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► **To cite this version:**

M. Birch, A. Cowell. TITANIUM CARBON ALUMINIUM: A NOVEL GRAIN REFINER FOR ALUMINIUM-LITHIUM ALLOYS. *Journal de Physique Colloques*, 1987, 48 (C3), pp.C3-103-C3-108. 10.1051/jphyscol:1987312 . jpa-00226542

**HAL Id: jpa-00226542**

**<https://hal.science/jpa-00226542>**

Submitted on 4 Feb 2008

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**TITANIUM CARBON ALUMINIUM : A NOVEL GRAIN REFINER FOR ALUMINIUM-LITHIUM ALLOYS**

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This work explores the possibility of achieving grain size control in aluminium-lithium alloys with the titanium carbon aluminium (TiCA1) master alloys invented at the Technical University of Berlin and developed by London and Scandinavian Metallurgical Co Ltd (LSM).

Grain refining tests were conducted on a single batch of 8090 alloy using addition rates of 0.2wt% and 0.4wt% of TiCA1 and 3/1 titanium boron aluminium (TiBA1). Other tests using 0.4wt% of binary TiAl gave poor results, showing that the grain refinement obtained from TiCA1 was not due to the titanium content alone.

Results with the ternary master alloys show a decrease in grain size with increase in grain refiner addition. At the lower addition rate TiCA1 gives a smaller grain size in the alloy than does TiBA1, but at the higher rate the difference in grain size is less marked. Test-to-test variation is less severe with TiCA1; at 0.4wt% addition rate TiCA1 gives controlled grain refining in 8090 alloy to a grain size of about 200 microns.

Introduction

Titanium boron aluminium (TiBA1) is widely used for the grain refinement of aluminium alloys and has proved very effective. However, there are some aluminium alloys which are difficult to grain refine with TiBA1. Among these are aluminium-lithium alloys containing zirconium in which grain size control is particularly difficult.

Although grain refining of aluminium alloys with carbides has long been considered a possibility (1, 2), until recently no method was available for producing carbides which would nucleate aluminium effectively. Following the development of a method for producing a titanium carbon aluminium alloy (TiCA1) capable of grain refining aluminium (3 - 5), work was undertaken to show whether the new grain refiner would prove effective for the grain refinement of lithium-containing aluminium alloys. While TiCA1 is unlikely to displace TiBA1 as a grain refiner for general application, it is expected to prove useful in the refining of specific alloys, in particular those containing zirconium (6).

Experimental Programme

The aim of the programme was to establish the grain refining properties of TiCA1 in 8090 alloy, and to compare the results with the grain refining of these alloys with TiBA1. It was hoped this would allow recommendations to be made for effective methods of achieving grain refinement in the cast house.

The 8090 alloy used in this work was supplied by Alcan International Laboratories, Banbury. It was prepared as a single batch with the usual zirconium content but without the addition of grain refiners for the as-cast structure. Grain refining alloys were produced at London and Scandinavian Metallurgical Co Ltd. (LSM). The TiBAl master alloys were made on a commercial scale, and TiCa1 on a 35kg pilot scale in the research department. A summary of the compositions of the materials used is shown in Table 1.

The microstructure of TiCa1 contains a dispersion of TiAl3 and TiC. The TiC is typically present as evenly dispersed small particles (0.5 to 3 microns). The phase volume of TiC in an alloy containing 1wt% C is just under twice that occupied by TiB2 in an alloy with 1wt% B. TiAl3 is present as fine needles.

The Alcan grain refining test was used in this work. It was modified to help overcome problems of crucible erosion and alloy oxidation during testing (7,8). All the tests were carried out at 730C and conducted over one hour. Sample preparation and evaluation has been described elsewhere (8).

### Results

Figure 1 shows the effect of grain refining aluminium with TiCa1 and TiBAl having two Ti:B ratios. Two addition rates of TiCa1 were used; one was similar to that for TiBAl alloys (0.2wt%), the other twice as large. Our experience in refining aluminium alloys indicates that larger addition rates of TiCa1 are usually needed to match the grain refining results obtained with TiBAl. There is therefore no advantage in the use of TiCa1 for refining most alloys; however in view of the difficulties in refining zirconium-containing alloys it was felt that the programme was worth pursuing.

