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STROBLOY - THE NEW COMBINED GRAIN REFINER AND MODIFIER FOR HYPOEUTECTIC ALSI FOUNDRY ALLOYS

Eivind Bondhus, Trond Sagstad
Hydelko KS, Såheimsveien, 3660 Rjukan, Norway
Tlf.: +47 3509 3600 Fax.: +47 3509 3197
E-mail: eivind.bondhus@hydro.com / trond.sagstad@hydro.com

Abstract

Hydelko presents a new combination alloy for use in hypoeuctectic aluminium silicon foundry alloys. Strobloy simplifies today's addition practice of grain refiner and modifier by reducing the number of additions from two to one.

Strobloy is a combination product between the well-established TiBloy, and strontium. The alloy contains nucleating particles in the form of the mixed boride (Al, Ti)B_2, which is beneficial regarding settling and grain refining efficiency. Strontium is present as fast-dissolving Al_4Sr particles.

Trials carried out indicate that Strobloy shows very good performance compared to separate additions of TiBloy/AlTi5B1 and AlSr master alloy. The grain refining efficiency and modification level is the same or better. This paper displays results collected from tests done with different strontium levels in an A356 alloy. Comparisons to separate additions of TiBloy and AlSr are presented.

Introduction

Based on a historical perspective, AlTi5B1 has normally been used as a grain refiner in AlSi foundry alloys. As an alternative to this grain refiner, Hydelko and Aluminium Rheinfelden introduced TiBloy in 1993 [1]. TiBloy is designed specially for the foundry industry. With its small, low-density borides, TiBloy has proven better properties regarding grain refining efficiency and long holding times in this alloy system [2,3].

Since its introduction, TiBloy has increased in demand, and is now a well-established grain refiner for aluminium-silicon alloys. As a further development of this alloy, Hydelko is now presenting Strobloy. Strobloy is based upon TiBloy, but with strontium added. Therefore, Strobloy both grain refines and modifies the casting. This will simplify today's addition practice, by reducing the number of additions from two to one product.

Trials have been carried out in order to document Strobloy's efficiency, both as a grain refiner and as a modifier. Hydelko has tested the alloy with different addition rates. Reynolds Corporate Technology Center has also participated with several trials. In this paper, the results from these tests are displayed.

Theoretical background

Strobloy is manufactured in order to have the benefits of both TiBloy as a grain refiner and strontium as a modifier. This is done by first letting titanium and boron react to make (Al, Ti)B_2. These particles have low solubility in aluminium. By adding strontium after this reaction, a minimum of phases containing Ti, B and Sr will be created. Therefore, (Al, Ti)B_2 and Al_4Sr will be the dominating phases in Strobloy. Figure 1 shows the microstructure in Strobloy. The largest, grey particles are the strontium containing phase; Al_4Sr. These particles are the same fast-dissolving Sr-particles that are present in a normal 5% or 10% Sr master alloy.

Mixed borides

By changing the Al level in the diboride you can also change the average particle size. Strobloy is designed especially to have small sized (Al,Ti)B_2. It contains only (Al,Ti)B_2 particles, compared to other AlTiB based grain refiners that also contains Al_3Ti. The diboride size distribution is in the range of 50 - 1000 nm and contains at least 100 times more particles compared to other conventional grain refiners, and of course, a higher number of potent nucleus.

The chemical composition of the diboride $(Al_x, Ti_{1-x})B_2$ in Strobloy has $x \approx 0.35$, and the density of the particles is decreasing with increasing Al content. Smaller and lower density particles have advantages in the matter of fading/settling and the particles will be stable in the melt for a longer period compared to other grain refiners with lower x in the $(Al_x, Ti_{1-x})B_2$ composition. Strobloy as a grain refiner has therefore at least three different advantages compared to conventional grain refiners [1,2]:

- It contains more potent nuclei per Boron unit
- The particles are significantly smaller
- The particles have lower density

