CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

OTTAWA

MINES BRANCH INVESTIGATION REPORT IR 61-30

FRACTURE OF 65S ALUMINUM BAIL ANGLE ON CAGE OVER SKIP COMBINATION AT LEITCH GOLD MINES LTD., BEARDMORE, ONTARIO

by

G. J. BIEFER

PHYSICAL METALLURGY DIVISION

COPY NO. 8

APRIL 11, 1961

~~Industrial Confidential~~

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SUMMARY OF RESULTS

While in service at Leitch Gold Mines Ltd. two 65S aluminum bails fractured. Lengths of the fractured bails and a sample of the shaft drip water were sent to Mines Branch for examination. It was found that the primary cause of the failure was wear of the aluminum bails against wooden guides, but fatigue and an intergranular corrosion attack also appeared to be contributing factors.

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*Head, Corrosion Section, Physical Metallurgy Division, Mines Branch, Department of Mines and Technical Surveys, Ottawa, Canada.

INTRODUCTION

The information summarized below was obtained by Mr. M. A. Twidale of the Fuels and Mining Practice Division, Mines Branch, in correspondence with Mr. J. J. Lazurko, Ontario Department of Mines, and Mr. G. A. McKay, Manager of Leitch Gold Mines Ltd., Beardmore, Ontario.

In Shaft No. 1 of Leitch Gold Mines Ltd., the North Compartment is provided with a cage over skip combination. The main load-carrying structural members (that is, bails) are four aluminum angles, which run the entire length of the combination. Two angles are on each side, and they are arranged so that the flanges enclose wooden guides which run vertically the length of the shaft. This arrangement keeps the cage-skip combination properly positioned in the shaft. However, the intermittent contact between the guides and the aluminum flanges leads to a loss of aluminum by wear, and a resulting diminution of the load-bearing strength of the aluminum angles.

On September 26, 1960, ore had just been unloaded, and the empty skip was being lowered for another load of ore when the hoistman noticed an unusual bumping, and stopped the hoist. It was found that the two aluminum angles on one side of the combination had failed, at a point just below the cage, that is, above the skip. Two sets of guides were broken, and needed replacement. The conveyance was scrapped, and replaced by a new one.

Mr. Lazurko noted that the failure was caused by wear. There were no wear plates at the point of fracture, and the arms of the angles had been greatly thinned by intermittent rubbing against the guides. This problem had been noted before; two of the angles, in opposite corners of the combination, had been replaced two years before. The conveyance was five years old.

Mr. McKay of Leitch Mines supplied the Mines Branch with lengths of the fractured angles, cut about 6 in. from the fracture, and a specimen of drip water from the shaft for analysis.

EXPERIMENTAL

The results of a chemical analysis of the aluminum angle metal appear in Table 1; the composition fits the specifications of Alcan 65S alloy. The analysis of the water appears in Table 2. Essentially, the water is a solution of sodium chloride at the relatively acid pH of 3.2; the salinity of about 2.5% is surprisingly high, approaching that of sea water (about 3.5%).

The short lengths of fractured aluminum angle sent by Leitch Gold Mines are shown in Figure 1. In service, the distance between them was sufficient for the vertical arms to enclose a wooden guide, but otherwise they are positioned correctly relative to each other. The thinning of the right hand vertical arm, due to wear against the wooden guide, is particularly evident.

It is reported that the angles were provided with steel reinforcing plates over part of their lengths, but not at the point of fracture. Figure 2, which shows the underside of the left hand angle of Figure 1, exhibits a distinct line of demarcation which evidently marks the edge of the steel reinforcing plate. The lighter area below the line of demarcation was observed to be severely etched, due to galvanic attack of the aluminum in contact with the more cathodic steel.

For the left-hand angle of Figure 1, the fractured face is shown. The fracture occurred in the plane of a rivet hole, that is where the load-carrying capacity of the angle was least. From available information, the rivet hole was empty at the time of fracture. It should be noted that the right-hand angle of Figure 1 fractured in the same way as the other; however, the area of the fracture near the rivet hole had been sawn off for metallography before the photograph was taken.

