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Development of Aluminum Cylinder Head Castings for Diesel Engines

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An Al-Si-Mg-Cu alloy and its heat treatment process for the cylinder head castings of diesel engines have been developed. Developed alloy is not only superior on the mechanical strength, but also on the thermal fatigue durability comparing with the conventional aluminum casting alloys. This alloy allows increasing the engine output under the condition of higher combustion pressure. In order to improve durability of cylinder head castings, it has been studied that influences of precipitation behavior in various contents of alloy elements and heat treatment conditions. And it was founded out that precipitated phase and its microstructures influence to thermal fatigue durability. This study results in improving the both mechanical and thermal fatigue properties. In addition to optimizations of aluminum casting alloy, casting processes have been improved. Developed tilting casting process prevents generation of oxides. New cooling system of the mold contributes to increase solidification speed, and to decrease shrinkage porosities with lower riser weight.

Keywords: *Diesel engine cylinder head, Aluminum casting, fatigue, thermal fatigue.*

1. Introduction

In our company, it has produced a variety of commercial vehicles and diesel engines for light to heavy duty use. Diesel engines are required higher reliability because it is an important power source to support the operation of the logistics and also manufacturing in industry. As main components of diesel engines, cylinder head, cylinder block, connecting rod, crank shaft and cam shaft, those are called “5C” components, are also required higher reliability. In particular the cylinder head is a key component for the weight reduction and improving durability of the engine. In order to meet these demands, it is increased of which not only adoption of aluminum castings but also development of higher strength aluminum alloys.

In order to improve mechanical strength and thermal fatigue durability in simultaneously, we have studied chemical components of alloys, heat treatment procedures and other manufacturing processes of aluminum castings. And also it was studied that the mas-production process which does not generate inclusions and shrinkage porosities as a detrimental defect as high quality aluminum casting.

2. Development of aluminum alloy

In conventionally, Al-Si-Cu-based JIS AC2A and AC2B or the Al-Si-Mg-based JIS AC4C alloys are widely used in the cylinder head castings. These aluminum alloys are suitable for cylinder head because conventional alloys have a good cast-ability in which good fluidity and less shrinkage cavities in complex shape castings. In addition to above, mechanical strength is able to be increased by heat treatment. However, it is reported that thermal fatigue durability of alloys including Cu is not higher than the alloys not including Cu [1]. This is due to differences in precipitation microstructures. We have investigated changes of precipitation types and morphologies by chemical content and heat treatment conditions. And influence of precipitation microstructures on thermal fatigue durability was studied. In this study, it is found out that precipitation microstructures do not influence only in mechanical strength but also thermal-mechanical fatigue durability. In AC4C alloy including 0.3mass% of Mg and 7mass% of Si, it is known that Mg-Si binary β'' or β' phases precipitate as a reinforcement phase. These precipitates improve ductility of Al matrix during thermal fatigue deformation because it is easy to growth in high temperature environment. On the other hand, in alloys including Cu, Q', θ' and/or relating phases are precipitate. These precipitates increased mechanical strength but prevent ductility of Al matrix during thermal fatigue deformation. Less ductility of Al matrix reduces thermal fatigue leaves. In our series of studies, it was founded out that 1mass% of Cu and long term of over aging treatment moderately disperses Q' phase. Optimized precipitate microstructure has been improved both of mechanical fatigue strength and thermal fatigue durability. Fig.1 shows results of high cycle fatigue test of conventional and developed alloys. Fatigue strength of developed alloy increases +20MPa comparing with the

conventional alloy. And also thermal fatigue leaves of developed alloy improved to almost 2 times of the conventional alloy as shown in Fig.2.

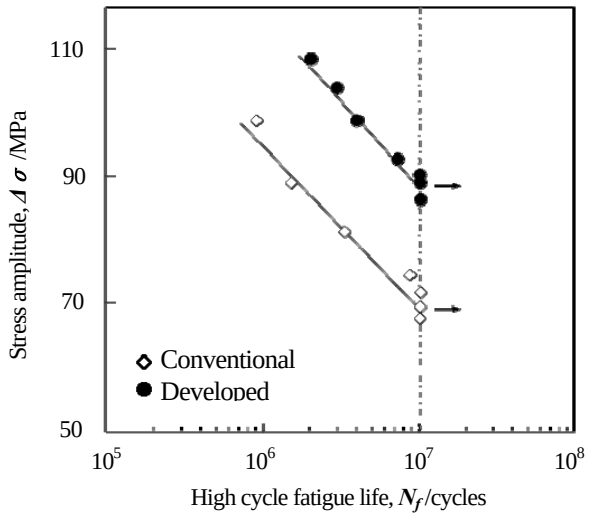

Fig.1 Result of Mechanical fatigue test in conventional and developed alloys.

