OTTAWA July 9, 1945.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1903.

Metallurgical Examination of a Damaged Aluminium Alloy Truck Wheel.

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(Copy No. 14.)

Bureau of Mines
Division of Metallic
Minerals

Physical Metallurgy
Research Laboratories

CANADA
DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

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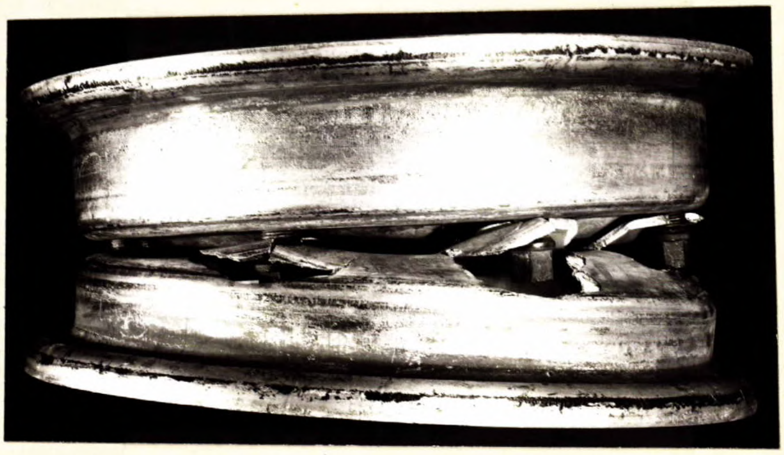
Origin of Material and Object of Examination:

A damaged aluminium alloy truck wheel was submitted by the Directorate of Metallurgy, Army Engineering Design Branch, Department of Munitions and Supply, Ottawa, Ontario. The accompanying letter was dated June 2, 1945. The material, covered by Requisition No. 699 (A.E.B.D. Lot No. 592, Report 13, Test No. 76), had been obtained from Mr. J.L. Callahan, for Director of Automotive Design, Army Engineering Design Branch, (File No. 73-W-4).

(Continued on next page)

(Origin of Material and Object of Examination, cont'd) -

Figure 1.



SIDE VIEW OF DAMAGED ALUMINIUM
ALLOY TRUCK WHEEL.

(Approximately 1/6 actual size).

-

This experimental truck wheel, shown in Figures 1 and 2, was a 6.00 x $1\frac{1}{2}$ W.D. divided type. It was formed from AC.65S-O alloy of 0.320-inch gauge and heat-treated to the S-T condition. The usual material for this component is hot-rolled, low carbon open hearth steel suitable for deep drawing. The wheel failed after some 3,000 miles of service conditions. The actual load was approximately 5,000 pounds, slightly less than the 5,375-pound rated service load for the regular steel wheel.

Request was made for a metallurgical investigation to determine the quality and, if possible, the reason for failure of the truck wheel.

(Continued on next page)

(Origin of Material and Object of Examination, cont'd) -

Figure 2.

TOP VIEW OF DAMAGED ALUMINIUM
ALLOY TRUCK WHEEL.
(Approximately 1/6 actual size).

Chemical Analysis:

The chemical analysis, as determined by the Bureau of Mines laboratories, was as follows:

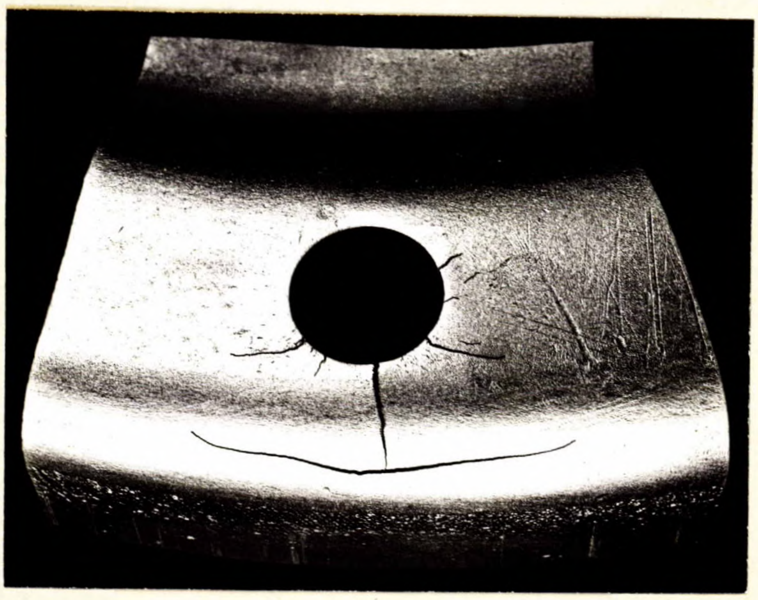
Element		Per Cent by Weight	COMPOSITION LIMITS FOR AC.65S. Maximum	Minimum
			- Per	cent -
Copper	-	0.19	0.40	0.15
Magnesium	-	0.85	1.20	0.80
Silicon	-	0.45	0.80	0.40
Chromium	-	0.17	0.35	0.15
Iron	-	0.30	0.70	--
Titanium	-	0.06	0.15	--
Manganese	-	0.01	0.15	--
Zinc	-	Not detected.	0.10	--

The composition is within the required specification limits but each element is at the extreme low side of its range. The cumulative effect of this lower alloy content would be to reduce the strength and increase the elongation of the material.

