CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

OTTAWA

MINES BRANCH INVESTIGATION REPORT IR 64-98

EXAMINATION OF DIE-CAST ALUMINUM MOTOR END BELLS HAVING VARIABLE MACHINABILITY

by

W. A. POLLARD

PHYSICAL METALLURGY DIVISION

COPY NO. 5

NOVEMBER 24, 1964

Mines Branch Investigation Report IR 64-98

EXAMINATION OF DIE-CAST ALUMINUM MOTOR END BELLS HAVING VARIABLE MACHINABILITY

by

W. A. Pollard*

SUMMARY

The poor machinability of one of the castings was apparently caused by the presence of primary crystals of a phase of the α-AlFeMnSi type with chromium. The most likely source of these inclusions is thought to be the "sludge" which is sometimes formed at the bottom of aluminum alloy melts by the segregation of high melting point primary intermetallic constituents which fail to dissolve owing to inadequate stirring and/or temperature control.

* Senior Scientific Officer, Non-Ferrous Metals Section, Physical Metallurgy Division, Mines Branch, Department of Mines and Technical Surveys, Ottawa, Canada.

INTRODUCTION

Two die-cast aluminum alloy electric motor end bells were received from The Hoover Company Limited, Hamilton, Ontario. In a covering letter dated 24 August 1964 it was stated that one of the castings was hard to machine, while the other was satisfactory.

It was requested that the cause of the poor machinability be determined so that its origin (whether in the alloy as supplied to the foundry or whether picked up during remelting), could be established.

A certificate of analysis from one of the suppliers of the material was also included with the covering letter.

CHEMICAL ANALYSIS OF ALLOY

Drillings were taken from each casting and submitted for chemical analysis. The results, together with the "specification" and "heat" values given in the above-mentioned certificate are shown in Table 1. It will be seen that the main compositional differences between the "good" and the "poor" samples are in the iron, manganese and chromium contents. In the poor sample the specification limits were exceeded for each of these elements. In both samples the nickel content, although below the specification limit, was much higher than that of "Heat No. 153".

TABLE 1

Chemical Analysis Results

	Si%	Cu%	Zn%	Fe%	Mn%	Cr%	Ni%	Mg%
"Good" sample	8.18	3.54	1.45	0.85	0.32	0.05	0.15	0.07
"Poor" sample	8.34	3.96	1.36	1.65	0.92	0.17	0.11	0.09
Specification	7.5-9.5	3.0-4.0	1.25-1.50	≤1.0	≤0.5	-	≤0.5	≤0.1
"Heat No. 153"	7.95	3.26	1.34	0.97	0.18	-	<0.05	0.09

METALLOGRAPHIC EXAMINATION

Samples were taken from each casting and polished for metallographic examination. The structure of the good sample was typical of the alloy in question but the poor sample contained, in addition to the usual phases, many large primary crystals (see Figure 1). Attempts to identify this phase by etching tests were inconclusive although most of the etching characteristics were similar to those of constituents of the α-AlFeMnSi type.

It seems very probable that the poor machinability of this casting was caused by the presence of this constituent which, as is usual with such phases, is relatively hard and brittle.

IDENTIFICATION OF CONSTITUENT

In order to make a closer identification of the unknown constituent, samples were extracted from the poor casting by an electrolytic method. A piece of the casting was made the anode in a cell of which the cathode was a nickel strip and the electrolyte a solution of 10% HNO_3 and 10% HCl in water. At a current density of about 0.1 amp/sq in. and a potential difference of about 8 volts, the aluminum matrix was dissolved and some of the constituents present, including the unknown phase, fell to the bottom of the cell. The residue was washed with 50% HNO_3, the silicon removed by a heavy liquid separation and the remainder was found to be almost entirely the unknown constituent.

The extracted crystals were idiomorphic and the most frequent characteristic form was the rhombic dodecahedron although twinning was common especially in larger crystals. Figure 2 shows a representative sample of extracted crystals.

Spectrographic and chemical analysis of the crystals gave the results shown in Table 2.

TABLE 2

Analysis of Extracted Phase

	Al%	Fe%	Mn%	Si%	Cr%
Spectrographic	43.8	17.2	17.8	15.3	5.8
Chemical	56.4	17.9	9.9	9.8	2.15

Although the agreement between these analyses is poor it appears that the phase is of the α-AlFeMnSi type with chromium replacing some of the iron and manganese. The description of this type of phase is given by Phragmen[1] generally agrees with that of the present material, although some of the etching characteristics are different and have presumably been modified by the presence of chromium.

DISCUSSION

The difference in machinability between the two die castings has been shown to be probably caused by the presence, in the poor casting, of a comparatively high concentration of large primary crystals of a phase of the α-AlFeMnSi type with chromium. The unusually large amount of this phase appeared responsible for the high concentration of iron manganese and chromium in the poor castings.