The grain refining results obtained for times above 30 minutes should be treated with caution; our experimental technique inevitably led to some loss of lithium as the test proceeded. With the use of rod refinement practices this is of no practical significance, since the metal solidifies within a few minutes of the master alloy addition.

Since the level of titanium introduced into the melt when grain refining with TiCa1 is higher than that introduced with 3/1 TiBAl, it is necessary to demonstrate that any grain refining effect is not due to titanium alone. Figure 2 shows the effect of grain refining 8090 alloy with 10%TiAl. A test is also reported in which no grain refining addition was made. The unrefined grain size at the start of tests on 8090 alloy varied considerably, having a mean value of 1018 microns and a standard deviation of 256 microns (16 observations).

Figure 3 shows the effect of grain refining 8090 alloy with 0.2wt% and 0.4wt% additions of TiCa1. For comparison, results are presented in figure 4 showing the grain refining effect of 3/1 TiBAl.

### Discussion

Preliminary work with 99.7%Al led us to expect that in virgin aluminium systems TiCa1 would be a less efficient grain refiner than TiBAl at the same addition rate. However it can be seen from Figure 1 that at short contact times TiCa1 is a very efficient

refiner for 99.85%Al. After about 10 minutes fade sets in rapidly.

Figure 2 shows that a 0.4wt% addition of 10%TiAl gives considerable grain refining of 8090 alloy. However the grain size is still large when compared to the grain size achieved at the same addition rate of TiAl (figure 3). This confirms that any grain refinement achieved by titanium alone has been greatly enhanced by the addition of carbon to form titanium carbide.

Figures 3 and 4 show the grain refining effect of 0.2wt% and 0.4wt% of TiAl and TiBAl respectively. Apart from 0.4wt% TiAl addition, the sets of curves display considerable test to test variability compared to that expected when using the same master alloy to refine a pure aluminium base. However at both addition rates TiAl gives a very much more consistent performance than a similar amount of TiBAl. It is important to note that the 8090 alloy used here was all from the same batch. Experience with this alloy indicates that batch to batch variation in grain refining response can occur.

The grain refining curves also show a smaller grain size for a given addition rate when refining with TiAl rather than TiBAl. This is most marked for a 0.2wt% addition.

It is possible to speculate that TiAl is a more effective grain refiner in 8090 alloy because it is not poisoned by zirconium, which has been shown to have a deleterious effect on the efficacy of TiB2 nuclei (7).

It is difficult to explain the test to test variation in the grain refining response of 8090 alloy. Considerable grain size variation also occurs in the unrefined alloy. Possibly components of the alloy (eg Cu) show a constitutional grain refining effect which is sensitive to minor variations in composition between samples from the same batch.

Although TiAl is unlikely to be an effective substitute for TiBAl in most applications, it should be considered when establishing a grain refining practice for commercial lithium-containing alloys. Test to test response to grain refining additions is such that trials under cast house conditions should be made before a practice is finally chosen.

LSM is continuing the development of TiAl, including the production of rod. When the alloy is available in this form it should provide advantages to the cast house producing 8090 or other zirconium-lithium or zirconium containing alloys.

### Conclusions

The following conclusions are drawn from this work:

1. The response of aluminium-lithium alloys to grain refining treatment shows considerable test to test variation.
2. TiAl shows less test to test variation as a grain refiner for 8090 alloy than does TiBAl.
3. TiAl at 0.4wt% addition rate can provide grain refining of 8090 alloy to a grain size of about 200 microns.