Both fracture faces could be divided into two distinct regions. Extending from the rivet holes was a dark area, which appeared to be corroded. The rest of the fracture was brighter in appearance. The darker areas showed no necking down, indicating that the fracture had been brittle. The brighter areas showed necking down; that is, the fracture had been ductile. In Figure 1, at the right of the rivet hole, the line of demarcation between the two different regions, and the necking-down to the right of it, can be clearly seen.

For the region near the fractures, examination with a low power stereo-microscope and metallographic cross-sections did not reveal any major cracks in addition to that represented by the fracture. However, the cross-sections showed that intergranular corrosion was taking place. (Figures 3 and 4)

Some of the grains at the fracture were distorted indicating that the fracture was partly transgranular. (Figure 5) Other grains at the fracture were undistorted; the fracture on these was probably intergranular.

Apart from the fracture, the surfaces of the angles which are seen in Figure 1 were observed to be loosely coated with what appeared to be mud. When this was removed the aluminum surface beneath it was observed to be generally smooth, that is, comparatively uncorroded. Microscopic examination showed that the "mud" contained shiny particles. These were identified as alumina, according to X-ray analysis, so it is possible that an aluminum paint was applied to the angle at some point in its life. Apparently the paint provided some protection, though it was noted that there was nonetheless severe etching in a few areas. At some localities the corrosion attack had the appearance of a network, which agreed with the evidence of the metallographic sections that the alloy was suffering intergranular corrosion attack.

CONCLUSIONS

The failure occurred at the weakest part of the aluminum angles, at a point where there were no reinforcing plates and where the structure was weakened by the presence of empty rivet holes.

Three factors contributed to the failure:

(1) Loss of weight-bearing cross-section of the aluminum angles due to wear against wooden guides.

(2) Intergranular corrosion attack.

(3) Fatigue cracking.

Wear was probably the primary cause of the failure, as weakening by this mechanism can be assumed to have started as soon as the conveyance was put into service. The intergranular corrosion attack probably helped initiate and propagate fatigue cracks. It is of interest that, at the time of fracture, about 17% of the original weight-bearing cross-section had been removed by wear against the guides, while the major brittle cracks radiating from the rivet holes had extended over about 20% of the original total area. The remaining 63% of the cross-section was evidently insufficient to bear the load, and a ductile fracture occurred.

The intergranular corrosion attack was noteworthy. According to reference 1, the attack fulfilled some of the criteria for stress corrosion. Sensitized aluminum alloys have been shown to be particularly vulnerable to stress cracking in 3% sodium chloride at low pH,[2] that is in a solution resembling the shaft water at Leitch Gold Mines. However, alloys of composition similar to Alcan 65S are not considered to be prone to stress cracking[1] and do not appear to show intergranular attack in sea water.[3]

It is planned to obtain further samples of this particular mine shaft water, in order to confirm its surprisingly high salinity.

ACKNOWLEDGMENTS

The metallographic work was carried out by R. I. Hamilton and others of the Non-Ferrous Metals Section of the Physical Metallurgy Division. The chemical analysis was carried out by the Mineral Sciences Division, and the water analysis by the Industrial Waters Section of the Mineral Processing Division.

REFERENCES

1. F. A. Champion. The Interaction of Static Stress and Corrosion with Aluminum Alloys. Metallurgia 53, No. 316, 63-68 (Feb. 1956).

2. P. T. Gilbert and S. E. Hadden. A Theory of the Mechanism of Stress-corrosion in Aluminum-7% Magnesium Alloy. J. of the Institute of Metals 77, 237 (1950).

3. T. E. Wright, H. P. Godard, I. H. Jenks. Performance of Alcan 65-S-T-6 Aluminum Alloy Embedded in Certain Woods under Marine Conditions. Corrosion 13, No. 7, 77-83 (July 1957).

TABLE 1

Composition of the Aluminum Angles

Element	Result from Chemical Analysis, wt %	Specifications for Alcan 65S, wt %
Copper	0.32	0.15 - 0.40
Magnesium	0.96	0.80 - 1.2
Silicon	0.59	0.40 - 0.80
Titanium	0.04	0.15 max
Iron	0.42	0.70 max
Chromium	0.17	0.15 - 0.35
Manganese	0.07	0.15 max

