

## **GRAIN REFINING OPTIMISATION OF A356 ALLOY BY Mn-ADDITION\***

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**ABSTRACT:** Raw materials for semi solid processing are specific alloys, defined by different properties. The chemical composition is one of these properties. Producer of raw material as well as the processing industries have special requests on the behaviour of the required materials. An essential property is the microstructure of the material which is influenced by chemical composition as well. So the content of elements in the alloys must be analysed carefully. Fine and globular grains are necessary for thixotropic behaviour. For this reason, a typical Thixoforming alloy is tested by addition of various grain refiners and different Mn-additions before and after the semi-solid process-step “heating”. The assessment of the tests is done by metallography.

**KEYWORDS:** Grain refining, alloy optimisation, AlSi7Mg, Mn-addition, metallography

## **1 INTRODUCTION**

This report gives some results of the project “raw material production” which is part of the Sonderforschungsbereich 289 at the Department of Process Metallurgy (IME – Metallurgische Prozesstechnik und Metallrecycling).

In preliminary tests, which considered the influence of impurities on the microstructure, a good effect of Mn-addition on grain size and globular structure was found. These properties are essential to produce thixotropic slurries.

In this paper examinations on chemical grain refinement of a typical thixoforming alloy (AlSi7Mg) and optimisation by Mn-addition is presented. The objective is to modify the microstructure, so that while reheating the desired small and rounded grains can be obtained within a short time of isothermal holding.

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## 2 EXPERIMENTAL PROCEDURE

### 2.1 MELTING AND ALLOYING

The basic alloy is melted in an induction furnace. Then Sr and Mn are added to the melt and the temperature is hold at 720°C for ½ hour. The melt was stirred manually in order to enhance the solution of the alloy-elements. Finally the grain refiner was added into the melt. The holding time was 5 minutes, so fading is avoided. The prepared melt is cast into a water cooled crucible.

### 2.2 ALLOYS

#### 2.2.1 Basic alloy

The basic alloy is the main component of each melt.

	Si [%]	Fe [%]	Cu [%]	Mn [%]	Mg [%]	Ni [%]	Zn [%]	Sr [ppm]	Ti [ppm]
(1)	7,1	0,14	<0,01	<0,01	0,35	<0,01	0,02	200	200
(2)	6,5-7,5	0,1-0,6	0,1-0,25	0,05-0,35	0,17-0,45	-	0,05-0,35	200-250	200-250

**Tab 1:** Chemical composition of the thixoforming alloy AlSi7Mg (A356)

(1) composition of the applied basic test alloy,

(2) composition of the European standardised alloy [1]

Therefore a smaller tolerance range for alloying elements is necessary than in standard alloys. The content of accompanying elements is even lower than in any European standardised alloy.

#### 2.2.2 Pre-alloyed Mn-powder

Up to 0.4% Mn has been added. A common method to add Mn into aluminum is to stir a pre-alloyed Mn-powder in the form of briquettes into the melt. The die formed briquettes consist of the respective alloy- and aluminum-powder. The amount of Manganese is generally between 50-90%. If the content of the alloying element is high, diluting of the basic alloys can be neglected, but since holding temperature is quite low, dissolution of the Mn requires more time.

#### 2.2.3 Sr-addition

Grain modifying of the Si-rich eutectic components is effected by Sr- or Na-addition. The most important advantages of Sr-addition is its long-time efficiency, lower metal loss by oxidation, lower intake of hydrogen and avoidance of super-modifying in comparison to Na-addition. On the other hand the grain refinement could be more effective by Na-addition [2]. In our work a Sr-addition is preferred.

#### 2.2.4 Grain refiners

A wide range of different grain refiners are available on the market [3].