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Table 1. Composition of Master Alloys

Master Alloy	Composition (wt%)			
	B	C	Ti	Al
TiAl	-	1	8	bal
3/1 TiAl	1	-	3	bal
5/1 TiAl	1	-	5	bal

FIGURE 1. COMPARISON OF TIBAI & TICAI GRAIN-REFINING EFFECT IN 99.85%Al

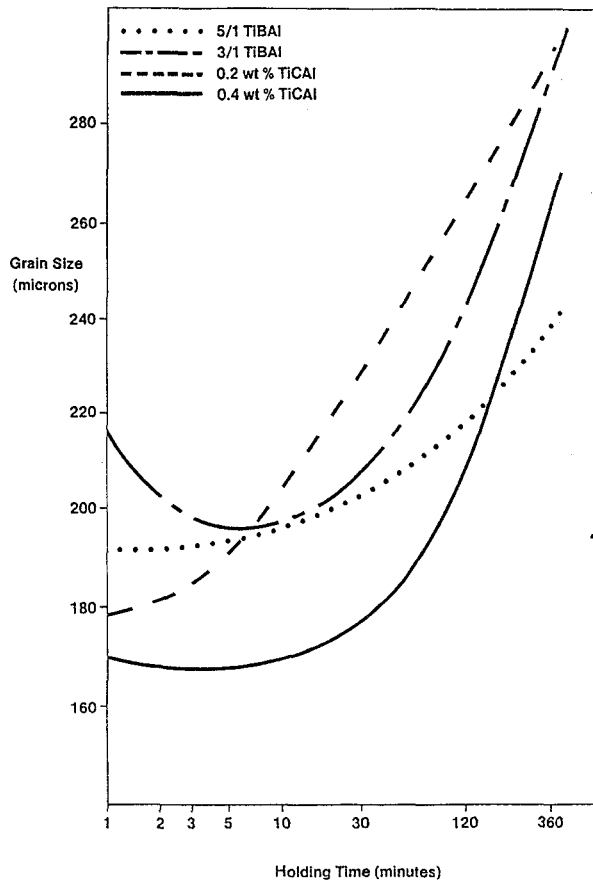


FIGURE 2. EFFECT OF GRAIN REFINING 8090 ALLOY WITH 10% TIAI

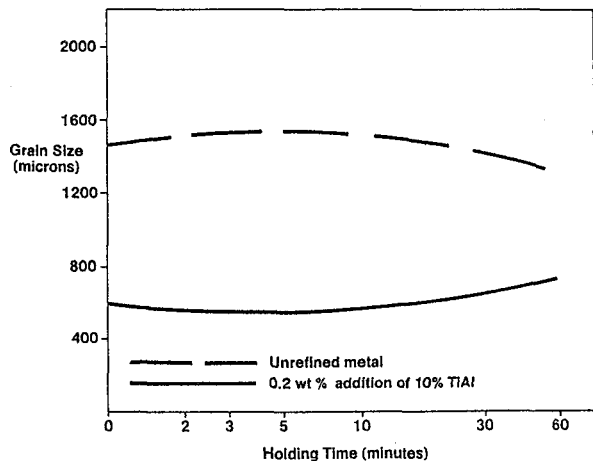


FIGURE 3. EFFECT OF GRAIN REFINING 8090 ALLOY WITH TICAL

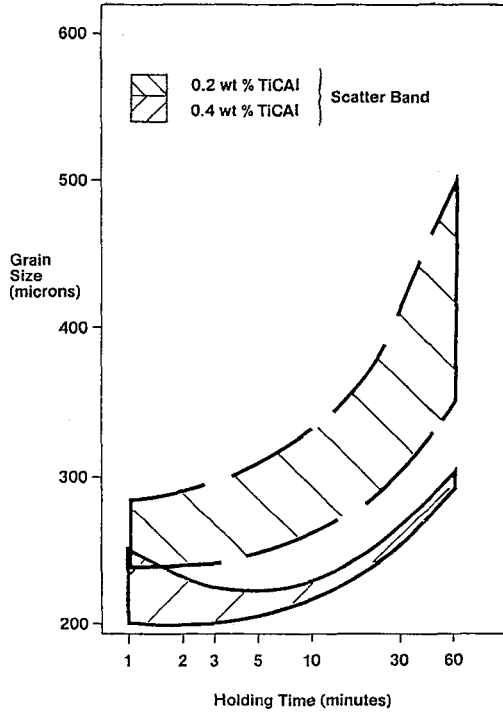


FIGURE 4. EFFECT OF GRAIN REFINING 8090 ALLOY WITH 3/1 TIBAI

