POSSIBILITES OF THE CONTROLLED GASIFICATION OF ALUMINUM ALLOYS FOR ELIMINATING THE CASTING DEFECTS

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Abstract

The work deals with the controlled gasification of castings from aluminum alloys. In troubled places of castings the thermal nodes that cannot be always fitted with risers and interior shrinkage with negative influence on tightness and the mechanical properties of casting are formed. If a riser cannot be used for eliminating the negative impact then it is possible to use the Probat Fluss Mikro 100 product. The practical part of the work deals with the monitoring of controlled gasification which creates as a result of adding the Probat Fluss Mikro 100 product and titanium hydride in various proportions. Using the Probat Fluss Mikro 100 as nucleating phase and then with the aid of titanium hydride the hydrogen are brought in the melt. With the aid of visual comparison the effect of controlled gasification is evaluated.

Keywords: Aluminum alloys, gases in the metal, hydrogen, titanium hydride, volume changes

1. INTRODUCTION

Automotive industry and engineering are the biggest consumers of aluminum castings. The share of aluminum castings in these areas is growing. With increasing demands for ecology and emission limits are aluminum castings, with low weight, an integral part of today. In some applications, they can also replace structural steel. This alternative will achieve the preferred ratio of low density and good mechanical properties.

Increasing customer demands for quality and mechanical properties of the castings were the basis for the creation of this work. Foundry processes during crystallization and solidification are accompanied by volume changes of the metal which could be compensated eg. by the riser. In areas of thermal centres (if we cannot use risers) shrinkage cavity with a negative impact on the tightness and the mechanical properties of the casting are created.

This work was aimed to prevent shrinkage cavities with the help of preparations Probat Fluss Mikro 100 and titanium hydride (TiH_2). By adding of Probat Fluss Mikro 100 to melt alloy we bring the nucleation phase there, in which bubbles of hydrogen start to grow (heterogeneous nucleation). Hydrogen then bring into the melt by means of titanium hydride. Using the above mentioned preparations achieve prevent shrinkage of unsatisfactory dimensions and creating a plurality of voids (porosity) of smaller size. The resulting cavity will be distributed throughout the volume of problematic portion of the casting, whereby it is possible to expect an increase of mechanical properties and service life of the casting. The aim of this work was based on visual inspection of the microstructure and density index (Dichte index), provide basic information for controlled gassing of aluminum alloys.

2. A GAS IN ALUMINUM CASTINGS

The only gas, which dissolves in the aluminum alloys, is hydrogen. The source of hydrogen is moisture, which occurs in the furnace atmosphere, linings, poorly dried crucibles and salts. The liquid metal is able to dissociate the water. Then, the oxygen reacts with the aluminum, aluminum oxide is formed and the hydrogen in the metal dissolves. The sources of hydrogen are especially [1]:

- covering and refining salt,
- lining and new crucibles,

- batch material.

In the reaction of the melt with the gaseous compounds containing hydrogen, is eliminated just atomic hydrogen, which is easily and quickly absorbed by the melt. Dissolution of the hydrogen in aluminum alloys is an endogenous process [1]. For the aluminum alloy is distinguished by the difference between the solubility of hydrogen in the solid and liquid state, where at 660 °C the aluminum in the solid state solubility of 0.036 cm^3/100 g. However, at the same temperature has a liquid state solubility of hydrogen 0.77 cm^3/100 g [2]. The solubility in the liquid state is about 20 times greater than in solid state. To change the solubility occurs throughout the range of temperatures of crystallization. Elements such as Si, Zn, Mn and Cu solubility decreases, whereas the elements Mg, Ca, Li and Ti enhance solubility [2].

When sharply reducing the solubility of hydrogen gas formed during solidification cavities (pores). Small value of partition coefficient leads to a large increase in hydrogen prior to crystallization front. In these areas the residual partial pressure is growing rapidly and thereby the growth of cavities is supported. During solidification interval is used as the nucleation crystals own solid phase and a nucleating potential foreign nucleous.

Ideal for the formation of gas cavities are microshrinkages [1]. The rate of solidification, gas content and morphology of the solid phase depend on the shape and position of the pores in the structure. High gas content in the melt causes the creation of cavities in the final casting, mainly spherical shape. During rapid solidification no further growth and bubbles formed spherical or elongated bubbles enclosed in interdendritic spaces (microshrinkages). With the growth of the two-phase zone is more applied theories of microshrinkages. Hydrogen remains in the metal as a supersaturated solid solution. With rapid cooling is greater supersaturation of solid solution, thereby avoiding the less hydrogen gas and porosity smaller [3].

