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EXAMINATION OF FAILED ALUMINUM ALLOY AIRCRAFT COMPONENT

by

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SUMMARY OF RESULTS

The component failed through a section that had been seriously weakened by the presence of a flaw (known as "extrusion defect"), which was introduced during primary manufacture of the material.

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INTRODUCTION

A request was received via the Technical Information Service of the National Research Council (letter dated 4 February 1965, TIS No. 59532; 5014) to examine a sample from a failed aluminum alloy aircraft component, which was supplied. The enquiry originated with Dale and Company, Marine, Fire, Life and Casualty Underwriters, 333 Kennedy Street, Winnipeg, Manitoba. More detailed information was subsequently supplied (letter dated 2 March 1965) together with a further sample of aluminum alloy bar, which had been involved in the accident.

The aircraft concerned had crashed on landing and had been repaired by the replacement of broken parts. On its first flight after repair the aircraft again "cracked up" on landing. The samples supplied were parts of the "Cabin bottom" assembly to which undercarriage struts were attached. The components were made from aluminum alloy bar approximately 2 in. x 7/8 in. and the struts were attached to the ends of the bars by bolts or pins approximately 1-in. diameter. Failure had apparently occurred by one strut attachment being forced through the end of the bar causing two fractures, one at the extreme end and on the centre line of the bar, the other at the top (or bottom) of the hole roughly at right angles to the first fracture (see Figure 1).

Dale and Company called particular attention to the duplex character of one of the fracture surfaces and wanted to know whether the fibrous and discoloured region was an "old break" that had been neglected when the aircraft was repaired.

VISUAL EXAMINATION

Figures 2 and 3 are views of the fracture surfaces on the sample from the broken bar. From the direction of the extrusion marks on the unmachined surface of the piece it can be deduced that the fracture shown in Figure 2 occurred through the end of bar and the fracture shown in Figure 3 occurred at the top or bottom of the bar (see Figure 1).

Figure 2 shows the unusual nature of the "end" fracture. As shown in greater detail in Figures 4 and 5, part of the fracture was "fibrous" with marked alignment parallel to the axis of the bar and (in the original) had brown discolouration. The boundaries between the fibrous zone of the fracture and the remainder, which had a more normal appearance, were clearly marked and contained hairline cracks, one of which may be seen in Figure 4. The appearance of the other fracture surface was typical of a more ductile break through sound metal and is thought to have occurred by bending after the failure through the end of the bar.

METALLOGRAPHIC EXAMINATION

A cross section through the fracture containing the fibrous zone was polished for metallographic examination and Figure 6 shows part of this section under oblique lighting. The fibrous region is shown on the left side, the direction of the defect being perpendicular to the plane of the photograph. The cracks, which were visible at the boundary between the zones in the fracture surface (see Figure 4), appear in Figure 6 as white lines and it will be seen that a more or less continuous system of cracks and pores form a closed, roughly eliptical region in the section. A longitudinal section (see Figure 7), showed that this closed region extended roughly parallel to the axis of the bar. Examination at higher magnifications showed that the region of unsoundness consisted of pores and strings of unidentified, non-metallic foreign material (see Figures 8 and 9).

The general metallographic structure of the sample (other than the defects noted) was typical of that of an extruded aluminum alloy. However, in cross sections near the defects, the grain structure was somewhat irregular but this was not considered to be significant other than it supports the proposal that the defect was caused during the extrusion operation.

CHEMICAL ANALYSIS

A sample from the second bar supplied was submitted for chemical analysis. The results were as shown below.

	Cu, %	Mg, %	Mn, %	Si, %	Fe, %
Sample	4.56	1.57	0.69	0.15	0.31
CSA HA.5 CG 42	3.8-4.9	1.2-1.8	0.30-0.90	0.5 max.	0.5 max.

It will be seen that the composition of the material corresponded to CSA. HA.5.CG42, which is similar to Alcan 24S alloy. The fractured sample was not large enough to allow a chemical analysis sample to be taken easily but it seems probable that the alloy was the same as the analysed sample (see also hardness tests below).

HARDNESS TESTS

Hardness determinations on both samples gave results of 125 Brinell (500 kg load, 10 mm ball), which is typical of 24S-type alloys in the T4 temper.

DISCUSSION

The examination reported above has shown that the fracture in the end of the bar took place through material that was seriously weakened by the presence of a defect which, from its appearance and characteristics, is probably what is known as "extrusion defect". This is a tubular region of oxide films and other surface debris that is drawn into the rear end of an extruded product as the result of the peculiar conditions of flow in the extrusion billet towards the end of the process. The occurrence and characteristics of the defect are well documented[1].

