# On the Effect of De-gassing over Melt Quality of A 354 Alloy

# <sup>1</sup>Shahid Akhtar, <sup>2</sup>Roberto Molina, <sup>3</sup>Derya Dispinar, <sup>3</sup>Marisa Di Sabatino and <sup>1</sup>Lars Arnberg

<sup>1</sup> Department of Materials Science and Engineering, Alfred Getz Vei, NTNU-7491 Trondheim (NORWAY)

<sup>2</sup> Teksid Aluminum, Via Umberto II,3/5 10022 Carmagnola (ITLAY)

<sup>3</sup> Sintef Materials and Chemistry, Richard Birkelands vei 2 B, N-7465 Trondheim (NORWAY)

This study of melt quality has been conducted in an aluminium foundry which produces components for the automotive industry. The results show the effect of de-gassing on the melt quality in terms of removal of inclusions/bi-films. Melt cleanliness level was assessed by the pressure filtration (PREFIL) and reduced pressure test (RPT) and with new ALSPEK MQ® analyzer. The bi-film index data from RPT shows that there is significant improvement in melt quality after the de-gassing process with nitrogen.

Key words: Aluminium Castings, De-gassing, Melt quality, Oxides/Bi-films, RPT

# 1. Introduction

A need for improved properties, lower production costs and greater strength /weight ratio has forced the replacement of cast or forged ferrous parts by aluminium alloy castings in many critical applications [1]. The high property requirement of aluminium castings has required superior melt quality and melt treatment processes and a more stringent control on melt cleanliness with respect to inclusions and hydrogen content to minimize microporosity [2] The molten metal quality must be monitored and controlled at all stages of the manufacturing process [3]. To obtain high performance castings, the quality of the metal must be optimized prior to final pouring operation, i.e., the melt must be free from inclusions, impurities and dissolved gases. There are two main groups of techniques for controlling and monitoring the cleanliness of the molten metal [4] respectively:

Inclusion removal techniques such as fluxing, flotation, sedimentation and de-gassing [4].
Inclusion measurement techniques, which include filtration systems such as PoDFA (Porous Disc Filtration Apparatus), PREFIL, and non-destructive such as the ultrasonic and LiMCA (Liquid Metal Cleanliness Analyzer) techniques [4].

The two important interactions that take place between an aluminium melt and its environment are the absorption of hydrogen and the formation of oxide films. It is impossible to prevent the formation of oxide on the liquid aluminium surfaces. The formation of the alumina oxide film is an important part of the melting process because it protects the metal from further oxidation. The problem occurs when an oxide film is entrained in the melt during foundry operations like charging, fluxing, and degassing, skimming, transferring, mould filling. The entrainments events are surface folding actions in which a non-wetting surface film is folded over itself with gas trapped in between two halves. This constitutes a defect that will act exactly like a crack in the liquid and is known as 'double oxide film' defect or a 'bifilm' [1]. The most commonly used technique for bi-film index measurements is the RPT which is fast, simple and low cost. The RPT can be used to measure the effect of both detrimental defects i.e., hydrogen and bi-films, but it cannot be used to quantify the hard inclusions, so for good assessment of melt quality RPT must be combined with PREFIL or PoDFA tests [5, 6]. Di Sabatino *et al.* [7] and Kwon and Lee [8] have studied the effect of oxide inclusions on fluidity. They

found that increasing oxides content decreases fluidity. An extensive review of inclusion measurement methods has been presented by Dispinar and Campbell [9]. More details about the procedure and use of the RPT test to measure the bi-film index and its acceptance criteria are given in references [10-11]. The de-gassing is an important step of melt treatment process for improvement in the melt quality. The schematic of the mechanism of de-gassing for removal of the dissolved gas is shown schematically in Fig. 1. The rising bubbles in the de-gassing process collect the bi-films/inclusions and raise them to the surface where they are removed [12-13]. Thus, the de-gassing process cleans the melt from bi-films/ inclusions with simultaneous reduction in gas content.



Fig. 1 Schematic of the de-gassing process in aluminium melts [14].

The objective of the current study was to assess the A 354 melt quality in terms of hydrogen removal and melt quality before and after the de-gassing process in a commercial foundry for automotive parts. Melt quality was assessed by RPT and PREFIL tests. The new ALSPEK MQ® and ALSPEK H® analyzer was used for melt quality and hydrogen measurement respectively.