We meet very rarely with casting defects which are only gas bubbles/microshrinkages, thus we use the term porosity, which is a combination of bubbles and microshrinkages. Porosity is characterized by its incidence in interdendritic areas. The porosity encountered especially in alloys with a high solidification interval. If the predominant formation of bubbles, pores are more spherical shape. If microshrinkages predominate in the casting, the shape of pores is dissected and copies dendritic structure [1].

2.1. Elimination shrinkage with Probat Fluss Mikro 100 a titanium hydride

All metallic materials and aluminum alloys occur during the crystallization and solidification of the phase transformation from liquid metal to the solid phase, which is accompanied by a change in volume. Shrinkage in aluminum castings have a negative impact on the mechanical and fatigue properties of the material. The solution to the elimination of shrinkage can be controlled gas content of the material with hydrogen. During the solidification the solubility of hydrogen decreases due to decreasing interatomic distances during cooling. If achieved supersaturated state occurs to the exclusion of gas as bubbles, and if the hydrogen atoms fit between the aluminum atoms, form their own bubbles. Bubbles formed on the principle of heterogeneous nucleation at the interface of foreign particles - gas. The number of nucleations and hydrogen gas bubbles affects the size and the number. Many hydrogen and produces little nucleation resulting structure of the small number of large bubbles. This happens mostly when applying gasification tablets that melt emit hydrogen. When increasing the number of nuclei and amount of hydrogen leaving the resulting structure of the plurality of bubbles of smaller size. This eliminates shortage of liquid metal in thermal node. Establishment replace shrinkage porosity not detectable on x-ray visible even after machining [4].

Preparation Probat Fluss Mikro 100 is used for the casting of complicated casting with thermal nodes that cannot sprue. The resulting shrinkage then has influence on the strength and the permeability of the casting under pressure. With increasing demands on the quality of castings is required then these defects are eliminated as much as possible. To solve this problem helps preparation Probat Fluss Mikro 100 from producer Schäfer [4, 5]. It compensates for creating shrinkages and creates conditions for the development of micropores. The size of the pores generated is dependent on the rate of solidification of the metal in the casting section [5].

The master alloy is capable of dissolving in the melt releasing heterogeneous nuclei bubble sizes microns. In mass production it is possible to process the alloy, up to three hours, without adding and recovery of the nucleous. During solidification precipitate on nucleous hydrogen molecules and then bubbles are formed. For high number of nucleous, the bubbles are created in the entire volume of the casting. To obtain satisfactory characteristics of porosity, it is necessary amount of Probat Fluss Mikro 100 regulate. The dosage is recommended in the range of 0.05 to 0.4% by weight of the melt. It also depends on the technical parameters of the casting. The important principle is use it to leak the cast have closed the bubble effect. This product can significantly reduce scrap and improve castings quality [4].

TiH_2 (the unstable molecular titanium hydride) is an inorganic compound. It serves as a blowing agent, releasing hydrogen gas and at 668 ° C leads to its degradation.

3. EXPERIMENT

In the experiment were laboratory cast specimens of aluminum alloy AlSi10MgMn. In each measurements 4 or 5 samples were cast at ten-minute intervals, which solidified under a pressure of 8 kPa (vacuum) and atmospheric pressure. Subsequently, the index was measured by dual-density weighing equipment mk 2200 LC.

To the melt was first added separately titanium hydride in amounts of 1, 1.5, 2 and 3 wt.%, then were simultaneously added to the nucleonic phase of Probat Fluss Mikro 100 (PFM 100) in an amount of 0.5 % by weight of the melt. From each of the melts were cast at the same time samples of the uncoated material for comparison. All samples were cast from a temperature of 800 °C and subsequently subjected to an measuring density index (Dichte Index - DI).

Using 1 wt.% TiH_2 were cast four samples with an interval of 1, 10, 20 and 30 minutes after its addition. The measurements and obtained results are shown in **Figure 1**. **Figure 2** shows the effect of addition of 1 wt.% TiH_2 at intervals.

