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November 5th, 1943.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1528.

Examination of a Cracked Mosquito
Aircraft Rudder Pedal Bar.

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(Copy No. 10.)

Bureau of Mines
Division of Metallic
Minerals

Ore Dressing
and Metallurgical
Laboratories

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
Mines and Geology Branch

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Origin of Sample and Object of Investigation:

On October 28th, 1943, a letter (File No. 938BY-2-5(AMAE DAI)) covering a portion of a Mosquito aircraft rudder pedal bar, earlier delivered to these Laboratories by Flying Officers N. S. Spence and J. S. Roper, was received from Air Commodore A. L. Johnson, for Chief of the Air Staff, Department of National Defence for Air, Ottawa, Ontario. It was stated that this aluminium alloy sand casting was made by the Aluminum Company of Canada to Specification DTD. 298 and that after some machining, large cracks were noticed in the bar.

Request was made for an examination to determine whether or not these cracks could be traced to any metallurgical defect.

Chemical Analysis:

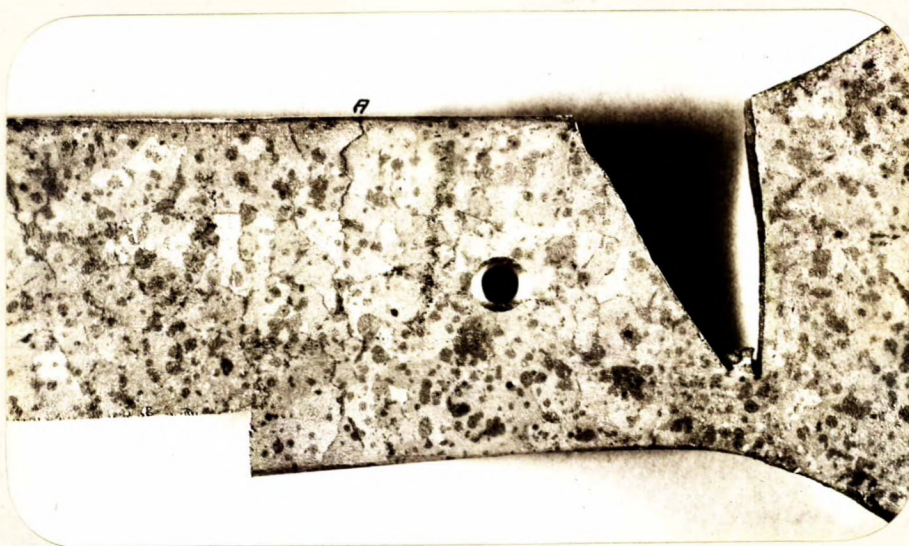
Drillings from the pedal bar were chemically analysed. The results were:

		As Found	Specification
		- Per cent -	D.T.D. 298
Copper	-	4.34	4.0-5.0
Silicon	-	0.14	0.9 max.
Magnesium	-	None detected.	-
Manganese	-	Faint trace.	-
Iron	-	0.12	0.7 max.
Titanium	-	0.12	0.25 max.
Zinc	-	Trace.	-
Nickel	-	None detected.	-
		Other impurities, 0.2 max.	

Macro-Examination:

Part of the largest crack in the bar can be seen at A, in Figure 1.

Figure 1.



(Approximately to size).
Note: Specimens were removed at cut areas prior to photographing.

(Macro-Examination, cont'd) -

The grain size of this casting was quite large; individual grains with a diameter of about $\frac{1}{4}$ inch and more were common.

A low-power binocular microscope disclosed the presence of numerous other fine intercrystalline cracks. The surface of the bar around many of these fine cracks was stained yellow. Some of these stains may be seen in Figure 1.

Physical Examination:

The casting was radiographed at the National Research Laboratories, Ottawa. Some porosity was found, but the fine intercrystalline cracks mentioned were not noticed. The large crack which caused the piece to be submitted for examination was, however, clearly visible.

Fracture tests showed that many of the stains mentioned under "Macro-Examination" extended considerably into the metal. Other grain surfaces (remote from the exterior surface of the part) were seen, after fracturing, to be copper-coloured.

Four microtensile bars machined from the casting were tested for ultimate tensile strength. The breaking loads, which are indicative but not absolutely accurate, were 32,200 p.s.i., 35,200 p.s.i., 31,700 p.s.i., and 22,000 p.s.i., respectively. The fractured surface of the last specimen had copper-coloured areas while that of the others did not.

The Vickers hardness (10-kilogram load) of the pedal bar was 100-103 V.H.N.

Microscopic Examination:

Specimens for microscopic examination were removed from cracked and uncracked portions of the casting. The intercrystalline nature of the cracking present was confirmed (see Figures 2 and 3).

A copper-aluminium eutectic constituent was segregated along a few preferred grain boundaries. A second constituent, evidently aluminium-copper-iron, was seen in the grains and on the grain boundaries. Figures 2 and 3, photomicrographs at 100 and 250 diameters respectively, illustrate these points.

Figure 2.