It is usual, in extrusion practice, to avoid or minimize the defect by stopping the extrusion before too much of the billet has been extruded and, as a further precaution, to etch sections from the last lengths of the section to detect any defect, if present.

In an extrusion from a single-hole die the extrusion defect is usually located roughly in the centre of the bar and the off-centre location of the defect in the present case suggests that a multi-hole die may have been used.

The defect would be expected to have a very serious effect on the strength of the section, particularly in a direction at right angles to the axis of the bar. In the present case, there was probably a component of the working stress in this direction, i.e., tension or torsion in this instance.

The effect of the defect and its relationship to the two crashes of the aircraft are difficult to explain from the metallurgical data. It seems unlikely that a partial failure of the part in the first accident would have been missed in an examination but it is not possible to say whether or not such partial failure did actually occur.

To summarize, the failure of the component is thought to have originated through the end of the bar which was severely weakened by a defect ("extrusion defect") introduced during manufacture.

REFERENCE

1. C.E. Pearson and R.N. Parkins - "The Extrusion of Metals" - John Wiley and Sons, Inc., New York (1960).

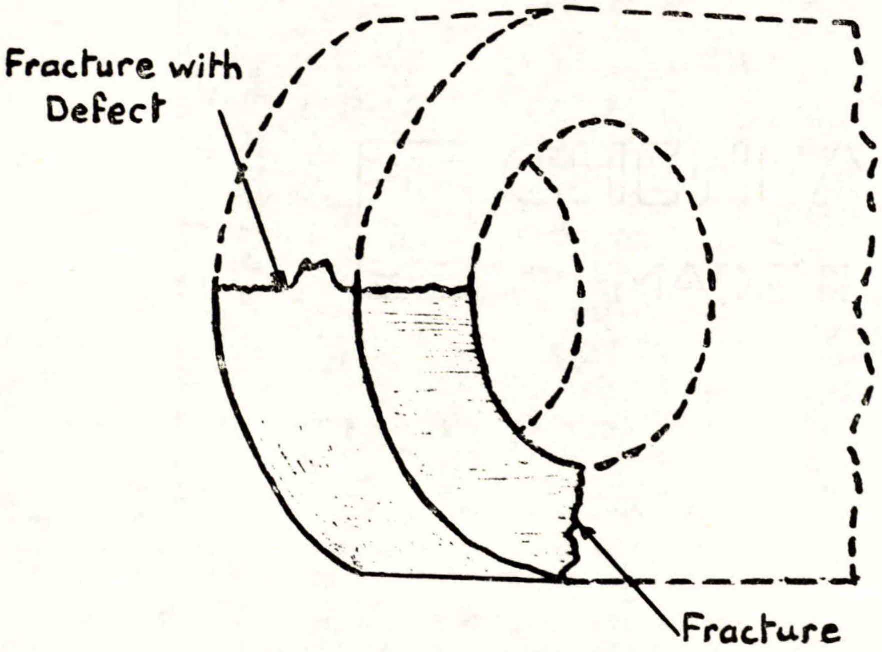
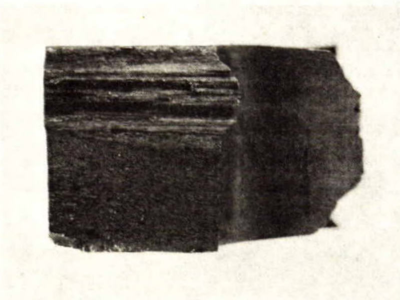


Figure 1. Sketch showing position of fractured sample in end of component. The fracture shown at the bottom may have been at the top.