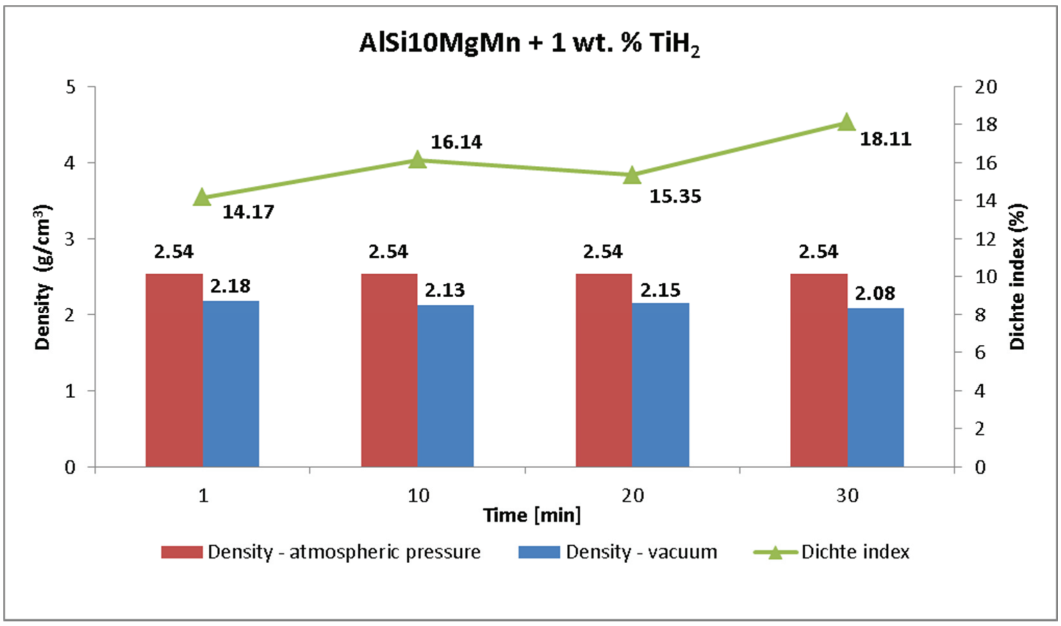

Figure 1 Graphic representation of the density and Dichte index (AlSi10MgMn + 1 wt.% TiH_2)

Figure 2 Samples cast under vacuum with addition of 1 wt.% TiH_2 at intervals first, 10th, 20th, 30th minute (left)

In the next step four samples with 1 wt.% TiH_2 + 0.5 wt.% PFM 100 were cast. The measured values are shown in **Figure 3**. It is obvious that the addition of a germ stage together with blowing agents positively influence the course of solidification and the pores are distributed throughout the volume of the casting (**Figure 4**).

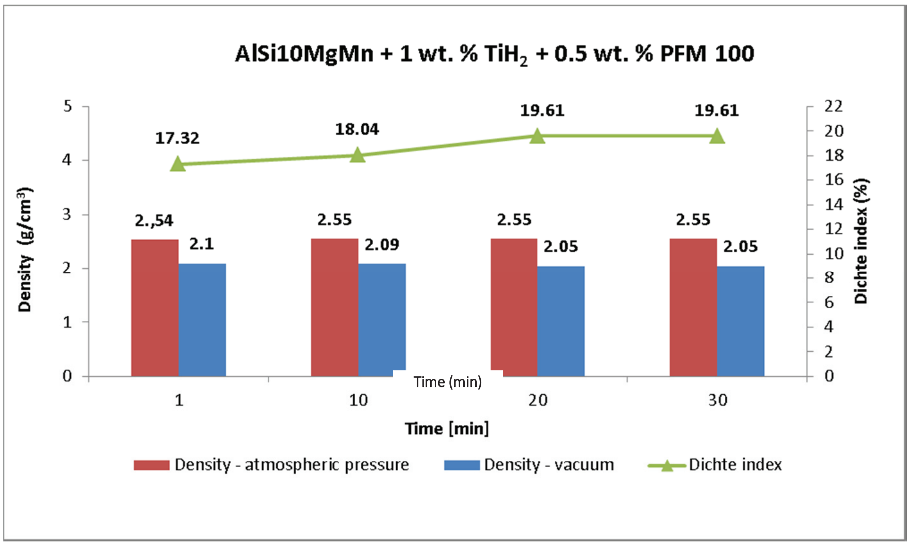

Figure 3 Graphic representation of the density and Dichte index (AlSi10MgMn + 1% wt. TiH_2+ 0.5% wt. PFM 100)

Figure 4 Samples cast under vacuum with addition of 1 wt.% and 0.5 wt.% TiH_2 PFM 100 in time intervals of the first, 10th, 20th, 30th minute (left)

Addition of 3 wt.% TiH_2 increased significantly the amount of hydrogen in the sample (**Figure 5**) and the formation porosity already at the first cast specimen. A large amount of hydrogen can be observed on the samples solidified under vacuum and the atmospheric pressure (**Figure 6**).

