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O T T A W A   February 13, 1945.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1791.

Examination of Welded Disc Wheel Clamping Bolts.

(Copy No. 10.)

Bureau of Mines
Division of Metallic
Minerals
=
Physical Metallurgy
Research Laboratories

DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

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Origin and Description of Material Submitted:

On January 26, 1945, under Analysis Requisition O.T. 4325, the Controller General, Inspection Board of United Kingdom and Canada, Ottawa, Ontario, submitted sections of split disc wheels and broken bolts for examination. This type of wheel is made by stamping two discs from sheet metal and bolting them together. The heads of the bolts are welded to one disc to prevent slippage.

Also submitted was D.M.S. Drawing B 14800, 14801, which gives the specification and dimensions of the bolts. It was noted that the bolt is to have the following composition:

		Per Cent
Carbon	-	0.25-0.30
Sulphur	-	0.04 max.
Phosphorus	-	0.04 max.
Manganese	-	0.40-0.60
Silicon	-	0.30 max.

In addition, the bolt is to be heat-treated to specified

(Origin and Description of Material Submitted, cont'd) -

properties and then zinc-plated.

The material submitted consisted of two sections of unused disc wheel, bolted together to show the method of assembly. Also submitted were four samples of broken bolts and three new bolts. No information was given as to the service life of the broken bolts nor the service life desired.

Object of Investigation:

To establish the probable cause of bolt failure and to ascertain whether welding seriously changes the characteristics of the bolt in a manner which would adversely influence serviceability.

Procedure:

(1) A section of the disc wheel was photographed as received. Figure 1 shows the photograph. Figures 2 and 3 show respectively the weld joining the bolt head to the disc and the ring of blue oxide on the underside of the disc caused by the heat of welding. Figure 4 shows the fractured heads of three of the bolts which failed in service.

(2) Longitudinal sections were cut through the heads of the unused welded bolts. These sections were then polished, etched, and photographed. Figures 5 and 6 respectively show these sections at this stage of preparation.

(3) The above sections were examined under a microscope. Figures 7 and 8 respectively show the condition existing at the roots of two of the welds. Figure 9 shows the normal heat-treated structure of the bolt material. Figure 10 shows the structure of the heat-affected zone of the bolt material.

(4) Hardness readings were taken, as shown in the

(Procedure, cont'd) -

table below, using a Vickers machine and a 10-kilogram load:

Area Tested		Vickers Hardness Numbers
Normal bolt material	-	161-169
Heat-affected zone of bolt	-	230-243
Normal disc material	-	93.2-107

(5) Chemical analysis of new bolts, broken bolts and disc material produced the following results. The specified bolt analysis is included for the sake of comparison.

		New Bolt	Broken Bolt	Bolt Specification	Disc Material
		- P e r	C e n t -		
Carbon	-	0.25	0.21	0.25-0.30	0.05
Phosphorus	-	0.018	0.019	0.04 max.	0.011
Sulphur	-	0.014	0.026	0.04 max.	0.031
Manganese	-	0.47	0.40	0.40-0.60	0.32
Silicon	-	0.20	0.23	0.30 max.	0.02
Chromium	-	None.	None.	None.	None.
Nickel	-	None.	None.	None.	None.
Molybdenum	-	None.	None.	None.	None.

Discussion:

A surface examination of the welds revealed considerable undercutting and unfilled craters. Figure 3 shows a ring of blue oxide extending 7/16 inch around the bolt, indicating that a temperature of approximately 600° F. had been attained in this area. These factors indicate the use of high welding currents and high welding speeds with consequent uncertainty of control.

An examination of the fractured areas of the broken bolts reveal that in every case the fractures are characteristic of the fatigue type of failure. This evidence points to the necessity of assessing present service life against the desirability of design changes.

Macro and micro examinations of longitudinal sections

(Discussion, cont'd) -

of the weld confirm the presence of undercutting and unfilled craters. It also disclosed cracks originating at the centres of unfilled craters and others originating at the unfused roots of the weld. The heat-affected zone structure and that of the normal bolt material are quite normal. This normality is reflected in the hardness readings obtained.

The chemical analyses show that a broken bolt is slightly low in carbon content, but this is not considered to be significant. With this exception, both new and broken bolts fall within the specified chemical limits. The analysis of the disc material is quite normal for deep drawing steel.

It should be emphasized that the cracks at the roots of the welds are probably responsible, under the action of alternating stresses, for the failure of the bolt. An examination of the broken bolts indicates that failure began at the roots of the welds. The cracks, which are well-nigh impossible to avoid in this type of joint design, act as severe stress raisers and as such can lead to failures in a very short time. In this application the service conditions of alternating stresses, together with cracks formed in fabrication, are such as to drastically lower fatigue strength.