Macroscopic Examination:

Figures 1 and 2 show the severe tearing which occurred at the location of the connecting bolts. Figure 3 shows the type of failure before tearing had occurred. These failures are characterized by radial cracks from the connecting bolt hole extending in the direction of the bend at the rim, and a circumferential crack at the rib bend extending in the direction of the main curvature of the wheel. The more severely damaged locations are extensions of these cracks by tearing.

Figure 3.



CRACKS AT BOLT HOLE AND RIM BEND.
(Approximately 3/4 actual size).

Thickness Measurements:

The metal thickness was measured at various locations on the damaged half of the wheel. The variations in thickness at the rim bend radius are listed in Table I; the measurement points are shown in Figure 4.

(Continued on next page)

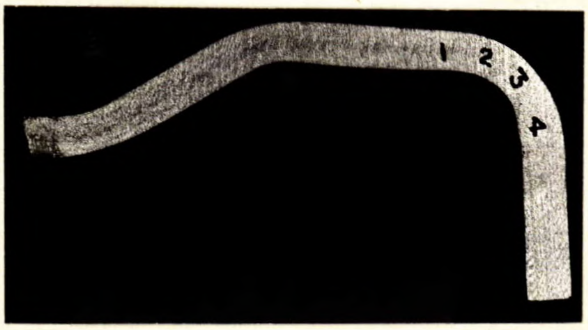
(Thickness Measurements, cont'd) -

TABLE I. -
Thickness at Rim Bend Radius, in Inches.

	Point 1	Point 2	Point 3	Point 4
Sample 1 -	0.285	0.274	0.261	0.297
Sample 2 -	0.291	0.272	0.258	0.298
Sample 3 -	0.273	0.265	0.267	0.298
Sample 4 -	0.283	0.266	0.256	0.291

Other locations on the bend had thicknesses of about 0.260 inch. The thickness of the metal of the main rim was about 0.294 inch. The metal thickness at points near the hub attachment bolt holes, where little deformation would have accurred in forming, was about 0.300 inch. The corresponding thickness on the undamaged half of the wheel was 0.310.

Figure 4.



MEASUREMENT POINTS ON THE RIM BEND.

(Approximately 2/3 size).

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Tensile Tests:

Round microtensile test bars were cut in directions parallel and perpendicular to the main radii of the wheel. The results are in Table II.

(Continued on next page)

(Tensile Tests, cont'd) -

TABLE II. - Tensile Tests on Aluminium Truck Wheel Material.

	Yield Strength, thousand p.s.i.	Ultimate Strength, thousand p.s.i.	Elongation, per cent.
Circumferential 1	36.0	40.0	18.0
" 2	35.0	40.0	18.0
Radial 1	36.0	40.0	23.0
" 2	34.0	38.5	22.0
Typical AC.65 S-T	39.0	45.0	12.0
Specified min. AC.65 S-T	35.0	42.0	10.0
Hot rolled, normalized, low carbon steel sheet	38.0	52.0	32.0

These figures indicate that the material used was on the low side of the range for AC.65 S-T and that although the yield strength is of the same order as the steel usually employed, the plastic range or interval between yield and ultimate strengths is considerably less.

Microscopic Examination:

The microstructure of the failed wheel was normal, with no indications of coarse recrystallization after forming. There were some indications of internal and surface defects. Figure 5 shows a subsurface blister or inclusion. There was evidence of blistering at scattered locations on the wheel.

Figure 5.

X75.

SUBSURFACE DEFECT AT RIM BEND.

-

(Microscopic Examination, cont'd) -

There was some evidence of mild corrosive attack which had not progressed to any extent. Figure 6 shows a crack near the actual point of failure. The crack is of the transcrystalline type.

Figure 6.

X100.

CRACK NEAR POINT OF FAILURE.

Discussion of Results:

The metallurgical examination of the wheel material revealed several minor shortcomings in the material. These were:

1. Low tensile properties.
2. Inclusions or flattened blisters.
3. Mild corrosion attack.

None of these seems severe enough to have had more than a supplementary effect in the wheel failure.

The stress concentration in the rim bend section due to the small thickness and the stress concentration at the outer bolt holes of the wheel both appear to have started a crack of the fatigue type. Once the section had been reduced by a penetration of the crack, failure occurred rapidly by tearing. The stresses to cause the fatigue crack at the rim bend would be from direct loading of the wheel, and the stresses to cause tearing

(Discussion of Results, cont'd) -

were side loads. It is possible that the cracking may have progressed to a considerable extent under smooth road conditions, and then, with rough terrain and heavy side loads, the failure changed to the tearing type.

There was no indication of cracking in the other wheel half. In this part the bolt hole stresses were distributed by bolt attachment plates riveted to the wheel. This part was also of slightly heavier gauge than the half which failed.

To avoid failure in this part when made from aluminium alloy, the following factors should be considered:

1. Reduction of stress at outer bolt holes by redesign or increased number of bolts.

2. Increase in the rim bend radius from the present 1-1/3 times the sheet thickness (0.40 inch) to 2 or 3 times the sheet thickness. This would allow easier forming and avoid "necking down" at this point.

3. Increasing the metal thickness or using an alloy of higher strength, such as 17S-T.

Conclusions:

The wheel component failed because of stress concentrations at the outer bolt holes and at the rim bend. This condition was aggravated by reduced metal thickness, particularly at the rim bend, and low strength of the material.

For this application the component should be redesigned for better stress distribution. Consideration of ease of forming in the design of the part and the forming dies would allow a higher strength alloy to be used.

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JRS:MC.