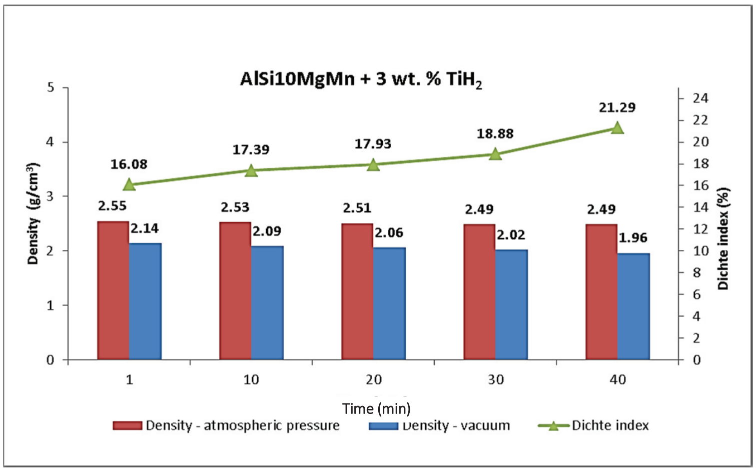

Figure 5 Graphic representation of the density and Dichte index (AlSi10MgMn + 3 wt.% TiH_2)

Figure 6 Samples cast under vacuum with addition of 3 wt.% TiH_2 at intervals first, 10th, 20th, 30th, 40th minute

From the material with the addition of 3 wt.% and 0.5 wt.% TiH_2 PFM 100 was cast five samples with an interval of 1, 10, 20, 30 and 40 minutes. Measured values are shown graphically in **Figure 7**. The wall of the sample casted at 30th minute was due to a large amount of hydrogen ruptured. When measuring the density index drew water sample and the measurement was not conclusive. A large amount of hydrogen can be observed on the samples solidified at atmospheric pressure (**Figure 8**). For samples casted under atmospheric pressure is obvious exclusion of large amounts of hydrogen bubbles, including the occurrence of blowholes concentrated.

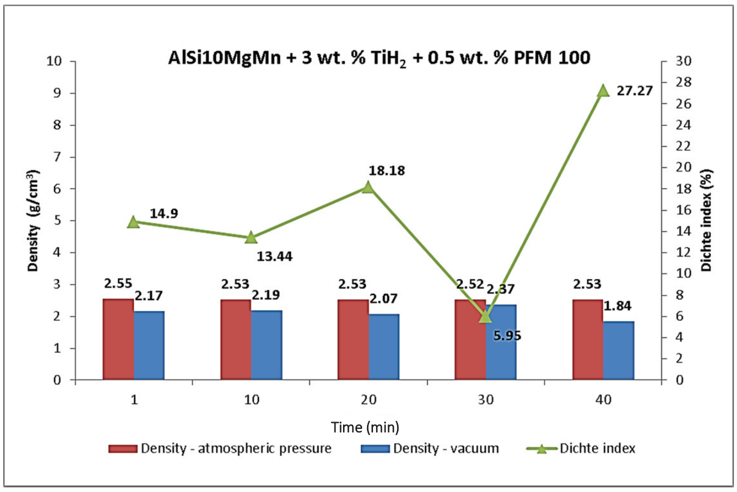

Figure 7 Graphic representation of the density and Dichte index (AlSi10MgMn + 3 wt.%TiH_2 + 0.5 wt.% PFM 100)

Figure 8 Samples cast under vacuum (top) and atmospheric pressure (below) with addition of 3 wt.% and 0.5 wt.% TiH_2 PFM 100 in time intervals of the first, 10th, 20th, 30th, 40th minute (left)

4. CONCLUSION

The work was focused on the possibility of controlled gas content aluminum alloys. In our case, we focus on the elimination of internal shrinkage using titanium hydride and preparation Probat Fluss Mikro 100. Based on theoretical findings heterogenous nucleation should have samples with added fetal stage and titanium hydride greater density index than samples containing only titanium hydride. This was true only for measurement with the addition of 1 wt.% TiH_2. Different results were obtained in samples with the addition of 1.5 wt.%, 2 wt.%, 3 wt.% TiH_2. One reason could be a large amount of hydrogen that did not have space to disperse and remain in the volume of the melt. In the case of addition of only titanium hydride originated concentrated porosity. With increasing time the degree of gassing and the effect of titanium hydride increase too. After visual comparison it can be argued, that the positive effect on the elimination of blowholes in the alloy AlSi10MgMn and give the desired porosity had a combination of titanium hydride and Probat Fluss Mikro 100 is always in the first minute.

Practical use of these products is advantageous for smaller casts a shorter setting time. In the event that the alloy contains a small amount of hydrogen is possible on the basis of experimental results melt gasification e.g. titanium hydride. Based on the experimental and obtained results, the ideal porosity distribution and elimination of shrinkage is achieved in samples casted in the first minute from addition of titanium hydride and Probat Fluss Mikro 100.

ACKNOWLEDGEMENTS

This work was carried out in the support of projects of "Student Grant Competition" numbers SP2016/89 and SP2016/103.

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