Single-V types of welds in which the root cannot be fused should not be used where fatigue may be an important factor. In this case this is the type of joint used. Ordinarily a change of joint design would be recommended without hesitation, to ensure a completely fused root. In this case, however, it is felt that if the average service life is satisfactory a design change should be avoided. On the other hand, unsatisfactory service life could probably be rectified by a change of joint design which would make possible a completely fused root.

Conclusions:

1. Welding defects have been found, such as unfilled craters, undercutting, and root cracks.

2. Failure was in fatigue and has been due to the presence of stress-raising root cracks.

3. The chemical analysis of the bolts shows that with the exception of the carbon content of a broken bolt the analyses are within the specified limits.

4. Root cracks as found are almost inevitable with the type of joint used.

5. Design changes should be avoided unless shown to be necessary by unsatisfactory service life.

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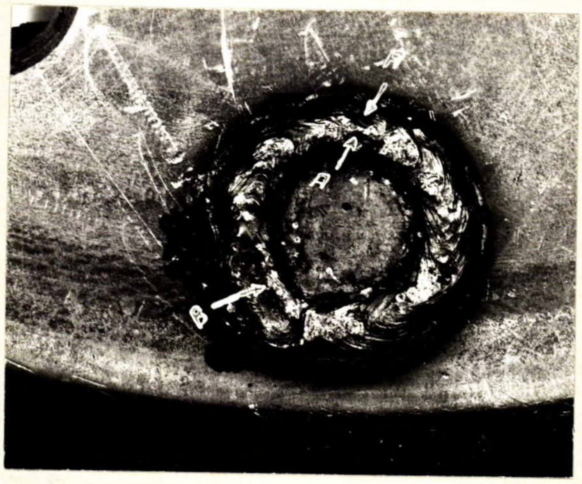
Figure 1.

TWO SECTIONS OF DISC WHEEL JOINED
BY NUT AND BOLT.

Note that bolt head is flush with disc material.

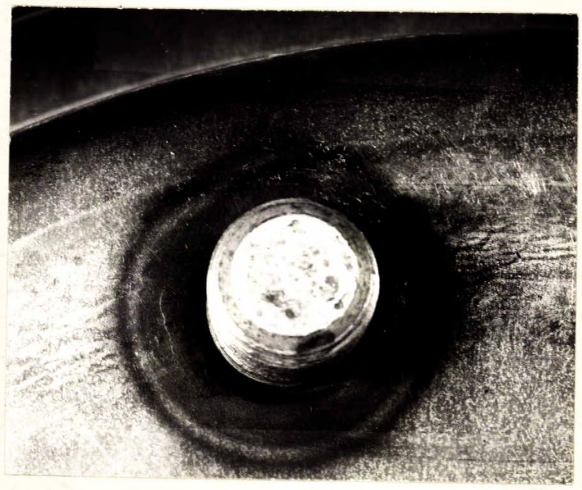
Figure 2.



PHOTOGRAPH OF WELD JOINING
BOLT HEAD TO DISC.

Note unfilled crater (B) and undercutting (A).

Figure 3.

