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EXAMINATION OF CAST-ON ALUMINUM ALLOY FLANGES ON WAVE-GUIDE SECTIONS

by

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PHYSICAL METALLURGY DIVISION

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W.A. Pollard*

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SUMMARY

Examination of cast-on flanges on wave-guide tubes by metallography and by strain gauge stress analysis failed to reveal a cause of cracking that was consistent with all the evidence. However, the castings were very unsound and the chemical composition of some were outside specification limits. It is suggested that if these defects were reduced by improved foundry practice the cracking could probably be reduced to an acceptable level.

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INTRODUCTION

On March 4, 1963, Mr. Douglas of Specialoid (Canada) Limited, St. Eustache, P.Q., requested assistance in determining the cause and possible cure of cracking in cast-on aluminum alloy flanges on wave-guide sections.

In written notes, Mr. Douglas stated that approximately 30% of these flanges were found to be cracked after storage at low temperatures although examination (at low magnification) immediately after casting had shown no cracks.

One cracked flange and one section of wave-guide with uncracked flanges at each end were initially supplied for examination. Preliminary results of the examination of these flanges were given in a letter dated March 27, 1963, and at the same time, other wave-guide sections were requested for examination. Three additional sections were supplied, together with a covering letter dated April 8, 1963. These flange sections were stated to have been cast on the day that they were forwarded.

VISUAL EXAMINATION

Figure 1 shows a length of wave-guide with a cast-on flange at each end. The risers had not been removed. The length of the section was about 20 in. and consisted of a tubular section (see Figures 2 and 3) of extruded 65S-T6 aluminum alloy, having an outside diameter of 2 in.

Coarse circumferential grooves had been machined in each end of the tube sections to key the flanges. In the written notes supplied it was stated that the ends of the tube were preheated to 450°F just before casting. A permanent mould is used. After removal of the riser the projecting ends of the tube (see Figure 2) are machined off flush with the faces of the flanges.

In the failed specimen supplied, which had been machined, several cracks could be seen with the unaided eye, as shown in Figure 4. These cracks occurred on the small diameter inner part of the flange, as shown in Figure 3. By sawing through the larger diameter part of the flange one of the cracks was opened with little difficulty and revealed that the section was almost completely penetrated (see Figure 5). The fracture surface was discoloured, indicating prior separation over its whole area except about 1/4 in. from the saw cut. (see Figure 5).

The appearance of the fracture surface suggested the presence of very coarse grains of the columnar type growing from the sides and meeting approximately in the centre of the section.

No cracks were detected in the second batch of flanges received.

CHEMICAL ANALYSIS

Samples for chemical analysis were taken from the outside of the cracked flange and from the risers of each of the second batch of flanges. The results are given in Table 1. The alloy used was stated to be Ternalloy No. 6 (Apex Smelting Company, Cleveland, Ohio) and the nominal composition for this is given in Table 1.

It will be seen in the cracked flange that considerable deviations from the specified composition occur in the magnesium, silicon and copper contents. Of these probably the magnesium is the most important as this constituent has an important effect on the strength characteristics of the alloy.

In the second batch of flanges only the magnesium content differed markedly from the specification.

METALLOGRAPHIC EXAMINATION

Sections were taken from the cracked flange - (a) through the crack, in a plane at right angles to the axis of the tube and (b) from the outer part of the flange remote from the crack.

After polishing, examination at low magnification revealed severe porosity in both sections, as shown in Figures 6 and 7. It will be seen that many pores were elongated and it was apparent that the cracks had occurred through suitably oriented defects of this type.

The sections were etched to reveal the grain structure, which, as expected from the appearance of the fracture surface, was very coarse and had a distinct columnar orientation in the section containing the cracks.

Examination of the sections at higher magnification confirmed that some parts of the crack passed through elongated grain boundary pores, whereas at other sections failure had apparently occurred at sound grain boundaries. It was not possible to determine conclusively whether the cracking had occurred in the solid or semi-solid state.

A number of sections from the second batch of flanges were examined and these were also porous although somewhat less so than the original samples.

STRESS ANALYSIS

The following examination was carried out by W.A. Marsh of the Engineering Physics Section.