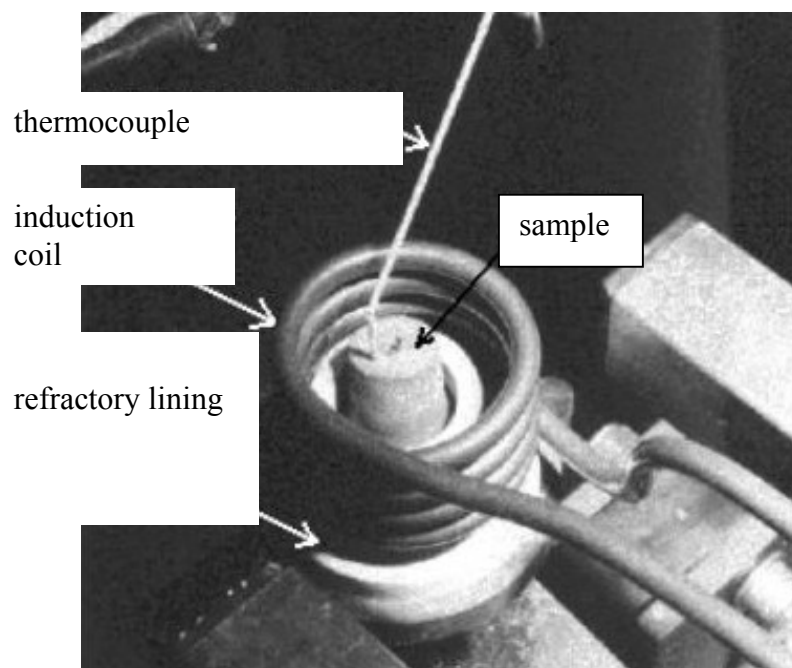
Depending on the application various master alloys are in use. Generally Al-Ti-B grain refiners are more common than Al-B, Al-Ti-C or Al-Ti alloys. The presence of boron increases the efficiency and fading time. However there is a tendency to minimise the boron content because of the formation of Ti-B particles. In some applications they have a negative influence [4].

The following grain refiners are tested:

AlTi5B1, AlTi3B1, AlTi5C0.2, Tibloy (AlTi1.7B1.7)

## 2.3 HEATING

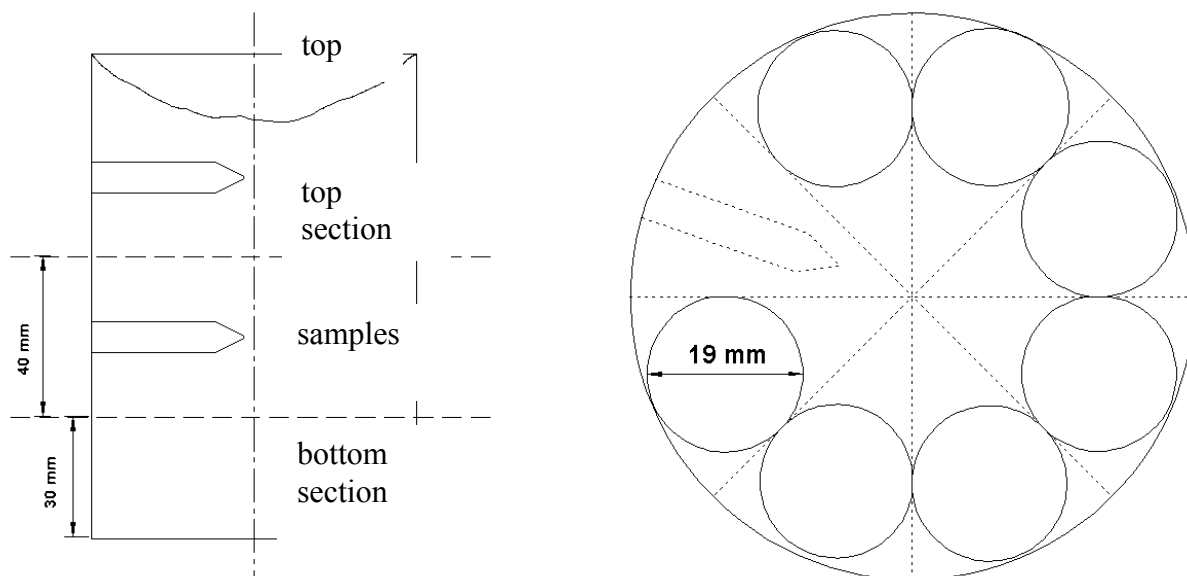
Samples were taken before and after heating (**Fig. 1**).



