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EFFECTS OF GRAIN REFINING ADDITIONS TO ALUMINUM ALLOYS

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Abstract

An efficient method of controlling the grain-size of commercial aluminum alloys is by continuous additions of grain-refining agents in the form of master-alloy rod which is fed automatically into the launder during casting. The simultaneous addition of titanium and boron in a single rod is more efficient and more economical than separate additions. Response of various alloys to grain refining may be determined using the laboratory test described. Effects of these additions on 6063 alloy are presented; preliminary results on other commercial alloys are included.

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Introduction

An efficient method of controlling grain size and minimizing cracking of billets in D.C. casting of commercial aluminum alloys is by making continuous additions of grain refining agents directly into the launder during casting operations. Additions by this method provides uniform quantities of refiner directly into the metal stream. Using direct rod additions to metal stream does require the refining agent to be effective in less than 2 minutes after additions are made, since the long holding times available for reaction usually associated with waffle type additions to large holding or reverberatory furnaces are not available. The advantages of uniform distribution of refiner, no fading effects, and constant addition levels far outweigh the disadvantage of rapid response time required.

Test Procedure

In order to determine the response time of grain refiners, a simple reproducible test has been developed and is in constant use at KBI. The test is not intended to predict actual grain size in D.C. cast billets, but only to provide a measure of time required to effectively grain refine commercial alloys. No attempt has been made to correlate test results with actual grain size attained during production runs.

Many grain refining effectiveness tests are in use today in the primary metal industry with none being entirely satisfactory for all purposes. One of these, a test method used by Alcan, was modified to fit our requirements and limitations.[1]

The modified test consists of casting the refined alloy into a preheated uncoated wrought mild steel mold (Figure 1), slicing a section from it and measuring the grain size by the intercept method, as follows:

1. Calculate the amount of refiner required to give the desired level in the 2500 gram charge.
2. Weigh up both alloy and refiner, the alloy to the nearest gram and the refiner to the nearest milligram.
3. Melt the alloy and hold it at 700°C ± 25°C using a high frequency induction furnace with a graphite crucible.
4. Add the refiner and stir for 45 seconds.

5. One minute after the refiner has been added, cast the alloy directly into a mold that has been heated to 350°C. The lip of the crucible is 3 inches above the mold.

6. Cast additional samples, 5, 10, 15, 20 and 30 minutes after the refiner addition.

7. After the specimens have cooled, section them and, measure the grain size by the intercept method using white light at 20X magnification. The intercepts are 20mm in length, and 3 intercepts per sample are counted and averaged to yield final grain diameter.

The 0.1 weight per cent Ti addition level is the one most generally used for comparison of refiners. However, other levels were used to determine the effect of concentration of titanium. In this work, levels of .005, .01, .02, .04, .05 and .08 weight per cent Ti were used.

Results

In the grain refining curves for 6061, 3003 and 5052 (Figures 2, 3 and 4), each point represents an average of 5 tests using six samples. The intercept method was used to measure grain size using white light; if polarized light had been used, the grain size plotted would have been 1/3 smaller as it is easier to detect adjacent grains with near-equal orientations. The white light counting is a more rapid determination of grain size and does provide reliable relative values. Figure 5 shows comparison of data obtained using the white light method and the two-colored light system used at Alcan.

Figure 5. Table Showing Comparative Grain Size Obtained by Counting Intercepts Using White Light and the Alcan Two-Colored Light Method

White Light	Alcan Two Light
.170	.110
.200	.150
.300	.190
.450	.310
.520	.400

With the exception of 6063 alloy, little improvement in final grain size is attained by longer holding times. Rod refiners that do not show an initial response at 1 and 5 minutes will normally not be effective at 30 minutes holding.

Structures

The $TiAl_3$ component is the most effective agent in grain refining and must be present in sufficient quantity to effectively refine the grain structure.[2]

Master alloys of Ti may be produced with different $TiAl_3$ structures. The needle form of $TiAl_3$ will usually be more effective than the blocky or chunky $TiAl_3$ form at high Ti levels. Needle $TiAl_3$ is the normal high temperature form.