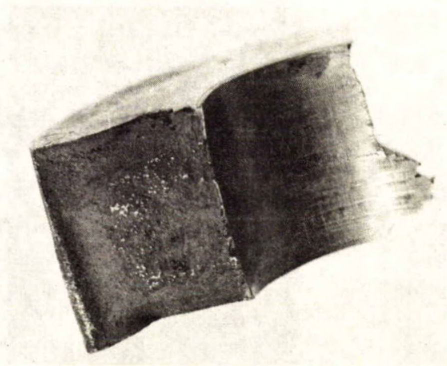
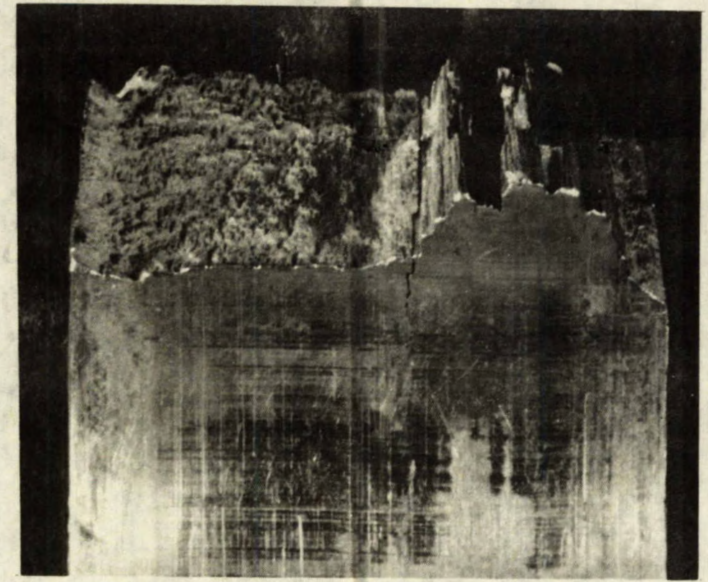


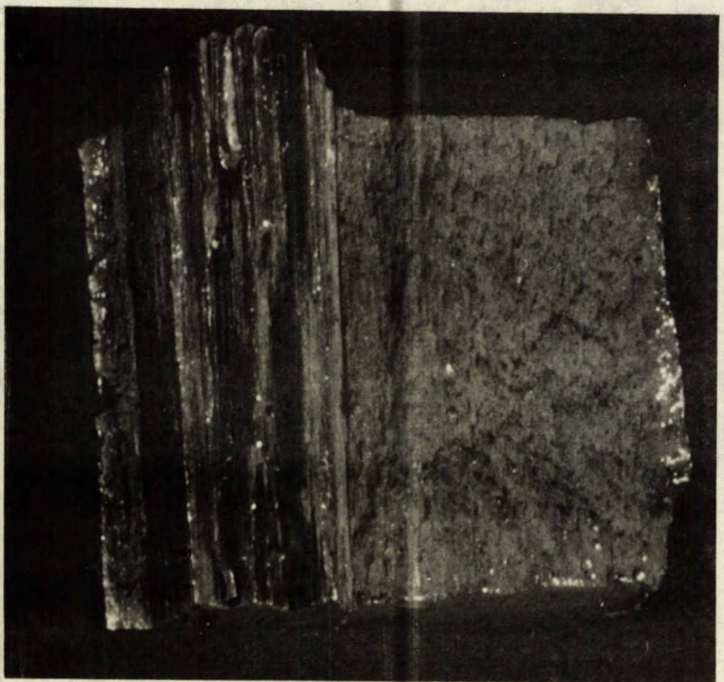
Figure 2. X1 approx. Figure 3.

Figure 2 and 3. Views of sample showing (Figure 2) end fracture with "fibrous" zone and (Figure 3) top (or bottom) fracture, probably caused by bending.



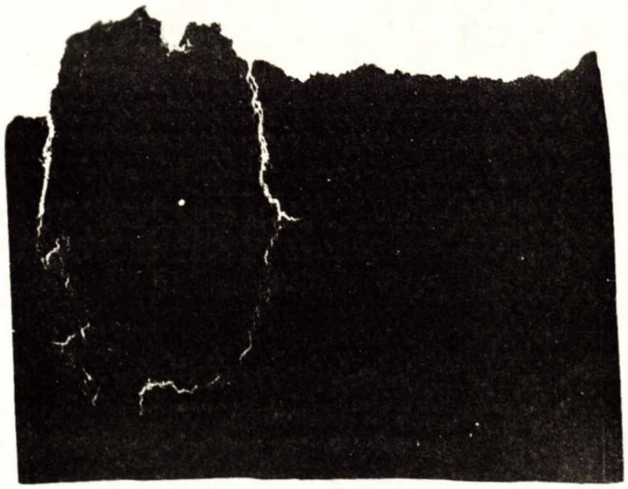
X3.5 approx.

Figure 4. View of "end" fracture showing crack at boundary between "fibrous" and "normal" zones.



X3.5 approx.

Figure 5. View of end fracture showing two zones.