Strain gauges were placed circumferentially on the smaller diameter sections of the flanges at one end of each of the supplementary specimens received. These flanges had no visible cracks when first examined nor did cracks appear subsequently.

Strain gauge readings were observed while the flanges were given the following consecutive treatments:

(a) Held at room temperature for 5 to 8 days.

(b) Held at -5°F for 14 days.

(c) Held at room temperature for 12 days.

(d) Two radial saw cuts at about 90 deg made in each flange to relieve circumferential strains, and the resulting 90 deg sector tapped loose from the wave-guide tube.

The maximum total residual strain detected was about 220 micro-inches per inch, which corresponds to a residual stress of about 2000 lb/sq.in. This level of internal stress is very low and would not be expected to cause cracking.

DISCUSSION AND CONCLUSIONS

Examination of the sample flanges supplied has failed to reveal the cause of failure in the cracked flanges. The appearance of the crack would suggest hot-tearing but it was stated in the covering letter that the cracks were not observed immediately after casting but only after storage. Strain measurements on uncracked flanges indicated that internal stresses likely to be produced during storage would not be high enough to cause failure.

Severe unsoundness in all of the flanges probably contributed to their failure and, especially in the cracked flange, the chemical composition of the alloy was seriously outside specification limits.

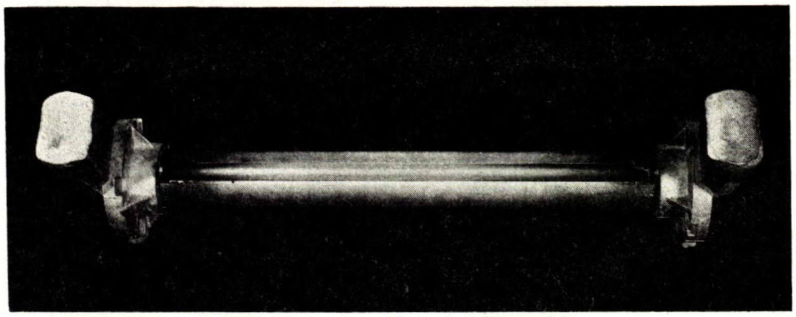
It is suggested that as the incidence of cracking is intermittent and occurs only in about 30% of castings, improving the soundness and strength by better temperature control, degassing and, possibly, grain refinement would be sufficient to eliminate the defect. Control of the chemical composition of the melt is obviously also an important factor.

TABLE 1

Chemical Analysis Results (Per Cent)

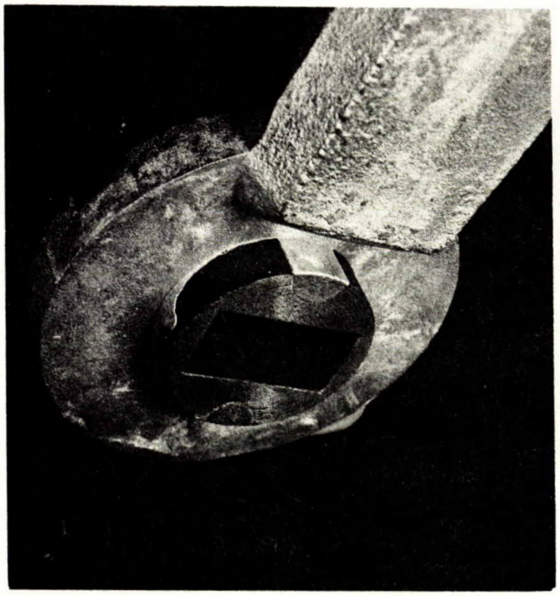
	Zn	Mg	Mn	Ti	Cr	Si	Fe	Cu	Ni
Cracked Flange	4.01	0.96	0.41	0.12	0.23	0.83	0.45	0.49	0.08
Second Batch (1)	3.77	1.18	0.46	0.17	0.28	0.17	0.32	0.16	n.d.
Second Batch (2)	3.75	1.18	0.48	0.20	0.32	0.16	0.33	0.15	n.d.
Second Batch (3)	3.77	1.19	0.46	0.18	0.30	0.18	0.33	0.19	n.d.
Ternalloy No. 6	3.4-3.9	1.6-2.0	0.4-0.6	0.2 max.	0.2-0.4	0.2 max.	0.8 max.	0.2 max.	0.2 max.

