAL EXAMINATION OF MITRE GATE LIFTING DEVICES FORGED SOCKETS

by

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METALLURGICAL EXAMINATION OF MITRE GATE LIFTING DEVICES FORGED SOCKETS

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SUMMARY OF RESULTS

An investigation into defects found on the surface of certain forged sockets removed from St. Lawrence Seaway mitre gates indicated that they were caused by the attack of molten zinc at a high temperature. Subsequently, it was found that the desocketing process used to free the wire cable, which was held in the socket by means of zinc, had been carried out in a furnace heated to 870 to 900°C (1600 to 1650°F).

Magnaflux examination revealed the presence of two hair-line cracks in one of five sockets examined. The cause of these cracks could not be determined, but recommendations were made for the examination of other sockets when they are removed for refitting of longer cables. A different technique for desocketing the wire cable was also recommended for the remaining sockets.

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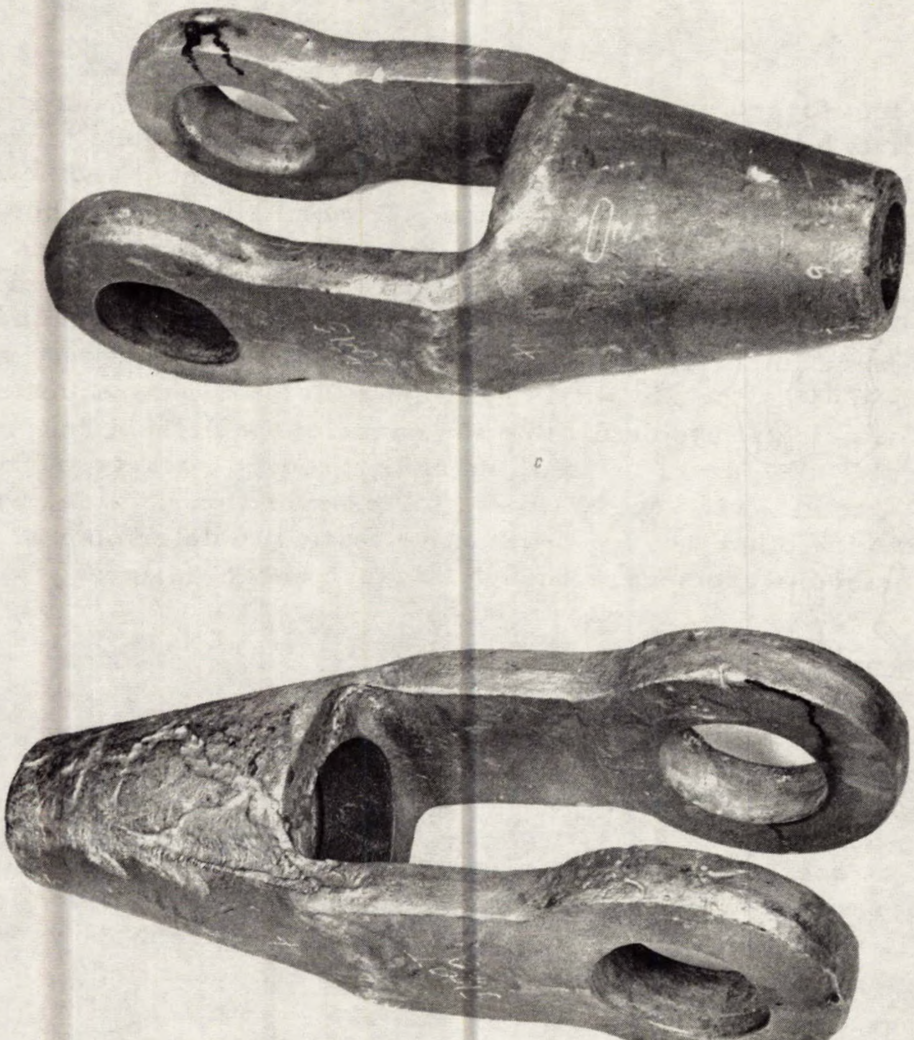
INTRODUCTION