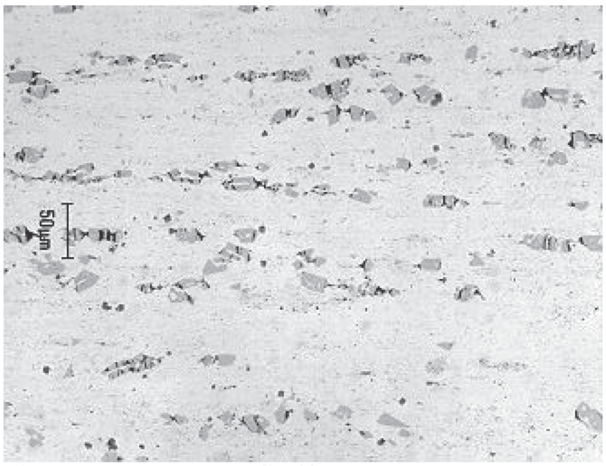

Figure 1 *Microstructure in Strobloy.*

Experimental work

Trials with different Strobloy addition levels have been carried out, both at Hydelko and at Reynolds Corporate Technology Center. Strobloy from the same charge has been used in the tests.

Reynolds trials

One lot of base stock was made up containing 7% Si, 0.3% Mg, and either 0,10% or 0,16% Ti. The metal was prepared in a 400-pound induction furnace and cast as a series of small "pigs". They were remelted in a 50-pound Speedy Melt electric resistance furnace. Upon achieving meltdown the temperature was set for 1400 degrees F. Once the temperature stabilized, the melt was degassed with a small air driven rotary degasser for 10 minutes using an argon 5% chlorine mixture. The addition to be studied was placed in the melt and stirred for 10 seconds with a graphite rod. The first series {1 minute} was taken as quickly as possible after the stir. The exact elapsed time for this first sample was difficult to determine.

Thermal analysis was conducted with an apparatus sold by GKS (Dr. Geoffrey K. Sigworth) Engineering of Johnstown Pennsylvania. The GKS equipment produces a log, which contains the times of the test, the undercooling at the liquidus (alpha undercooling) and an ASTM grain size number derived from the amount of undercooling. The undercooling at the eutectic temperature is determined, using 577°C as the reference temperature for Sr free A356.

About four readings per second are obtained

At each test time a "golf-tee" grain size sample, a chemical analysis button, and a thermal analysis test were obtained. Standard times were typically 1, 5, 30, 60, 90, and 120 minutes. In some cases the times were extended out to 6 hours. The golf tee samples were sawed off 2 inches from the top and turned smooth on a lathe. Just below the 2 inch point a small sample for metallography and microscopy was obtained at the center of the golf tee. Typical unetched structures were obtained at 500x using a digital microscope. Various etches were tried, but Poulton's triple etch gave the best results.

Four different strontium levels were used at Reynolds; 50, 100, 150 and 200 ppm Sr. Also two different titanium levels were used; 0,10wt% and 0,16wt%.

Table 1 *Chemical content in Strobloy used in the trials at Reynolds*

Material	Si (%)	Ti (%)	B (%)	Fe (%)	Mg (%)	V (%)	Sr (%)
Strobloy	0,04	1,49	1,2	0,11	-	0,01	6,49

Table 2 *Chemical content in some of the samples from the Reynolds trials.*

Material	Holding time	Si (%)	Mg (%)	Fe (%)	Ti (%)	Sr (%)
0,10% Ti - 50 ppm Sr	Ref.	6,56	0,27	0,12	0,94	0,0001
0,10% Ti - 50 ppm Sr	6 h	6,47	0,26	0,12	0,94	0,0028
0,10% Ti - 100 ppm Sr	Ref.	6,47	0,27	0,12	0,95	0,0001
0,10% Ti - 100 ppm Sr	6 h	6,52	0,27	0,12	0,94	0,0046
0,16% Ti - 50 ppm Sr	Ref.	6,94	0,39	0,09	0,16	0,0002
0,16% Ti - 50 ppm Sr	6 h	7,02	0,38	0,09	0,16	0,0029
0,16% Ti - 100 ppm Sr	Ref.	6,95	0,39	0,09	0,16	0,0002
0,16% Ti - 100 ppm Sr	6 h	7,04	0,37	0,09	0,16	0,0065
0,16% Ti – 150 ppm Sr	Ref.	6,96	0,38	0,09	0,16	0,0002
0,16% Ti – 150 ppm Sr	2 h	6,99	0,38	0,09	0,16	0,109

Hydelko trials

At Hydelko, thermal analysis tests have been carried out with an AlSi7Mg alloy supplied by Hydro Aluminium R&D Materials Technology. Ti and Sr were added as waffle, Strobloy as cut cast bar and TiBloy as rod.