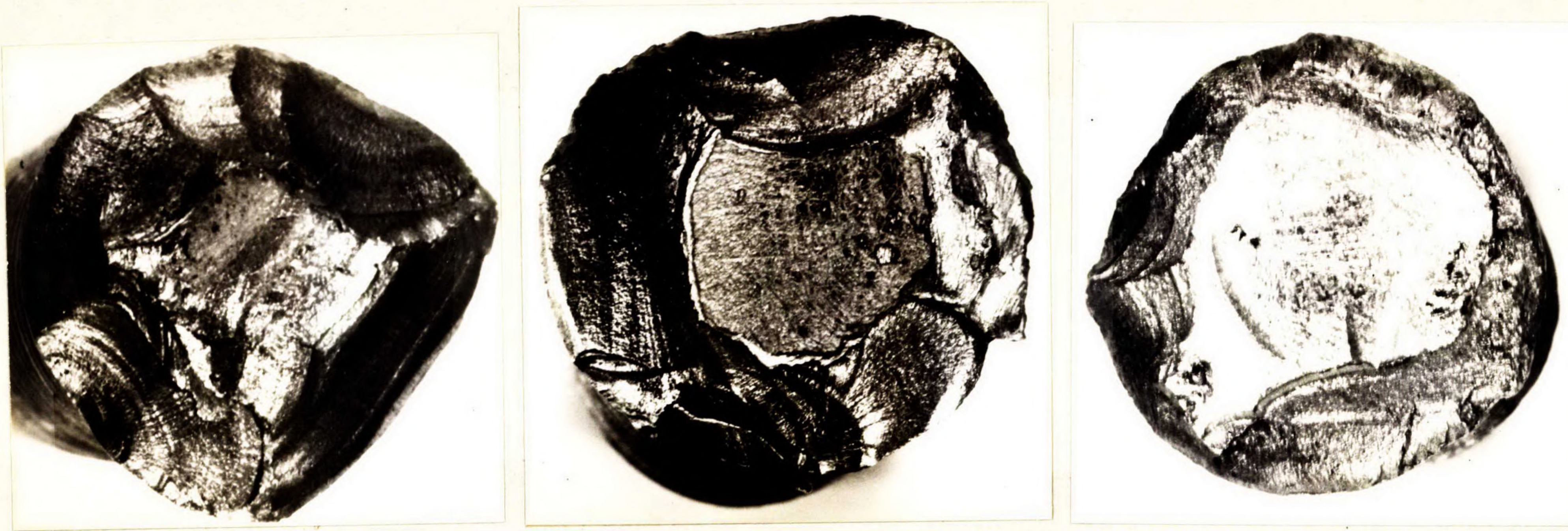


BOLT PROPER EXTENDING THROUGH DISC.

Note the ring of blue oxide on disc material.

(Approximately 7/16 inch wide).

Figure 4.

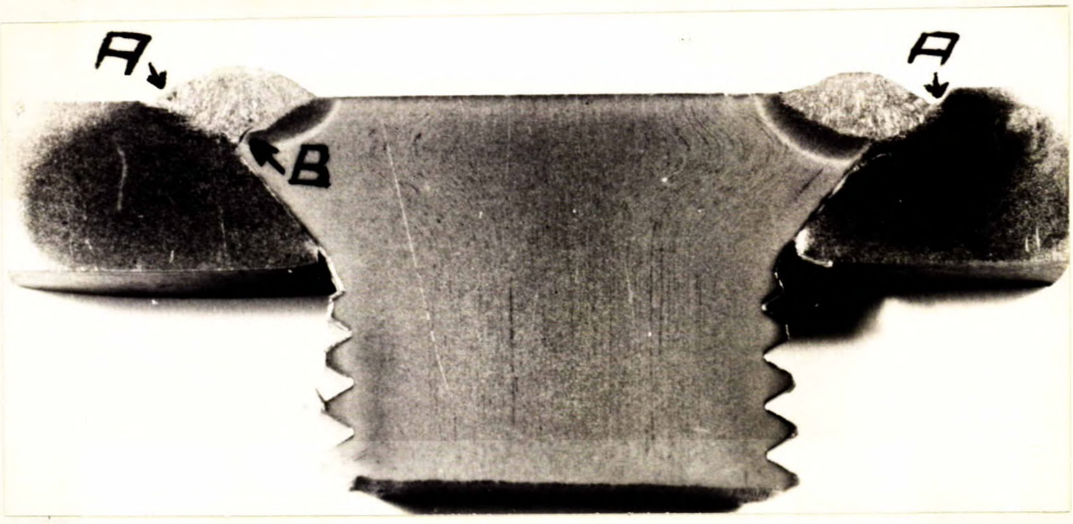


PHOTOGRAPHS OF BROKEN BOLT HEADS AS RECEIVED.

Note the "oyster shell" type of fracture typical of fatigue failures.

(Approximately 3 times actual size).

Figure 5.