References[2,3] to this type of inclusion in the literature indicate that its most probable origin is in the "sludge" which tends to collect at the bottom of melting and holding furnaces under certain conditions. This sludge is a segregation of higher melting point primary phases (such as the α-AlFeMnSi in the present case) which are formed when the melt temperature is low and, in particular, when ingot or scrap is added to the molten bath without adequate stirring.

These conditions are most likely to occur in pressure or gravity die casting foundries where alloy baths may be held for long periods. If metal is ladled from the top of the bath few inclusions will be encountered but if, occasionally, the ladle is dipped deeply enough to pick up some of the sludge many inclusions may be introduced into the casting.

The most satisfactory procedure to avoid inclusions due to this cause is to ensure that: (a) the bath is held at an adequate temperature (say 700 °C), and (b) when additions are made, the melt is thoroughly stirred to ensure complete solution of all the constituents: Preferably, melting should be done in a melting furnace and the metal subsequently transferred to a holding furnace. In this way the formation of sludge in the holding furnace, which is most likely to occur during melting is avoided. However, if it is necessary to make additions in the holding furnace adequate stirring and temperature control should be sufficient to avoid sludge formation.

It should be emphasized that the stirring referred to should be such as to reach to the bottom of the molten bath but should not cause undue turbulence on the surface.

The origin of the comparatively high chromium and nickel contents in the alloys is not clear but may have been the result of contamination with aluminum alloy scrap.

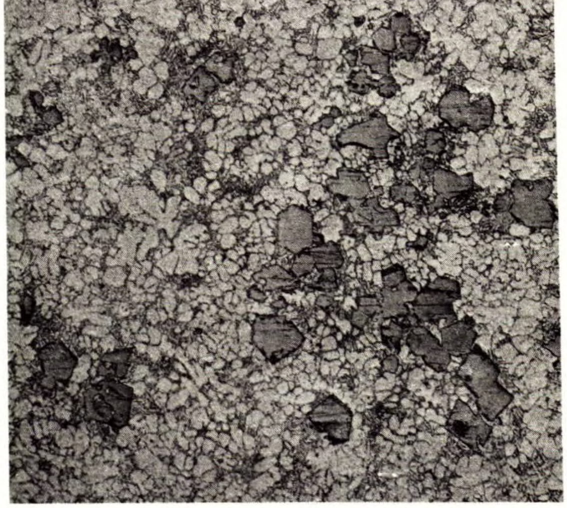
REFERENCES

1. G. Phragmen - "On the Phases Occurring in Alloys of Aluminum with Copper, Magnesium, Manganese, Iron and Silicon" - J. Inst. Metals 77, 489-552 (1950).

2. D. L. Colwell and O. Tichy - "Machinability of Aluminum Die Castings" - Trans. AFS 64, 236-241 (1956).

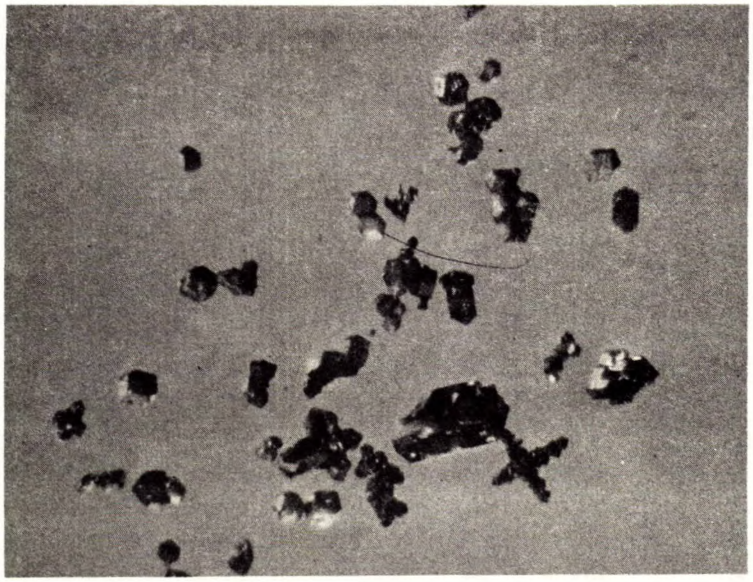
3. F. H. Smith - "Inclusions in Aluminum Castings" - Light Metals 23, 208-212 (1960).

WAP:vb



X100

Figure 1. Section through casting having poor machinability showing high concentration of large primary constituent.



X40

Figure 2. Extracted crystals of primary phase shown in Figure 1. Note typical rhomic dodecahedral shape of crystals.