**Fig 1:** Heating equipment

The induction coil consists of four turns of 45mm diameter. The temperature was measured in the sample. A Pt/Rh- thermocouple was placed in a 10 – 12 mm hole, drilled into the middle of the sample. At 580°C the solid-fraction was nearly 50%. The sample was taken out of the furnace and immediately quenched in water.

## 2.4 SAMPLING

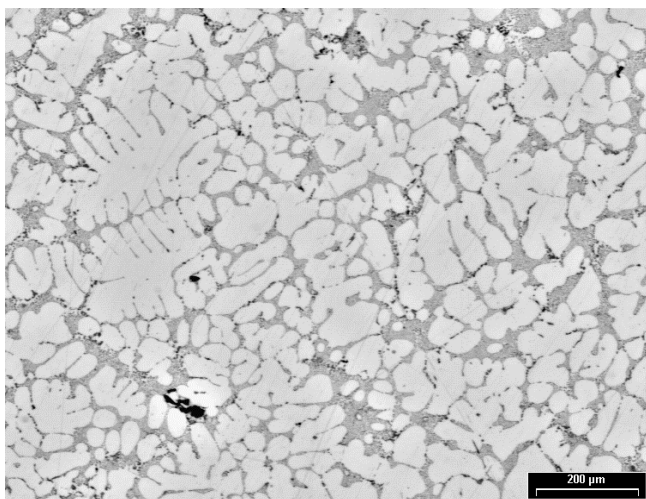


**Fig 2:** Sampling of the billets before and after heating

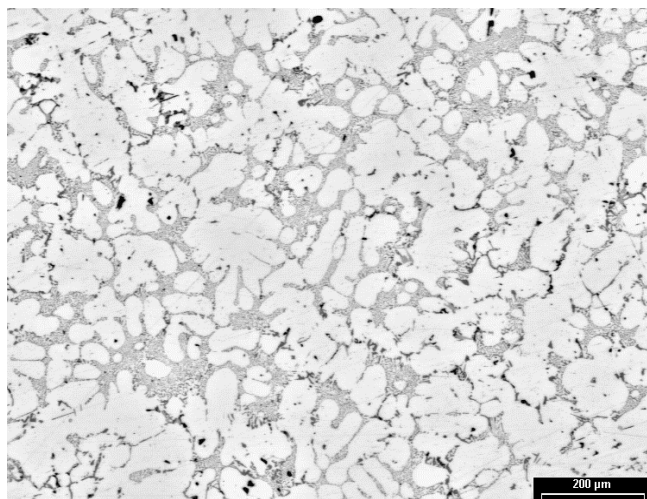
An original and the heated / cooled sample were cut into different sections (**Fig. 2**). Drillings were taken of all sections and analysed chemically. Furthermore seven samples were prepared for metallographic analyses.

## 2.5 METALLOGRAPHY

The average grain size and shape factor of the samples were analysed by computer aided image analysis.