Eight forged sockets were received from the St. Lawrence Seaway Authority and were removed from service because the attached cables were too short. These sockets were to be desocketed and new, longer cables installed. After desocketting, renormalizing and shot blasting (no details of these operations were available) deep grooves were noticed on three of the sockets, and some smaller defects on another two. Since there were 96 sockets still in service, the reason for and nature of these defects were important. As a result, in a letter dated January 15, 1963,(File 12-77-3-1) the Physical Metallurgy Division was requested to carry out an examination to determine the cause of the defects and to suggest remedial measures. Two of the badly grooved sockets and one with smaller defects were sent to Ottawa for examination. Cables were resocketed into the other two for destructive testing to determine whether or not these defects were severe enough to cause socket failure.

VISUAL OBSERVATIONS

The deep grooves were present on only one side of the sockets. The photographs in Figure 1, show the two sides of the socket identified as "C", and is typical of that found in socket "B". Figure 2 shows socket "A" that contained only a few minor laps, which are identified by arrows.



Mag. Approx. X1/5

Figure 1. Photographs of two sides of socket "C" showing the deep grooves on one side only (bottom photograph). A small magnaflux indication is shown circled in the top photograph, identified by "M".

Mag. Approx. X1/5

Figure 2. Photograph of socket "A" that contained no grooving as in "B" and "C", but which contained several magnaflux indications - three of which are circled in the upper area of this socket, identified by the letter "M". Arrows point out locations of two hairline cracks also found by magnaflux.

NONDESTRUCTIVE TESTING

The three sockets were completely X-rayed to check for internal soundness and defects. This inspection did not reveal evidence of unsoundness or the presence of any defects that were not evident to the eye.

The sockets were then magnafluxed using the wet method and "black" light. This technique did show two hairline cracks at each edge of the parting line on the upper part of the socket above the pinhole in socket "A". The arrows in Figure 2 indicate the location of the two cracks.

CHEMICAL COMPOSITION

Drillings were obtained from each socket and analysed chemically. These analyses are listed below in Table 1.

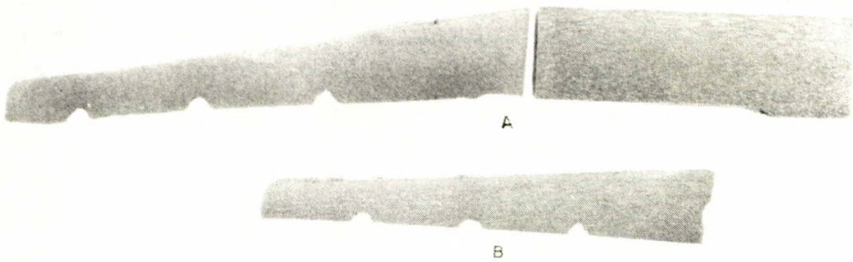
TABLE 1

Chemical Analyses of the Three Sockets

Element	Sockets		
	A	B	C
Per Cent C	0.28	0.32	0.48
" " M	0.47	0.51	0.59
" " Si	0.05	0.05	0.005
" " S	0.036	0.036	0.051
" " P	0.029	0.041	0.023

DEEP ETCH TESTS

There was some question as to whether these sockets were forged or cast. Certain features of the surface indicated they were forged. However, deep etching was carried out on sections cut from sockets "A" and "B". Photographs of these sections after deep etching in 1:1 HCl at 75°C (165°F) are shown below in Figure 3, and verify that the sockets were forged, as evidenced by the flow lines discernible in the sections.



Mag. Approx X1/4

Figure 3. Photographs of sections from sockets "A" and "B" after deep etching, showing the presence of flowlines.