In the 5.5% Ti 1.1% B refiner, all of the boron is combined with 2.5% of Ti as TiB_2, the remaining Ti existing as $TiAl_3$. In order to examine the two forms more closely, they were leached from their matrices and stereo scans made on the residues (Figure 7). A comparison of needle and blocky structure refiners (Figures 2 and 4) shows very little effect at low Ti levels. At levels of .02% and higher some difference can be seen. The response times to effectively grain refine at the 1 and 5-minute times are equal whether using needle or blocky $TiAl_3$ structures.

Effects at Time and Concentration

For the conditions of these tests, the grain refining was not generally a function of time except for 6063 alloy. Grain-refining curves for this alloy (Figure 6) show that:

1. Within limits, time can be traded for concentration. If the time between addition and casting is very short, a slightly larger addition than normal may be advantageous. Conversely, if there is ample time between refiner addition and casting, the addition level may be reduced.

2. The curves merge together at both the higher concentrations and the longer times.

It is probable that similar effects exist with alloys other than 6063. If so, it is also probable that the same type of relationship with time and concentration will be observed.

While these conditions may not reproduce conditions of commercial casting and while the grain size obtained in the test will probably not be the same as obtained in actual operation, the test does serve as a guide as to whether the refiner will perform satisfactorily under a specific set of conditions. When using rod additions continuously, this method of testing prior to installation will provide an answer as to whether or not continuous additions are feasible in a specific installation.