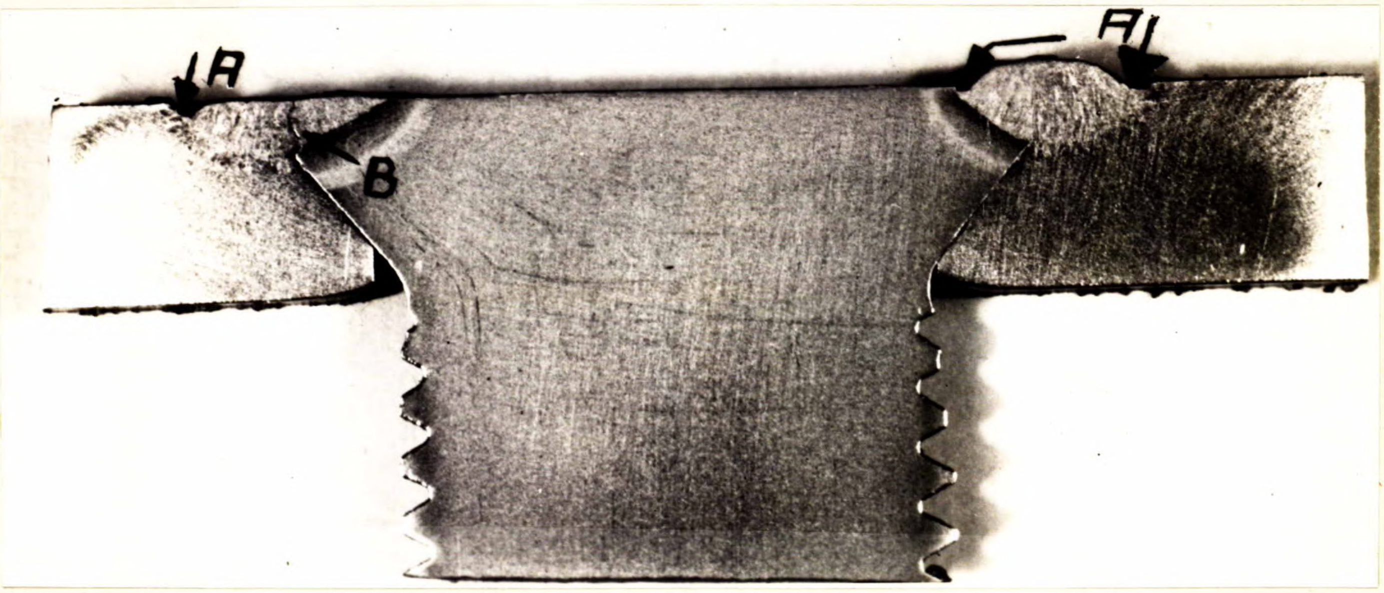


MACRO SECTION OF WELD AND BOLT HEAD.

Note undercutting (A) at right side and root crack (B) at left side.

(Approximately 3 times actual size).

Figure 6.



MACRO SECTION OF WELD AND BOLT HEAD.

Note undercutting (A) at both sides and crater crack (B) at right side.

(Approximately 4 times actual size).

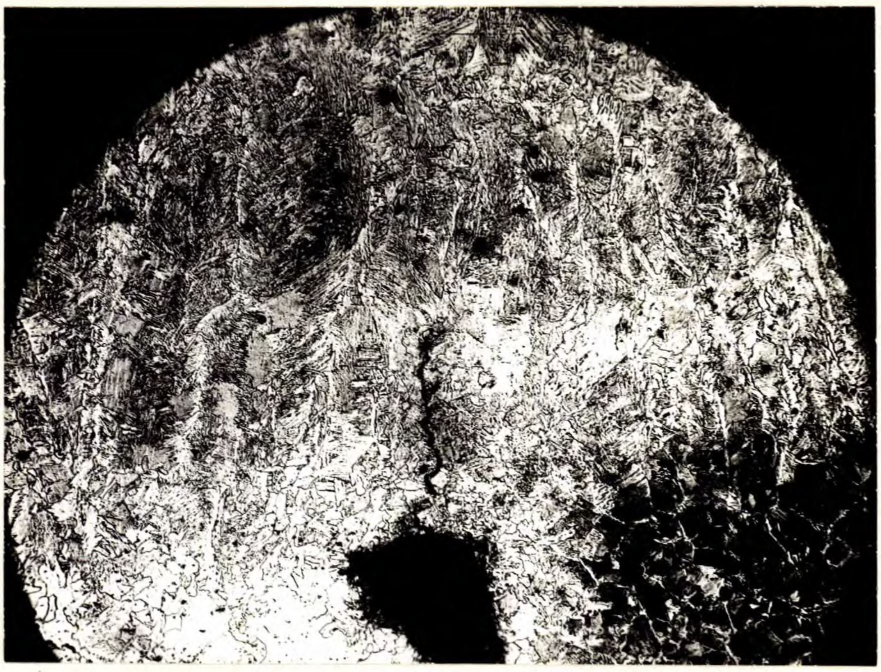
Figure 7.

X50, etched in 2 per cent nital.

UNFUSED AREAS AT ROOT OF WELD.

Bolt material, lower left; disc material, lower right; and weld at top.

Figure 8.



X100, etched in 2 per cent nital.

CRACK EXTENDING INTO WELD AND ORIGINATING AT THE UNFUSED ROOT AREA.

Figure 9.

X500, etched in 2 per cent nital.

NORMAL STRUCTURE OF BOLT MATERIAL.

Low-carbon martensite in a matrix of ferrite.

Figure 10.

X500, etched in 2 per cent nital.

STRUCTURE TYPICAL OF HEAT-AFFECTED ZONES OF WELDS.

Mainly low-carbon martensite with some fine pearlite, plus a small amount of ferrite in grain boundaries.

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