TABLE 2

Composition of Drip Water from the Shaft of Leitch Gold Mines

pH	3.2
Colour (Hazen units)	25
Turbidity (units)	30
Mineral acidity	62 ppm as $CaCO_3$
Total acidity	116 ppm as $CaCO_3$
Conductance	38,628 micromhos
Total $CaCO_3$ Hardness	2,406 ppm
Calcium	870
Magnesium	57
Sodium	9,000
Potassium	29.5
Iron (total)	150
Iron (dissolved)...............	8.5
Aluminum	0.6
Manganese (total)	3.6
Manganese (dissolved)	2.8
Copper	0.13
Zinc	0.60
Lead	0.12
Carbonate	0
Bicarbonate	0
Sulphate	150
Chloride	15,350
Fluoride	1.5
Sum of Constituents	25,474
% Sodium	88.5

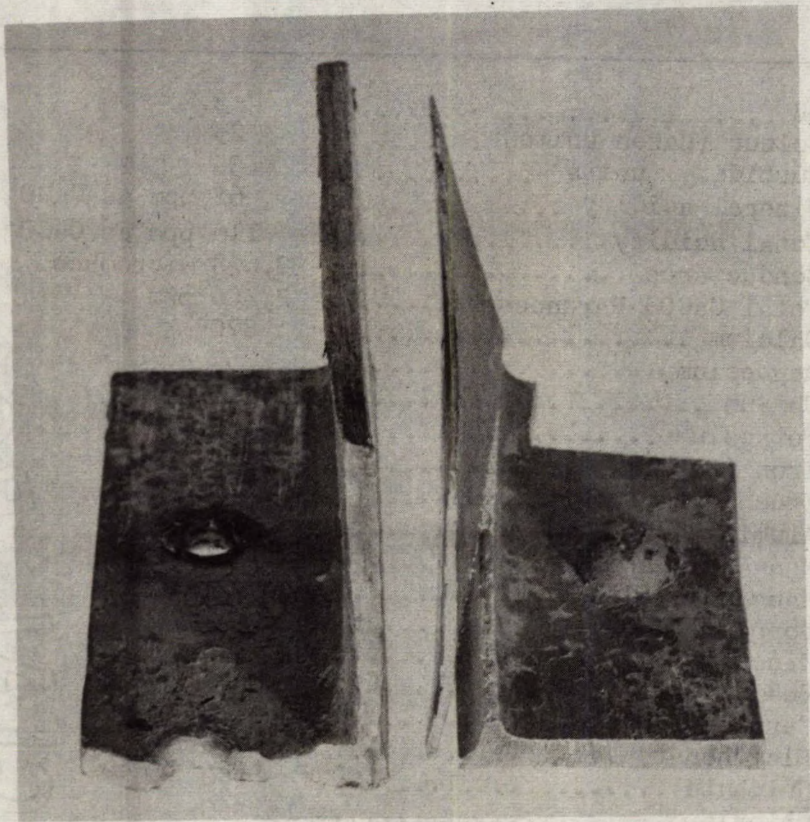

Figure 1 - Short lengths of fractured aluminum angles. The left-hand angle exhibits the fractured face; this face was cut from the right-hand angle before the photograph was taken. About X1/2.

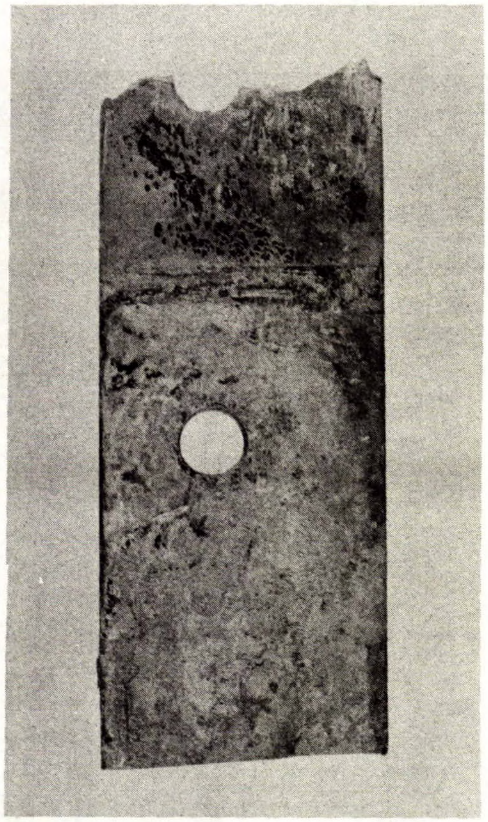

Figure 2 - Underside of left-hand fractured aluminum angle of Figure 1. The fracture is at the top of the photograph. About X1/2.