References

1. Smith, R. W., Private Communication, Queens University, Kingston, Ontario.

2. Mondolfo, L. F. and Marantonio, J. A., AIME Trans., Vol. 2, February 1971, page 465.

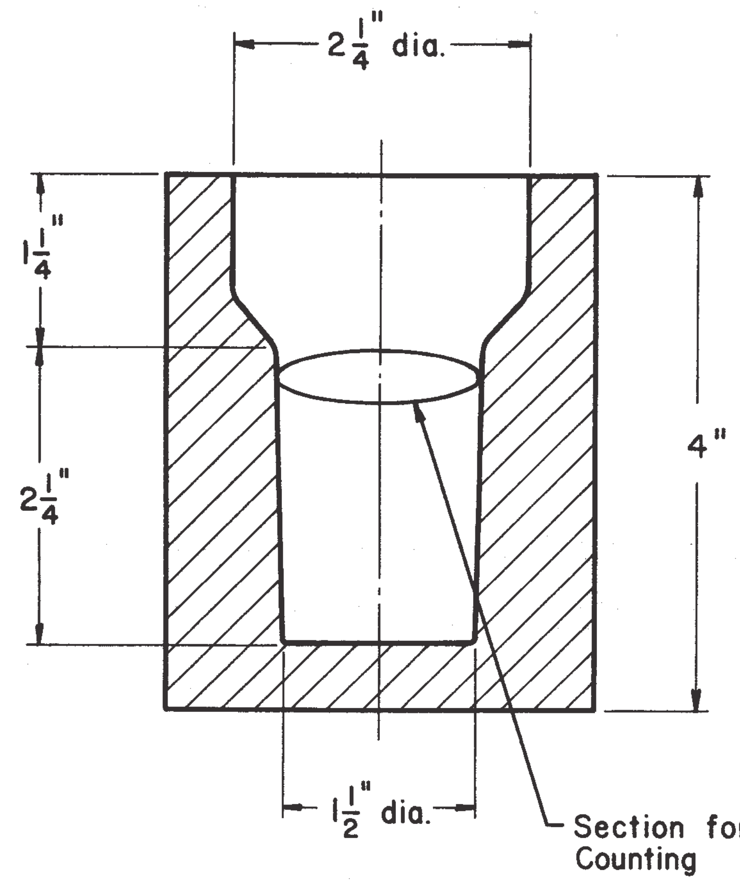

Fig. 1 Grain Refining Test Mold

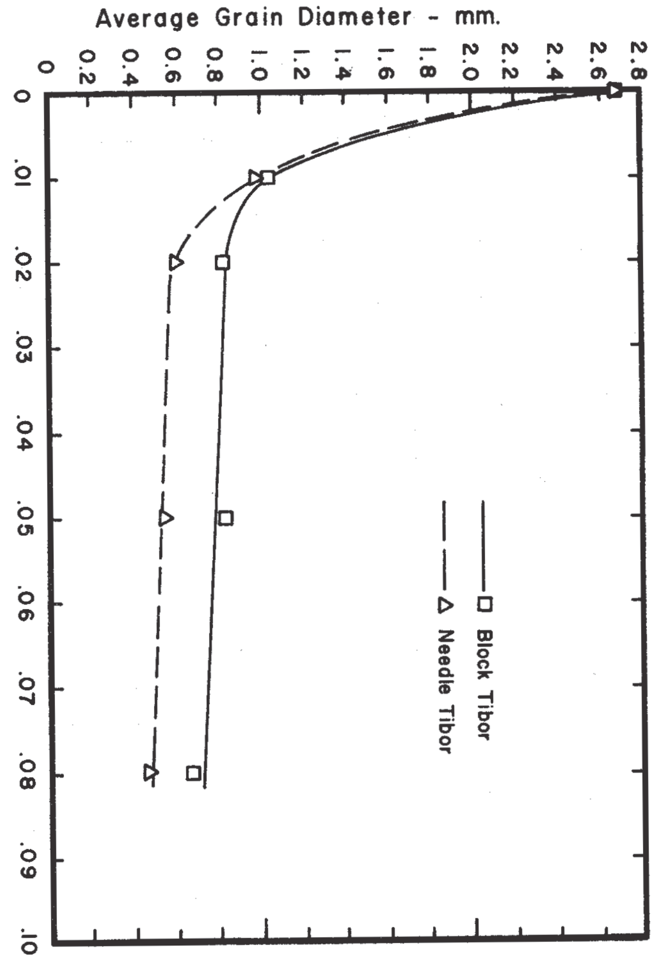

Figure 2 - Grain size vs. % of titanium addition
6061 Alloy – Refiner 5.5 % Ti 1.0 B

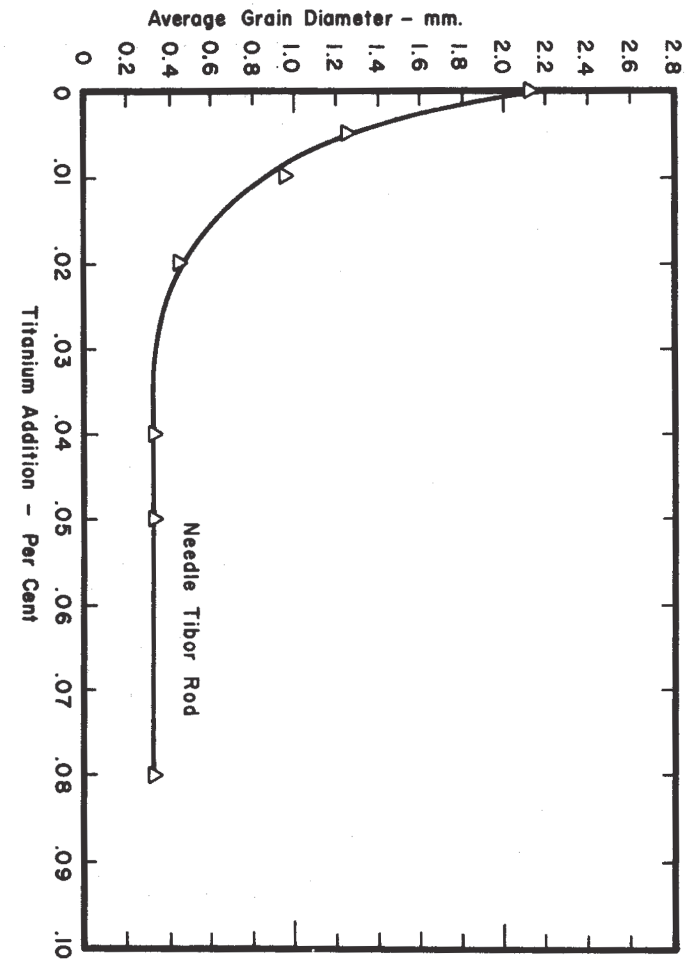

FIGURE 3 – Grain size vs. % of titanium addition
5052 Alloy – Refiner 5.5 % Ti 1.0 B