Three strontium levels were tested at Hydelko; 50, 100 and 150 ppm Sr. 0,75 - 1,5 - and 2,3 kg/MT 6,5% Sr Strobloy were added, respectively, to obtain these levels. For a comparison to this, trials with separate addition of TiBloy and strontium also have been done. 50 and 100 ppm Sr were tested in this regard.

Thermal analysis and grain size measurements

About 3 kg of material was melted in a resistance furnace. The melts tested for grain refining ability were kept at a temperature of approx. 730 °C during sampling. A commercially available thermal analysis package (Wintherm) was used in the assessment of the nucleating potential of the melt. The specimens were cast in Croning sand crucibles with an expendable thermocouple. Temperature/time data from the cooling curve (Figure 2) were recorded and later processed. Samples were cast before and 15 min. after Ti addition. After grain refiner addition samples were cast after 5, 30, 60, 90 and 120 min. holding time. The specimens were cut above the thermocouple and prepared for metallographic examinations.

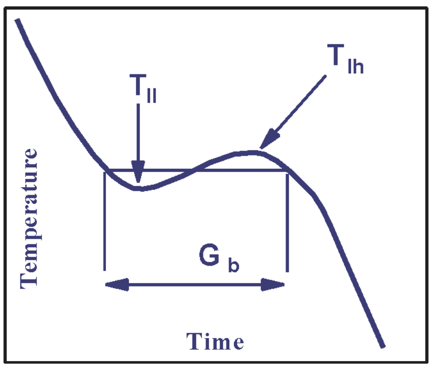

Figure 2 *Cooling curve*

Chemical composition

The chemical content of the base material and the additives is given in Table 3:

Table 3 *Chemical content in base material and additives used in the Hydelko trials.*

Material	Si (%)	Ti (%)	B (%)	Fe (%)	Mg (%)	V (%)	Sr (%)
AlSi7Mg	6,84	0,002	-	0,13	0,27	0,002	-
Strobloy	0,04	1,49	1,2	0,11		0,01	6,49
TiBloy	0,07	1,68	1,41	0,08	-	0,02	-

Table 4 *Chemical content in some of the samples from the Hydelko trials.*

Material	Holding time	Si (%)	Mg (%)	Fe (%)	Ti (%)	Sr (%)
0,10% Ti - 50 ppm Sr	5 min.	6,31	0,29	0,16	0,09	0,0051
0,10% Ti - 50 ppm Sr	60 min.	5,74	0,24	0,12	0,10	0,0028
0,10% Ti - 100 ppm Sr	5 min.	5,91	0,22	0,13	0,09	0,0090
0,10% Ti - 100 ppm Sr	120 min.	6,21	0,24	0,14	0,09	0,0059
0,16% Ti - 150 ppm Sr	5 min.	6,19	0,25	0,13	0,10	0,0130
0,16% Ti - 150 ppm Sr	60 min.	6,47	0,25	0,13	0,10	0,0105

Results

The results from the trials are presented as charts and tables containing data from thermal analysis and metallographic analysis. The modification index gives an indication of the modification (Figure 3-7), and the grain size counting tells the level of grain refinement (Figure 8-9). A comparison between Strobloy addition and separate addition of TiBloy and strontium is given. All reference samples are taken after titanium addition.

Modification.