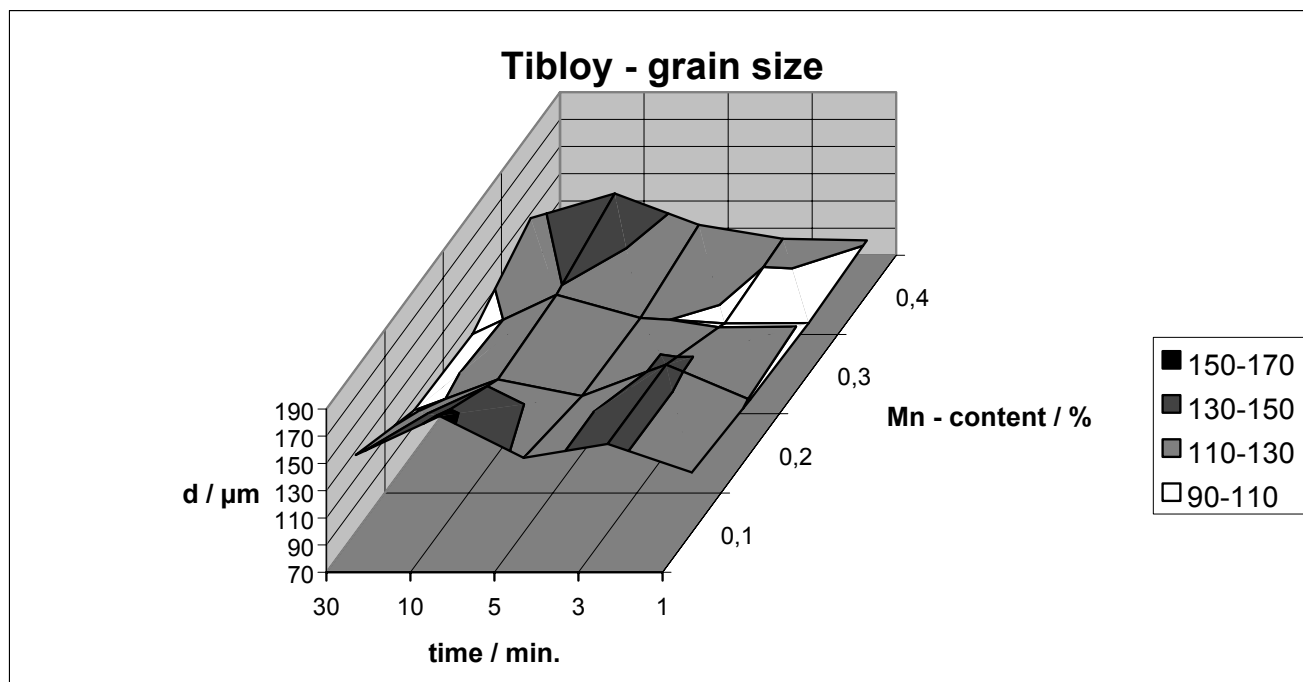
**Fig.3:** A356 + Tibloy\* + 0.1 % Mn



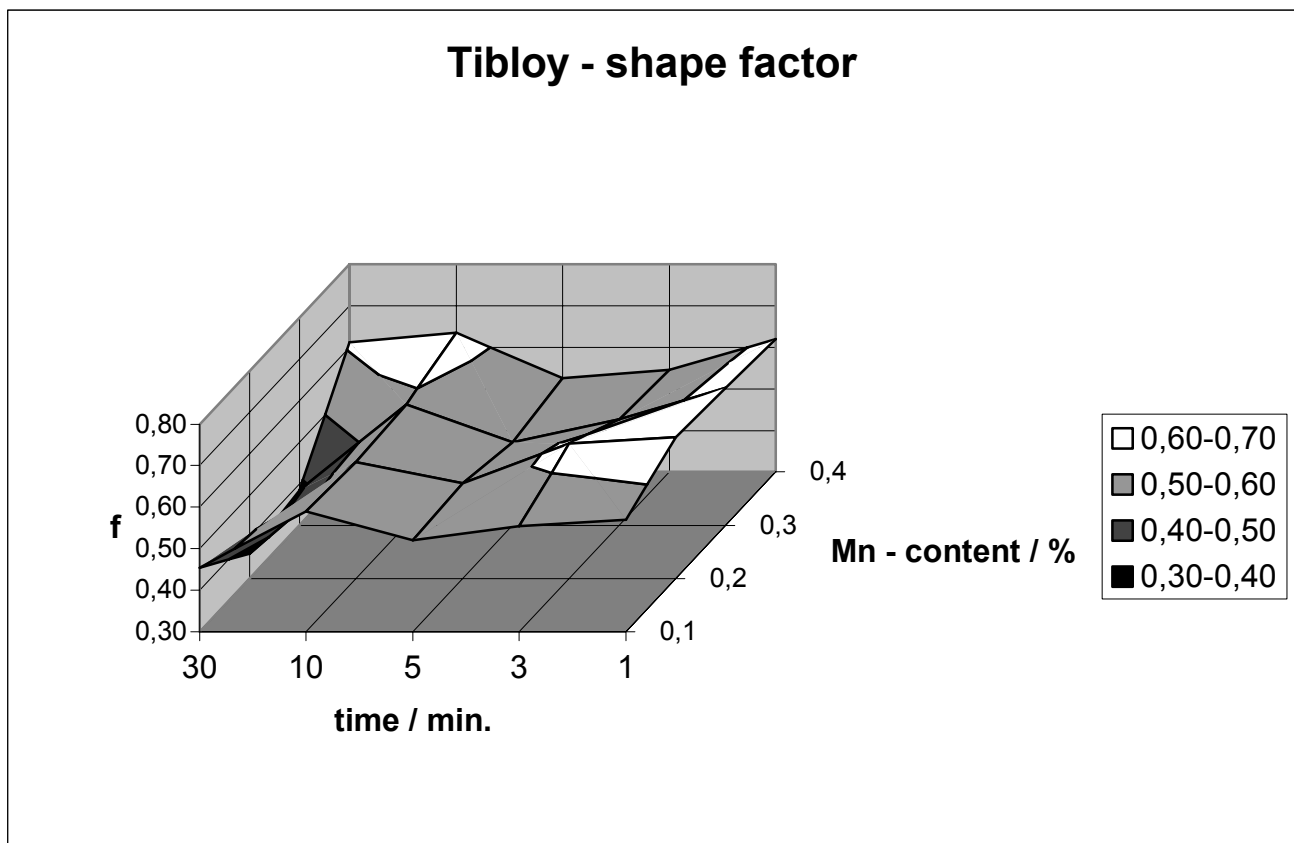
**Fig 4:** A356 + Tibloy\* + 0.4 % Mn

\*Ti = 0.2%

The microscopic observation shows insignificant effects of Mn-addition with different grain refiners. But the computer aided image analysis indicated some effects (**Fig. 5, 6**).



**Fig 5:** A356 + Tibloy – grain size



**Fig 6:** A356 + Tibloy – shape factor

By an addition of 0.15 - 0.35 % Mn the average grain size can be decreased to  $<100\mu\text{m}$  even when holding time is long. Further Mn-addition  $>0.2\%$  has a good effect on the shape factor especially when holding time is short.

### 3 SUMMARY

The material optimised by Mn-addition is suitable for thixoforming. The microstructure meet the demands for thixoforming within typical fine globular grains.

The Mn-addition between 0.2 – 0.4% has a good effect on the average grain size and the shape factor. This is independent of the type of grain refiners used. In practice holding times between 10 – 30 minutes are applied. In this case an average grain size  $<100\mu\text{m}$  and a shape factor  $>0.6$  can be reached.

Especially for shorter reheating times a Mn-addition has a good effect on the shape factor. Current and future work will focused on optimisation of further thixoforming alloys (e.g. AlSi6Cu3, AlMgMn,...) by addition of Mn as well as surface tension active elements.

The comparison between grain refined and optimised materials with other conventional thixoforming materials is tackled. The documentation of the complete thixoforming process from feed stock to product and assessment by chemical analysis, computer aided image analysis and testing of the mechanical properties is one of our, and cooperating RWTH departments, main aims.

## **4 REFERENCES**

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