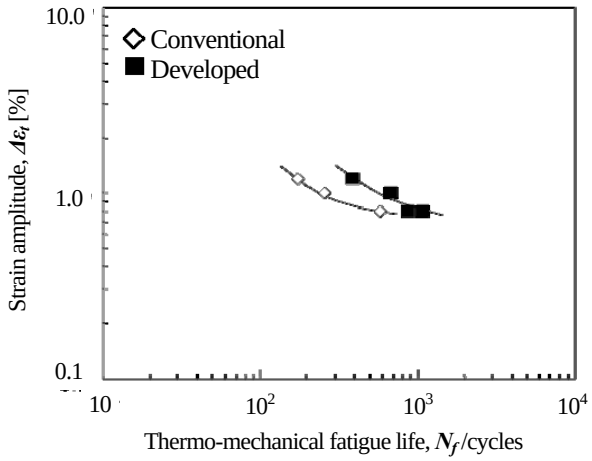

Fig.2 Result of thermal fatigue test in conventional and developed alloys.

3. Development of casting processes

3.1 Elimination of micro porosities

Microporosities locating casting surface are able to affects as initiation sites of fatigue cracks. In order to reduce of this affection, it was studied to improve the cooling method of the parmanent mold during solidification.

Fig.3 shows the structure of inserted chiller whitch made of Cu alloy on the lower face of parmanent mold. Inside of chillers have been cooled by water flow from the bottom side. Fig.4 shows the microstructures of the cylinder head castings. In the improved cooling method, higher solidification speed decreases microporosities of the casting surface.

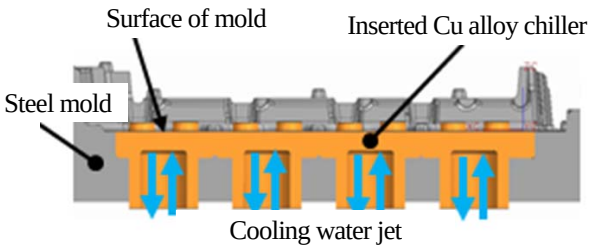

Fig.3 Stucture of parmanend mold with Cu alloy chiller

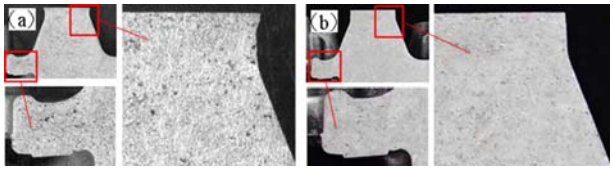

Fig.4 Microporosities in sections of (a) conventional and (b) improved castings.

3.2 Elimination of incrusions

It is also important to eliminate incursions such an aluminum oxide in order to prevent the affection for the fatigue crack generation. The pouring process has been also improved showing in Fig.5. A raddle handled with a robot tilts in synchronization with the mold. In this process, scooped molten metal from the crucible is poured directory into the mold. In this method, less to produce an oxide due to the absence for transfers of the molten metal.

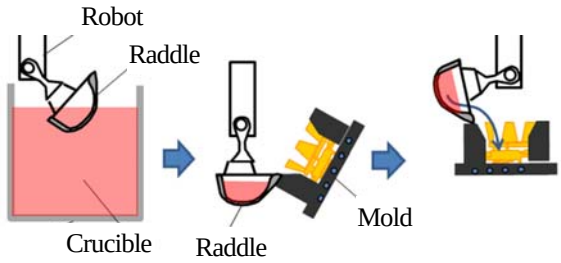

Fig.5 improved pouring process

4. Summary

Developed aluminum casting alloy, heat treatment procedure and casting processes totally improve the durability of cylinder head castings. It allows that the aluminum cast cylinder heads are able to be used for higher output and less fuel consumption of diesel engines.

[1] K. Moizumi, K. Mine, H. Tezuka and T. Sato: Material Science Forum 01/2002, 396-402 (2002), 1371-1376.