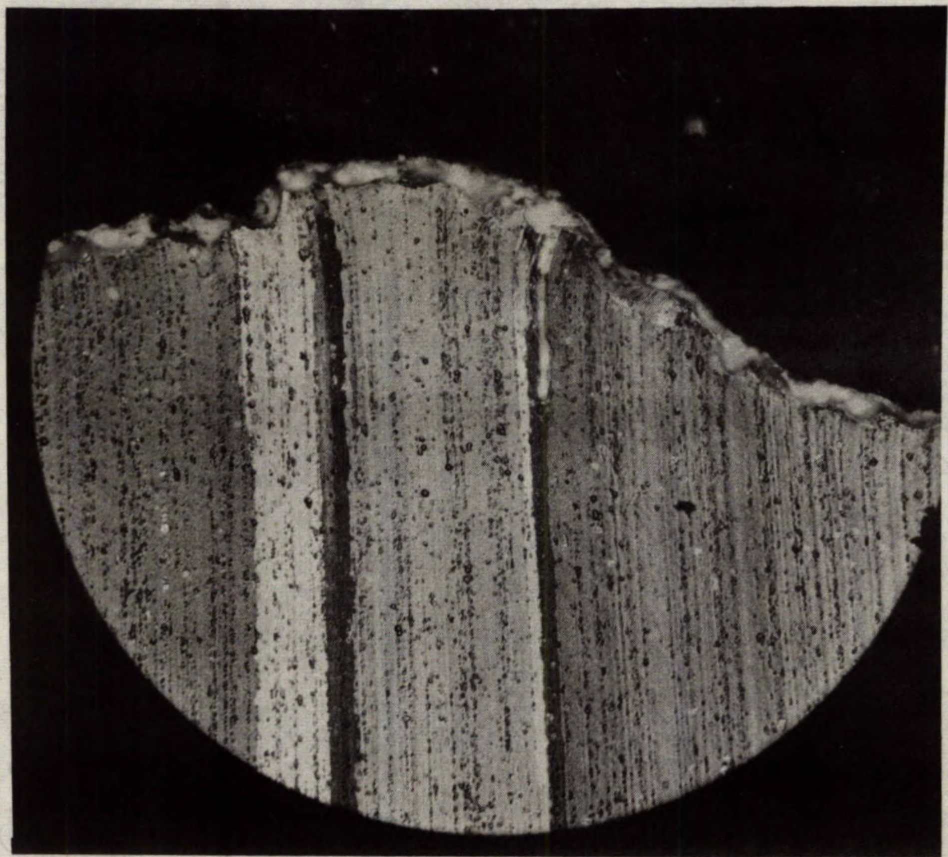

Figure 3 - Anodized metallographic cross-section in a plane at right angles to that of the fracture. The fracture edge is seen at the top, with a single intergranular corrosion penetration near the centre of the plate. X100.