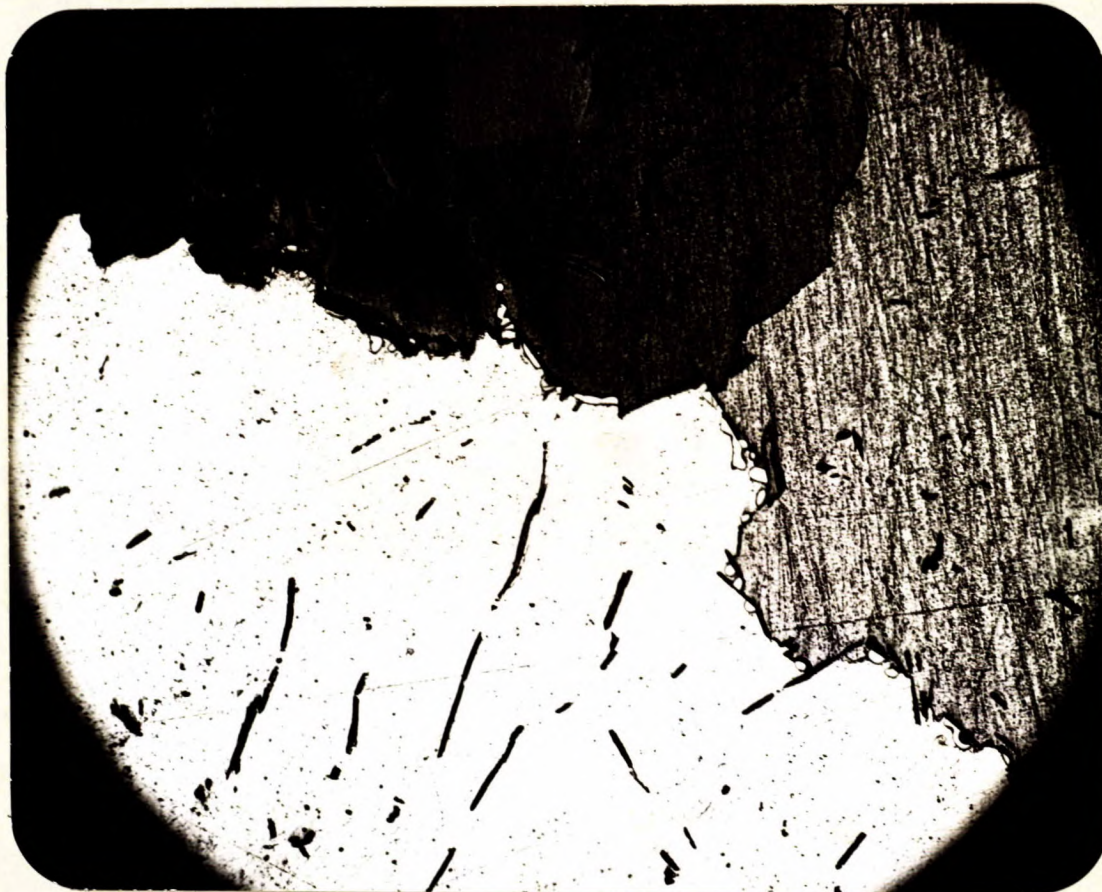


X100, Keller's etch.

Note intercrystalline crack. Copper-aluminium eutectic (white globular constituent) is segregated on preferred grain boundaries. Aluminium-copper-iron is black oblong constituent.

(Microscopic Examination, cont'd) -

Figure 3.



X250, Keller's etch.

Note intercrystalline crack. Copper-aluminium eutectic (white globular constituent) segregated along preferred grain boundaries, and aluminium-copper-iron (black oblong constituent) on the grain boundaries and in the grains.

Discussion of Results:

Chemical analysis results show that the composition of this casting conforms to the requirements of Specification D.T.D. 298. The relatively small amount of impurities present would make this casting more susceptible to grain growth than is ordinary.

Since it is probable that the yellow stains on the surface of this pedal bar around some of the intercrystalline cracks were caused by electrolyte from the anodising operation

(Discussion of Results, cont'd) -

being retained in the cracks and later seeping out, cracks very likely were present before the anodising operation was completed. These cracks could have been formed in cooling from the casting temperature or (and) the solution heat treatment.

Segregated copper-aluminium constituent caused, it is thought, the copper-coloured areas seen in fracture tests and in the break of the tensile bar which failed to pass the specification tensile strength requirement.

The coarse grains present, accompanied by this preferential segregation, indicate that this part was cast from too high a temperature. In this regard W. C. Devereux* states:

"Coarse grains--due to lack of care in melting--have low melting point eutectic heavily deposited at the grain boundaries, usually associated with impurities which tend to lie in the grain boundaries. Envelopes of eutectic are formed which are often brittle when cold, and weak at higher temperatures. Serious as this is with unheat-treated castings, coarse formation is always dangerous, and more troublesome, following heat treatment. Figure 3 shows two castings, one perfect as to grain size and shape, the other illustrates the point of faulty attention as to temperature and mould. The consequence is that after heat treatment the grain boundaries of many of the crystals are practically cracks with no defined strength."

Stresses imposed in machining operations would, of course, tend to open up previously formed cracks. If of sufficient magnitude they might also cause cracking along embrittled grain boundaries.

* Methods of Manufacture and Their Influence on Design, Aluminium Alloys--Wrought and Cast Parts, by W. C. Devereux. THE METAL INDUSTRY, London, Vol. 45, December 23, 1934, p. 490.

CONCLUSIONS:

1. This bar was cast from too high a temperature, resulting in coarse grains and segregation of the copper-aluminium eutectic constituent on preferred grain boundaries.
2. Fine intercrystalline cracks very probably were present before the machining operation, but whether they were or not, machining stresses might well cause the brittle grain boundary segregate to fracture.
3. It is thought that failure of the casting can be attributed to preferential segregation and coarseness of grain in the casting rather than to maltreatment in machining.

LPT:GHB.