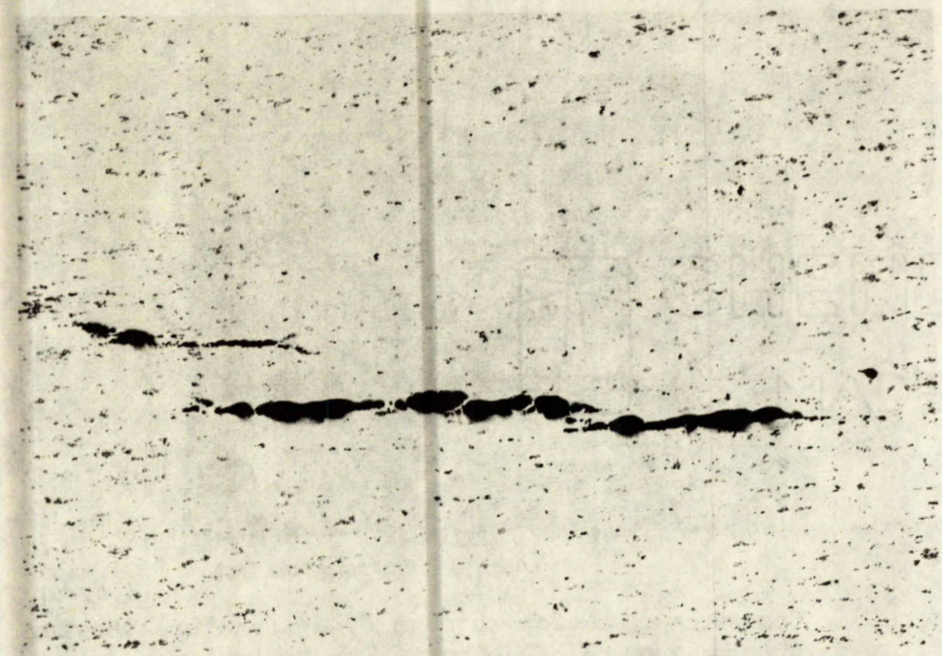


X3.5 approx.

Figure 6. Transverse section through "end" fracture showing tubular nature of defect. The white lines indicate cracks and voids. (Oblique illumination, unetched).

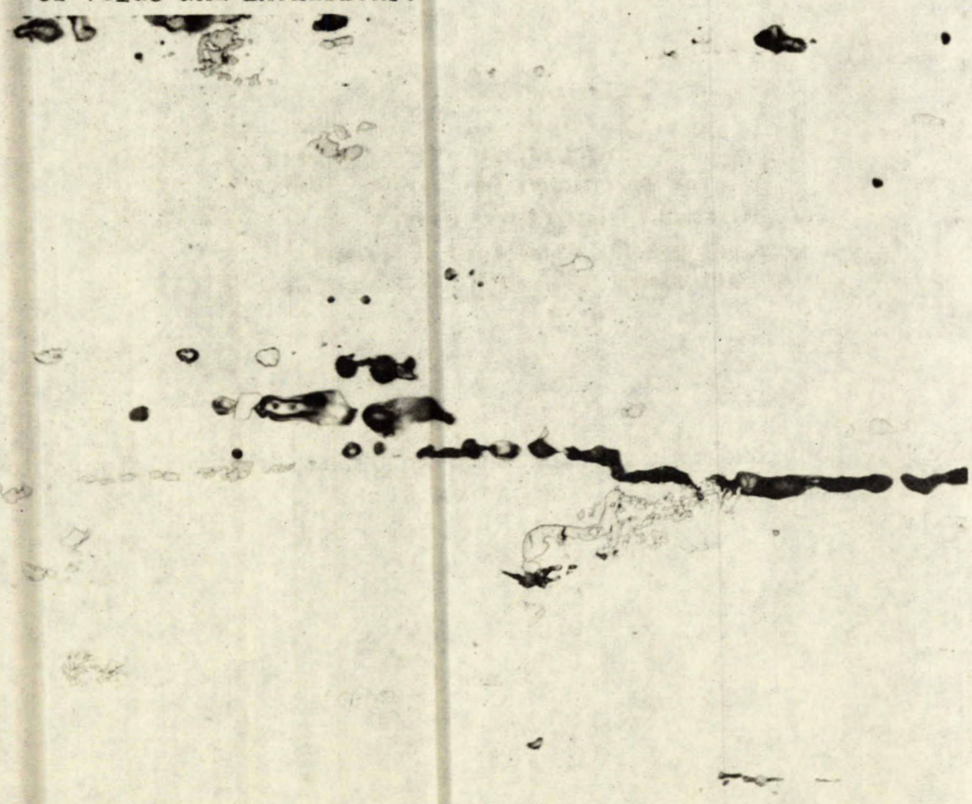
X3.5 approx.

Figure 7. Longitudinal section through defect showing elongation roughly parallel to bar axis.



X50

Figure 8. Longitudinal section through defect showing stringers of voids and inclusions.



X500

Figure 9. As Figure 8 at higher magnification, showing stringers of voids and inclusions in defect.