#### 2. Experimental Procedure

The chemical composition of an A354 alloy investigated in current study is given in Table 1.

Table 1 Chemical composition in wt (%) of an A354 alloy								
Si	Cu	Mg	Mn	Fe	Ti	Sr	Na	Al
9.04	1.124	0.422	0.005	0.116	0.023	0.0015	0.0001	Bal

The RPT and PREFIL test were carried out in different transfer ladles before and after the nitrogen de-gassing. The degassing time was six minutes and hydrogen level was targeted around 0.08 ml/100 g melt. In all the experimental trials hydrogen measurement was carried out with an ALSPEK H analyzer. The principle of operation of an ALSPEK H® analyzer is described by the Moores and Froesher [15]. The ALSPEK MQ® is a new tool to assess the aluminium melt quality. The device is using the change in buoyancy force to monitor transit times as shown in Fig. 2. In first stage before dipping the probe into the melt the buoyancy force is zero which reaches to maximum value once the probe is immersed in the melt. The buoyancy force again reaches to zero value once the melt start flow through the 40 ppi ceramic foam filter into the probe and that transient time is measured in term of melt quality index which range from value one to six, where one represents the best quality melt while 6 is the worst quality melt in terms of oxides and inclusions.



Fig. 2 Principle of aluminium melt quality analysis by ALSPEK MQ® analyzer.

## 3. Results and Discussion

The example of hydrogen measurement with the ALSPEK H® analyzer is shown in Fig. 3. The hydrogen content was 0.08 ml/100g melt after the nitrogen de-gassing treatment.



Fig. 3 Hydrogen measurement after the nitrogen de-gassing treatment.

The bi-film index data from RPT test is shown in Fig. 4.



Fig. 4 Bi-film index measurement before and after de-gassing.

Very high values of the bi-film index were observed before the nitrogen de-gassing in transfer ladle. After the nitrogen de-gassing for six minutes, the melt quality considerably improved in terms of the average bi-film index. In the transfer ladle after de-gassing, the bi-film index was reduced to 35 mm from an initial average value of 289 mm. The images of the sectioned RPT samples from the transfer ladle before and after nitrogen de-gassing are shown in Fig. 5.





The RPT test can be used to assess the detrimental effect of both, the hydrogen content as well bi-films [6, 9]. However, the hydrogen content tends to influence or somehow increase the bi-film index values by contributing toward the growth of oxide films and making them more visible in RPT sectioned surface [16]. It is difficult to assess here how much of the reduction in bi-film index is due to the hydrogen removal and how much is the effect of removal of oxides, both due to the de-gassing process. The PREFIL flow curves in Fig. 6 show that the melt quality is slightly improved after the de-gassing.



Fig. 6 PREFIL flow curves foe before and after de-gassing.

The filter analysis from PREFIL test shows that the inclusions were, predominantly, magnesium oxides (MgO) and alumina ( $Al_2O_3$ ) needles with a small amount of associated spinels. The optical micrograph of filters analysis is shown in Fig. 7.



Fig. 7 Micrographs of the filters obtained from PREFIL test.

The results from the ALSPECH MQ<sup>®</sup> analyzer shows that the melt quality index (MQI) did not change before and after the de-gassing operation. Its value was 2 which indicates the melt of good quality. The ALSPEK MQ<sup>®</sup> analyzer is designed to analyze the big chunks of inclusions, and it cannot predict the difference when the variation in melt quality is small.

### 4. Conclusions

The following conclusions can be drawn from this work.

- 1. De-gassing is an important melt treatment and the melt quality is considerably improved.
- 2. PREFIL test results confirmed the presence of defects, mainly magnesium oxide (MgO) and alumina  $(Al_2O_3)$  as well as oxide films.
- 3. For comparison of melt quality by RPT in terms of bi-film index values melt H<sub>2</sub>- content must be similar.
- 4. The comparison of melt quality by three different methods shows different results. It is important that industry may not rely on just one single test for assessment of melt quality.

#### Acknowledgment

The European Project Nadia- New Automotive components Designed for and manufactured by Intelligent processing of light Alloys (NMP-2004-SME 3.4.4.5, contract n.026563-2) is gratefully acknowledged for financial support. The authors would like to thank Renzo Galvagno, Roberto Di Matteo, Giovanni Amione, Macro Angiari, Roberto Picato and Paolo Amalberto of Teksid Aluminium (Italy) for their help during the casting trials as well sample preparation.

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