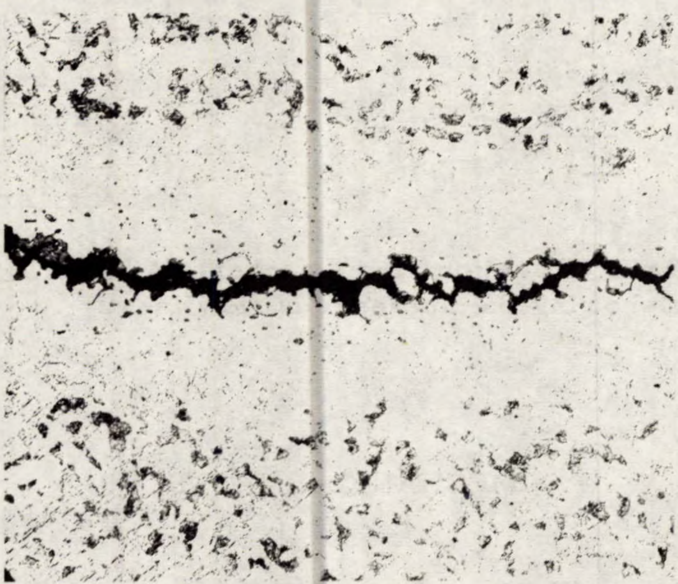
MECHANICAL TESTS

The supplied specification states that the "Rope sockets shall be of the two types shown on the exhibited drawing, forged without welds from carbon steel having an ultimate tensile strength of 65,000 to 75,000 psi". Tensile bars were cut from each socket and tested with the following results.

	Socket		
	A	B	C
UTS (psi)	65,950	67,950	87,800
YS (psi)	39,350	32,500	40,750
Elong (%)	35.5	33.0	24.5
Red. Area (%)	56.1	51.1	35.05

METALLOGRAPHIC EXAMINATION

Several samples were cut from the sockets and suitably prepared for metallographic examination. Figure 4 is a photomicrograph taken of one of the hairline cracks found in socket "A". The area adjacent to the crack had been decarburized and indicates that the crack was present prior to the last high temperature heat treatment that the socket had undergone.



Etched in 2% Nital Mag. X100

Figure 4. Photomicrograph showing one of the hairline cracks in socket "A". Note the decarburized layer adjacent to the crack.

Metallographic examination of samples cut to include the grooves showed patchy areas of galvanized coating despite the fact that these sockets were reported to have been degalvanized, normalized and shot blasted. Probably the most important aspect of this examination, however, was the smooth surface contour of the base of the groove and the nature of the undercutting at the edge of the grooves. This is characteristic of zinc attack and there is little doubt that the final surface of the grooves resulted from zinc attack. It could not be stated, however, that the entire mass of metal removed from the grooves resulted from zinc attack. Certain areas of coating still intact showed an abnormal iron zinc alloy structure believed to have been caused by relatively high temperature exposure.

ADDITIONAL TESTS

Samples were cut from socket "A" and immersed in molten zinc at temperatures of 450°C, 525°C and 600°C (840°F, 975°F and 1110°F) for both 4 and 8 hours. Metal losses of up to 40% were found at 600°C (1110°F), whereas they were only of the order of 3 to 5% at the two lower temperatures.

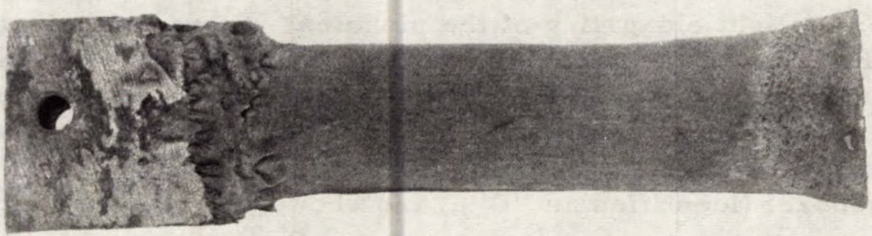
At this time, the two other sockets retained by the St. Lawrence Seaway Authority for mechanical tests were received at the Physical Metallurgy Division. These had been resocketed with cable and the cable pulled to destruction. Magnaflux examination showed no defective areas. There was some slight elongating of the pinholes. Visual examination of one of these sockets showed the grooving, but this time the grooving did not occur all over the bottom surface as before, but only on one arm and part of the body. An undercut, delineating the edge of the grooves, was readily discernible and was indicative of a liquid level line. Figure 5 is a photograph of this socket (identified as "D"), and shows the grooving and limiting line.