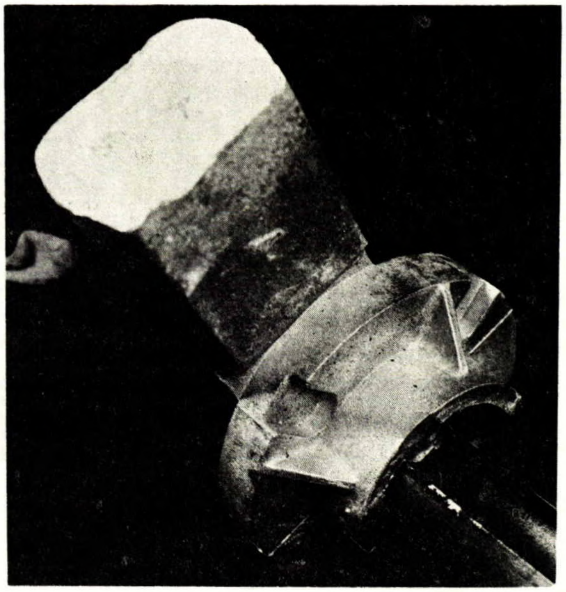
n.d. = not detected.



X 1/6 approx.

Figure 1. Length of wave-guide with cast-on flange at each end.





X 1/2 approx.

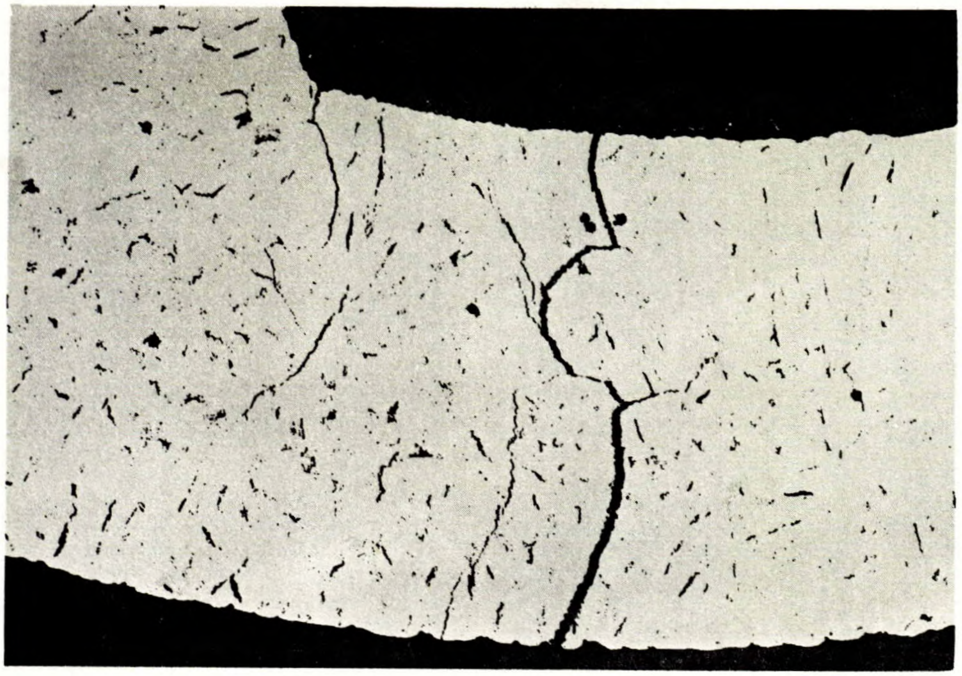
Figures 2 and 3. Cast-on flange before machining showing riser and tube section.

X 1 1/4 approx.

Figure 4. Flange showing crack (arrow).

X 3 approx.

Figure 5. Fracture surface of crack. Saw cut shown at left. The discoloured section (not shown clearly in photograph) extended from the right hand end to a line indicated by the arrows.



Unetched X10

Figure 6. Section through the crack showing severe unsoundness at grain boundaries and within grain.

Unetched X10

Figure 7. Section through cracked flange remote from the crack (outer part of flange) showing unsoundness.