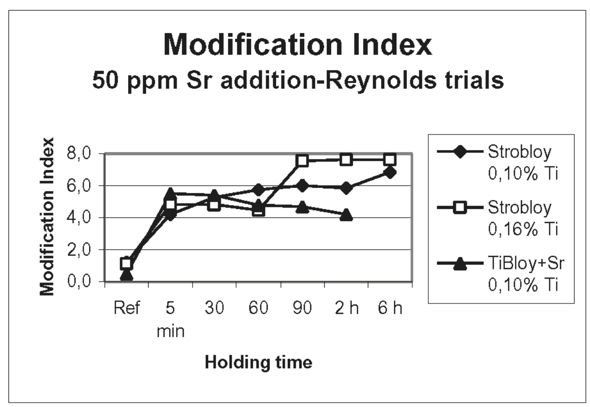

Figure 3 *Modification index in Reynolds trials – 50 ppm Sr addition.*

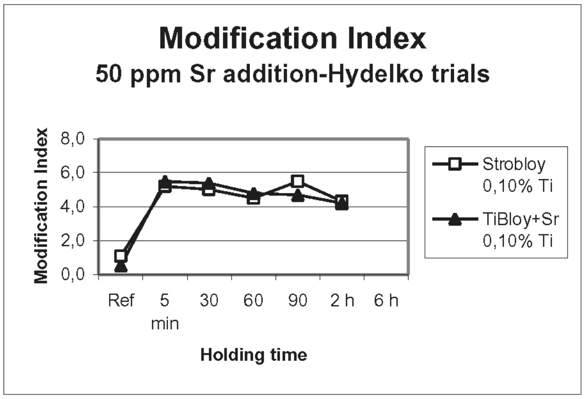

Figure 4 *Modification index in Hydelko trials - 50 ppm Sr addition*

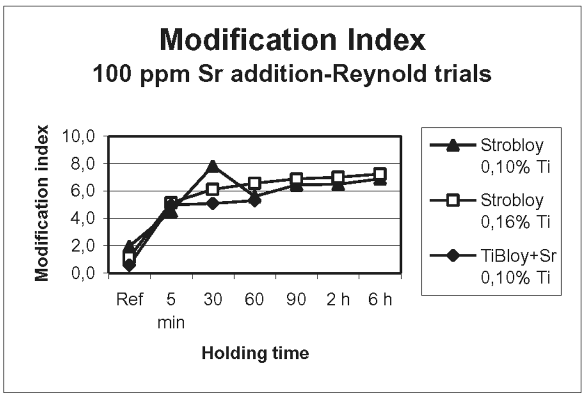

Figure 5 *Modification index in Reynolds trials - 100 ppm Sr addition*

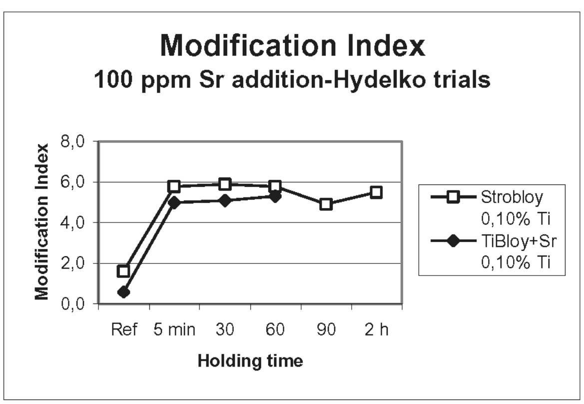

Figure 6 *Modification index in Hydelko trials - 100 ppm Sr addition*

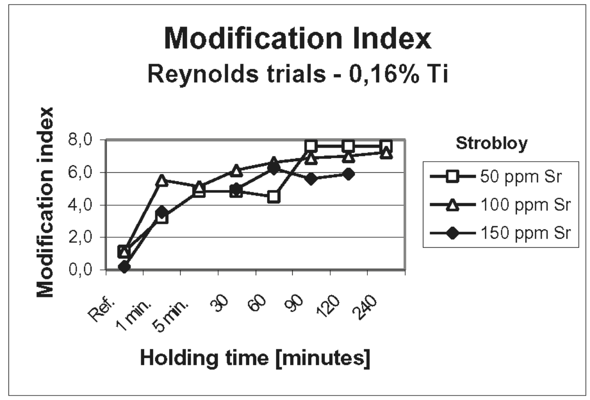

Figure 7 *Modification index in Reynolds trials – different Sr levels.*

Grain size

The results correspond with the three different Strobloy addition rates, according to 50, 100 and 150 ppm Sr addition. The titanium and boron addition will be as shown in Table 5:

Table 5 *Approx. addition rates of strontium, titanium and boron, and the Strobloy addition rate.*

Sr [ppm]	Ti [ppm]	B [ppm]	Addition rate [kg/MT]
50	12	9	0,8
100	23	18	1,5
150	35	28	2,3