Mag. Approx. X1/5

Figure 5. Photograph of socket "D" showing grooving and "liquid level" line (arrows) delineated by the grooves.

With this new evidence, it was postulated that the socket must have been subjected to high temperature heating while in contact with a pool of molten zinc for some period of time. Such conditions could account for the large metal loss.

To verify this, a large sample was cut from socket "A" and about three-quarters of it was immersed in molten zinc at 500°C (930°F), heated to 800°C (1470°F) and held there for 1-1/2 hours. Weight loss measurements showed a 35% loss in this time and a type of attack very similar to that found in the sockets. Figure 6 is a photograph of the test sample.



Mag. Approx. full size

Figure 6. Photograph of test sample after partial immersion in molten zinc at 800°C (1470°F) for 1-1/2 hours. Note smooth attack on body and undercutting at the air-metal interface (actually contained in a bone-ash flux layer to minimize zinc volatilization).

DISCUSSION

The postulation that the grooving was entirely due to zinc attack at a high temperature has been verified. Recent information has been obtained which states that the forgings were desocketed and renormalized in one operation, i.e., the forgings (with the zinc and wire cables still intact) were piled in a normalizing furnace, heated to 870° to 900°C (1600° to 1650°F) held 1 to 1-1/2 hours, and removed and air cooled. Undoubtedly, what occurred was that the zinc melted and collected on the bottom, surrounding three of the eight sockets. The pool of molten zinc attacked these sockets, resulting in the grooves shown in sockets "B", "C", and

"D". The other five sockets must either have been piled on top and so were not in contact with the molten zinc, or the three sockets that were attacked were in a low spot in the furnace. After this treatment, the sockets were air cooled and the ones in contact with the zinc were, in effect, regalvanized as the temperature dropped, thus accounting for the zinc coating remaining on the socket surfaces.

The presence of the hairline crack in socket "A" might possibly be cause for concern. It cannot be stated that these cracks were present in service. All that can be said is that they were present before the final normalizing treatment, which occurred after these sockets were removed from service. It is significant that the cracks were too fine to be revealed by X-ray, but magnaflux did reveal them under "black light". Unfortunately, this technique is not readily performed "in situ", but all sockets should be checked by magnaflux when they are removed for cable replacement.

CONCLUSIONS

1. The grooving occurred when the sockets were heated to 870° to 900°C (1600° to 1650°F) to desocket the cable and to renormalize the forgings. This suggests that there is no reason to suspect the sockets, now in service, of containing similar defects.

2. Two hairline cracks were present in one socket. The cracks were present prior to the renormalizing treatment. They may or may not have been present in service.

RECOMMENDATIONS

It is understood that the remaining 96 sockets are to be removed and longer cables installed. It is suggested that the following desocketing procedure be followed.

Suspend the sockets, pinhole down, from a rack. Place the rack of sockets in a furnace and heat to 425 to 450°C (800 to 840°F). The zinc should drain out and eventually the cable strands will drop out of the socket. This procedure will avoid undue contact of the sockets with the molten zinc. Tests at the Physical Metallurgy Division gave a desocketing time of about 3 hours, starting in a cold furnace.

The sockets should then be pickled to remove any zinc coating remaining, magnafluxed, renormalized (if this is thought to be necessary), shot blasted,and then regalvanized and the new cables socketted into place, in the normal manner.

ACKNOWLEDGMENT

The writer gratefully acknowledges the contribution of Mr. J. J. Sebisty, Senior Scientific Officer, Non-Ferrous Metals Section, of this Division, who carried out the metallographic examinations on the zinc coatings and the metal loss tests.

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