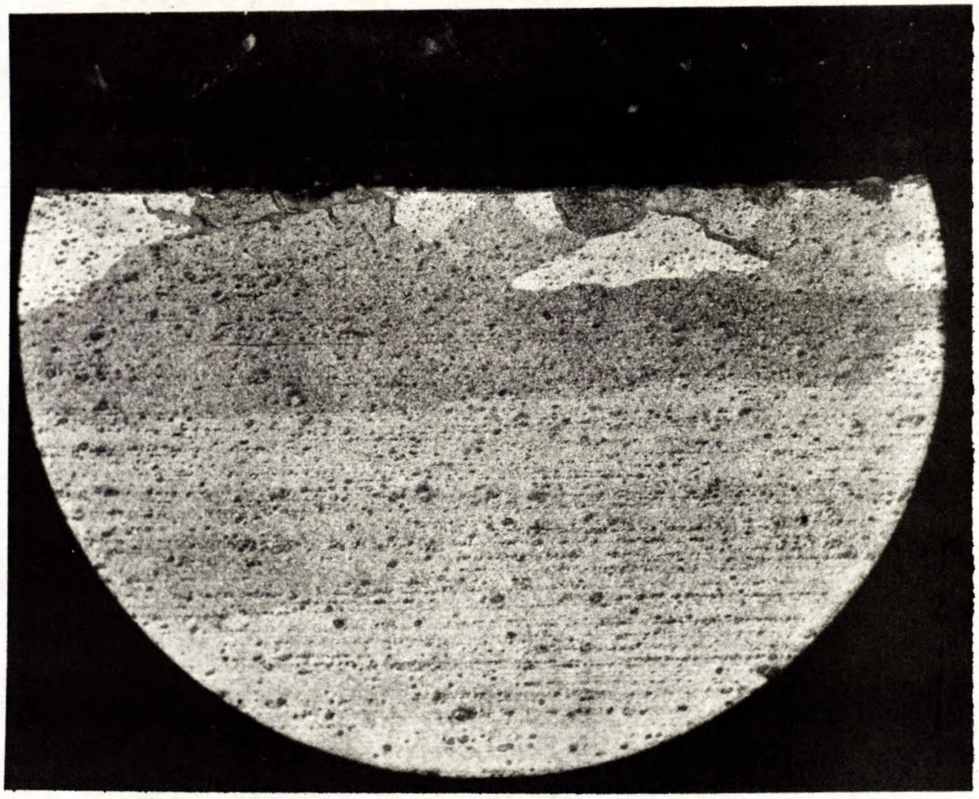

Figure 4 - Anodized metallographic cross-section in the plane of the fracture, at a point just below the fracture. The top edge of the plate is an outer surface of the angle (such as that shown in Figure 2) and exhibits intergranular corrosion attack. X100.

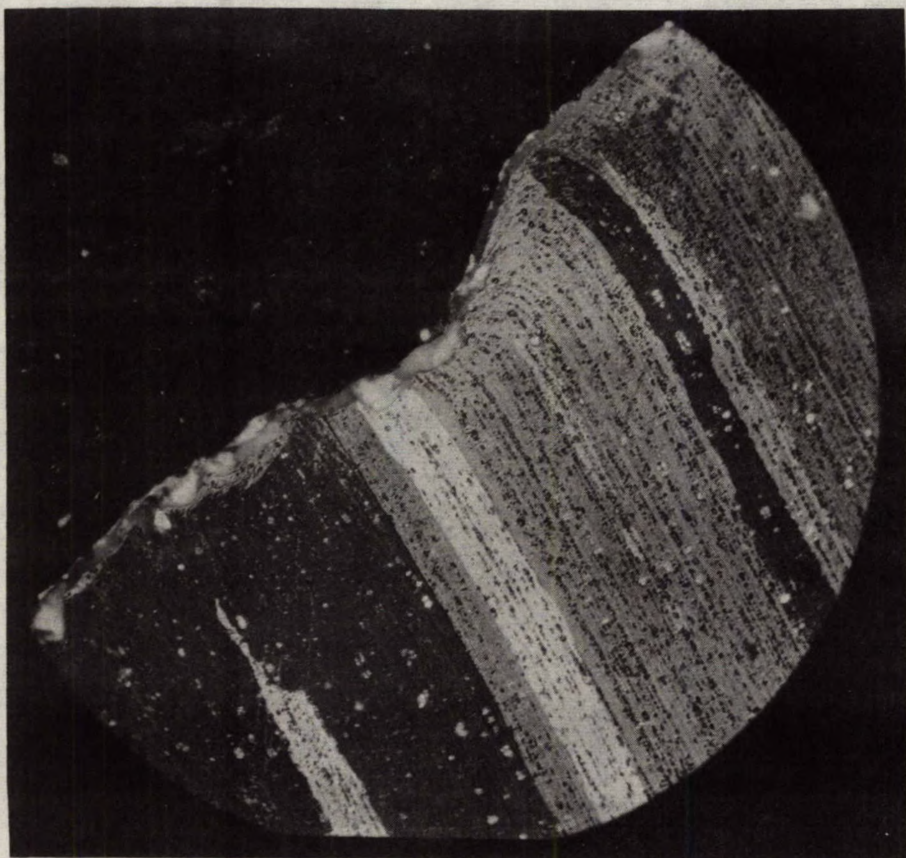

Figure 5 - Anodized metallographic cross-section in a plane at right angles to the fracture. The fracture edge is shown at the top of the plate; grains are seen to be distorted. X100.