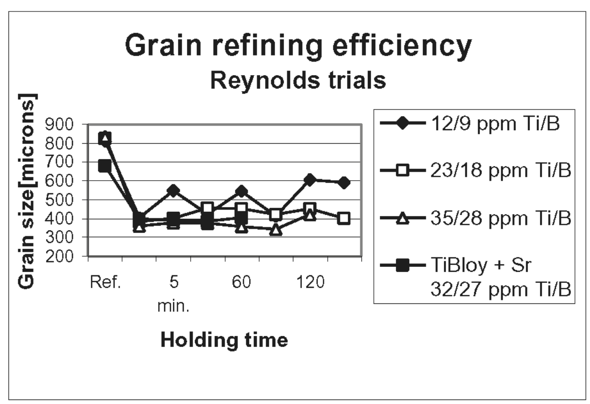

Figure 8 *Grain sizes measured in samples from the Reynolds trials.*

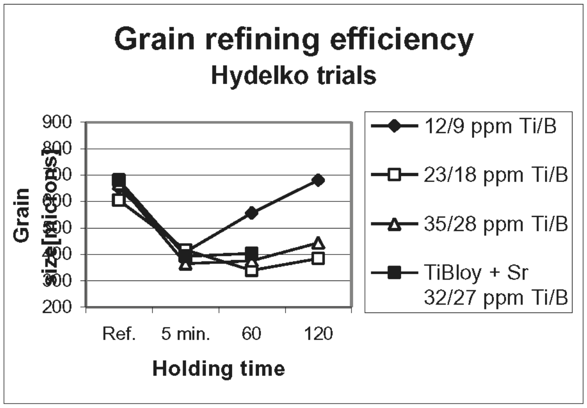

Figure 9 *Grain sizes measured in samples from the Hydelko trials.*

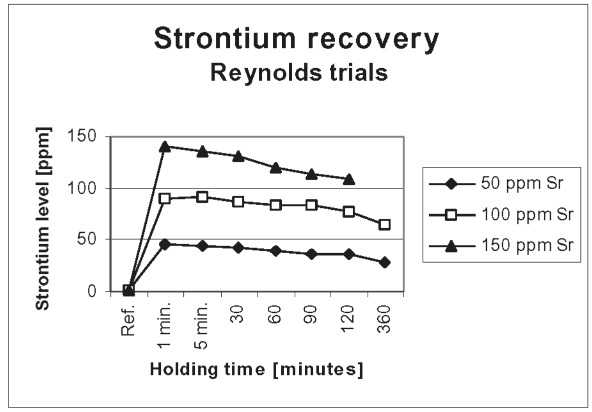

Figure 10 *Strontium recovery in Reynolds trials (0,16% Ti)*

Discussion

As an overall impression of these trials, Strobloy show good efficiency regarding both modification and grain refinement. Standard addition rate of TiBloy is 2 kg/MT, which means that approx. 32/28 ppm Ti/B is added to the melt. The lowest addition level of Strobloy was 0,8 kg/MT in these trials, which correspond with 50 ppm Sr and 12/9 ppm Ti/B. The grain size achieved at this addition rate is somewhat lower compared to the higher addition rates, but the modification level is still surprisingly good.

In this paper comparisons have been made between trials carried out at two different places, with different equipment and different personnel. Therefore, several factors will influence the results. The chemical content in the base material is not exactly the same, the thermal analysis equipment is different, and the practice may differ to some extent. But the comparisons have been given as an indication of what it looks like. The experiences are nothing but positive so far. All testing performed to-date seems to indicate that Strobloy is a product that effectively grain refines and modifies at approximately the same level as for separate additions of TiBloy and strontium.

Strontium recovery

Chemical analysis show that the strontium level decreases with increasing holding times. This is displayed in Figure 10. Due to Sr burn-off from the melt, the strontium level will decrease with the time. The loss seems to be most severe when the highest Sr levels is applied. What is worth noticing, is that the modification rate does not seem to decrease with the decreasing strontium level throughout the holding time.

Conclusion

In earlier work [1-3], it is found that TiBloy show better grain refining qualities in foundry alloys compared to the conventional grain refiner AlTi5B1. Strobloy seems to have beneficial properties regarding grain refinement and modification of alloy A356. Compared to separate additions of TiBloy and strontium, the efficiency of Strobloy is approximately the same.

References

[1] H. Koch, U. Hielscher, A. Schaathun, H. Fossli; “High effective permanent grain-refining for AlSi foundry alloys”, Rheinfelden: News from the R&D Department.

[2] E. Bondhus, T. Sagstad, “Grain refinement of hypoeutectic Al-Si foundry alloys with TiBloy”, Light Metals 1999, 693-698

[3] T. Sagstad, Nora Dahle, E. Bondhus, Hubert Koch, “Grain refining of hypoeutectic Aluminum-Silicon alloys with TiBloy”, Molten Aluminum Processing, AFS-1998, 97-116.

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