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Interfacial Phenomena in Casting Process

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The control of the interface phenomena and reactions might lead to a wide range of structures, properties and performances of the castings. This presentation is concerned with the research on the practical utilization of the interface phenomena, occurring between liquid metal and atmosphere, in commercial Al, Mg and Ti cast alloys. Alpha-case formation in Ti castings, which results in surface-related embrittlement, shows interface phenomena between liquid Ti and solid mold. The range of alpha-case layer could be controlled by thorough understanding of formation mechanism and interface behavior. As an example of practical utilization of interface phenomena between liquid metal and gas atmosphere, Eco-Mg development is presented. The application of ultrasound for grain refinement and degassing of Al and Mg alloys may be expected the use of interface phenomena among liquid metal, solid substrate and gas bubble.

Keywords: *Interface phenomena, Ti alloy, Eco-Mg, Al alloy, High intensity ultrasound treatment*

1. Introduction

There are many cases of interface phenomena involved in casting process. However, most of our knowledge regarding the control of interface phenomena and morphology has developed in recent years, as casting practices have transformed from the mysteries of art to an engineering science.

The control of the interface phenomena and/or reactions might lead to a wide range of structures, properties and performances of the castings.

The formation of interface in casting process may occur in a number of ways, including: A) surface oxidation, melts contamination from crucible, and degassing treatment during melting and holding, as well as B) heterogeneous nucleation, grain growth, and melts-mold reaction during solidification.

The morphology of interface depends upon numerous factors involved in one or more of the following aspects:

1. Melts composition (including segregation)
2. Presence of surface active elements
3. Melt treatment (including effective nucleants)
4. Time-temperature history (including diffusion)
5. Growth rate
6. Mold treatment

This presentation is concerned with the research on the practical utilization of the interface phenomena in commercial Al, Mg and Ti cast alloys.

2. Melting and casting of Ti

An example of interface phenomena between liquid metal and solid atmosphere is exhibited in melting and casting of Ti.

Despite the superior properties of Ti and Ti alloys, applications have been limited by several factors, including the cost-affordability, low production yield, and limited shape in isothermal forging, etc. Therefore, investment casting (lost-wax casting) has been used in order to cost-effectively satisfy complex shape requirements. However, what distinguishes Ti casting from all other metal casting is that Ti and Ti alloys exhibit extremely high reactivity in a molten state with atmosphere and form an alpha-case layer on the surface of the Ti castings (Fig.1), which can lead to crack initiation and propagation [1, 2].

In order to alleviate or mitigate the alpha-case reaction, one must have a thorough understanding of the mechanism by which liquid Ti reacts to the mold material. At the same time, structural factors such as surface-related embrittlement that occurs on the degradation of mechanical properties should be identified.

This study suggests a newly developed alpha-case controlled mold material for Ti investment casting.

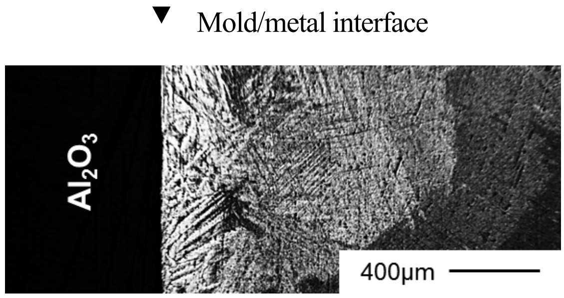

Fig. 1 Formation of alpha-case layer in Ti castings

3. Eco-Mg casting

It is well recognized that environmental benefits provided by lightweight, unlimited, and recyclable Mg alloy have the potential to grow significantly in the future. It could be realized practically by eliminating global warming SF_6 or other protective gases such as SO_2 and Be addition for environment and health issues as well as by ensuring safety during manufacturing and application. It should be done, however, without sacrificing process ability and mechanical property and increasing the life-cycle cost of Mg alloy [3-4].

As an example of practical utilization of interface phenomena between liquid metal and gas atmosphere, Eco -Mg development is presented in this section.

The concept of Eco-Mg (Environment conscious magnesium) approach is to incorporate simply CaO into conventional Mg alloys and generate the reaction of CaO on the surface of molten Mg alloys. The oxide film on the surface of molten Mg alloy changes from porous to dense and complex films. Therefore, the Eco-Mg approach exhibits the improved oxidation and ignition resistances, safety of parts, castability (i.e. increase of fluidity and reduction of hot tearing), and mechanical properties, mainly due to the improvement of melt cleanliness.

In this presentation, the background and recent research and development on Eco-Mg is introduced.

Fig. 2 shows one example of Eco-Mg castings.

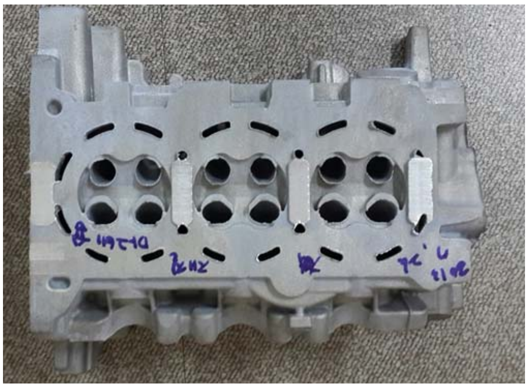

Fig.2 Sand cast cylinder head of AZ-type Eco-Mg by using general sand mold

4. Ultrasound treated Al casting

Generally, grain refinement is one of the effective method achieving improvements in structural uniformity, strength and ductility, reducing the size of defects and increasing the resistance to hot tearing in castings.

The application of ultrasound for grain refinement and degassing of Al and Mg alloys is concerned with interface phenomena among liquid metal, solid substrate and gas bubble.

When high intensity ultrasonic waves are introduced prior to solidification and propagated through molten metal, it has been found that they are effective in grain refinement, uniform dispersion of composition, degassing resulting in reduced porosity and in increasing fluidity.

The results may be explained by the cavitation effects and the influence of the fluid-flow phenomena (acoustic streaming).

In this study, nucleation enhanced ultrasonic melt treatment (NEUMT) using ultrasonic vibration prior to solidification is suggested for grain refinement and degassing in Al casting.

Fig. 3 illustrates grain refinement of Al alloy by ultrasonic melt treatment.

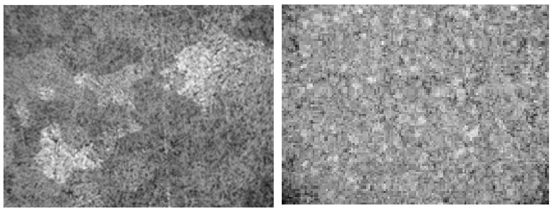

Fig.3 Grain refinement by ultrasonic treatment (left; without UST, right; with UST)

References

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