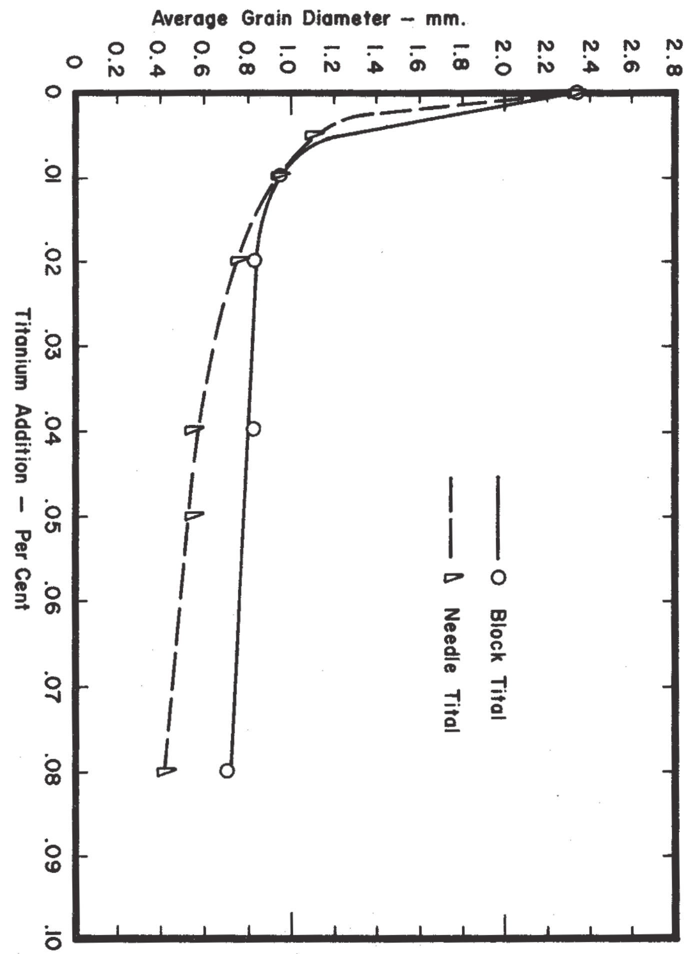

FIGURE 4 - Grain size vs. % titanium addition
3003 Alloy - Refiner 5.5% Ti

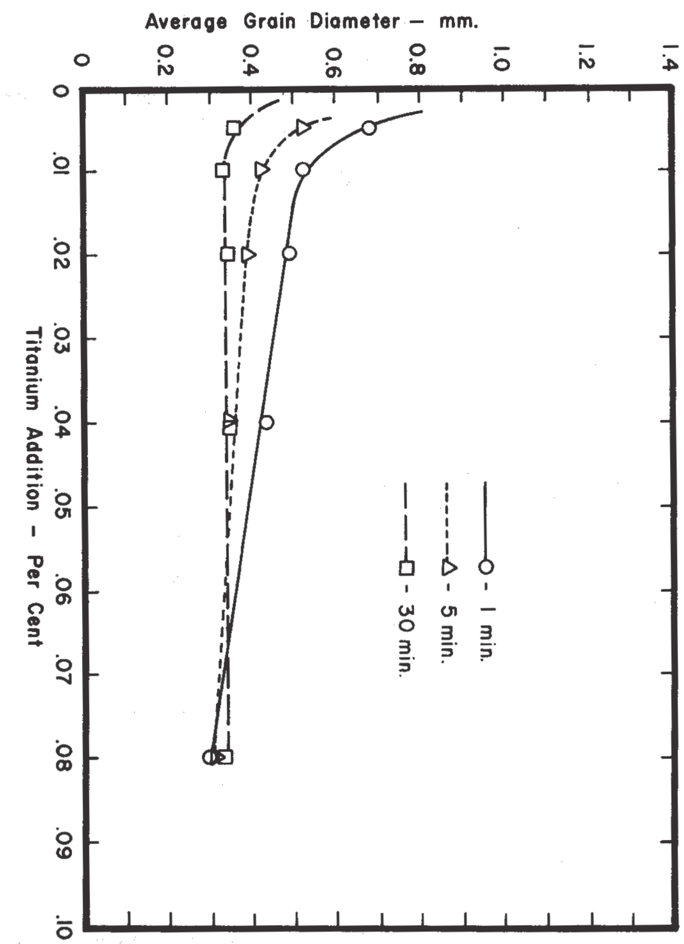

FIGURE 6 - Grain refining of commercial 6063. Refined with
KBI tibor rod after different times.

Figure 7. Scanning Electron Microscope Photomicrograph Showing Needle $TiAl_3$ Structure

Figure 8. Scanning Electron Microscope Photomicrograph Showing Blocky $TiAl_3$ Structure.