Shot Peening to Prevent Cracking in the Water Cooling Hole of Die-Casting Die

Y. Kobayashi [1], A. Matsui [1]

1 SINTOKOGIO, LTD., JAPAN

Abstract

Tensile stress is occurred on inside of water cooling hole of die casting die by cyclic heat stress. As a result, water cooling hole was broken by stress corrosion cracking and fatigue by cyclic thermal stress.The minimum diameter of water cooling hole is 3mm, the maximum hole depth is 300mm. Prevention of fracture on water cooling hole is tried that is induced residual stress by shot peening. In the previous experiment, 1500MPa residual stress is induced on inside of water cooling hole. Expanding of die life that was applied shot peening can be confirmed on actual production.

Keywords Die casting die, SCC, Water cooling hole, residual stress.

Introduction

The die-casting is the method that can produce mass products which are high in precision. Especially, die cast parts of aluminum alloy are used to auto motive parts due to high strength and less weight. [1]. In recent years, the thermal capacity of die casting dies increased due to the increasing size of die casting parts. As a result, quick cooling is required for product quality. Quick cooling can help reduce costs by shortening cycle time. The main disposal cause is crack that is called by heat checking on die casting die. The crack initiate boundary of crystal grain by thermal stress of repetition by molten aluminum alloy. We reported that it can expand the die life by shot peening. The recent problem is destruction from the water-cooled aperture to cool a die-casting die.Generally, dies have holes drilled into them and the holes are filled with water after casting to help accelerate cooling. The distance of the cavity surface and the water cooling hole surface have become closer in order to decrease cooling time. In this condition, tensile stress occurs at the surface of water cooling holes by heat stress. Die cast users have reported issues of Stress Corrosion Cracking (SCC). [2] It is very difficult to drill process, because the diameter is very small and the depth is very deep. Therefore, the inside wall is covered by a tool mark. The tool mark forms a notch and it becomes the stress riser point. Therefore I can suppose that these become the factor to produce a crack.[3][4][5] In this research, we investigate how to use shot peening to increase residual stress in order to prevent SCC in the water cooling hole of die casting die

Pre experiment

Specimen and evaluation method

Most of die casting die are nitriding after heat harden and annealing. It is very difficult to drill it is unclear to introduce enough residual stress by shot peening on narrow and deep hole. At first, maximum residual stress is investigated on the material of die casting die as a pre experiment. The target residual stress value on inside of water cooling hole is decided by pre experiment. Table1 shows chemical composition of specimen.

Direct air peening equipment was used for experiment. 0.1MPa~0.4MPa air pressure are selected. Coverage is over 100%. Table2 show the hardness of shot media that was used in this experiment.

Table1. Chemical composition (wt%)

	C	Si	Mn	Cr	Mo	V
SKD61	0.4	1.0	0.4	5.2	1.2	0.8

Table2. Hardness of shot media

Media	A	B	C	D
Vickers Hardness	700	850	1200	1350

After shot peening, residual stress, micro vickers hardness inside wall of cooling hole were measured. The compressive residual stresses were measured with the sin2θ-ψ method using X-rays . Table3 shows condition of X-ray measurement apparatus.

Table3. Condition of X-ray measurement apparatus

Characteristic of X-ray	Cr-Kα
Diffraction plane	αFe(211)
Tube voltage[kV]	40
Tube current[mA]	30
X-ray stress detector	PSPC
Diffraction angle 2θ[deg]	156.4
X-ray stress constant [MPa/deg]	-318.0
Irradiated area [mm]	φ0.5

Result

Fig.1 shows residual stress that is obtained by each media. As a result of pre experiment, maximum residual stress is approximately 1600Mpa on this material. Therefore, target residual stress is fixed to 1500MPa for inside of water cooling hole.

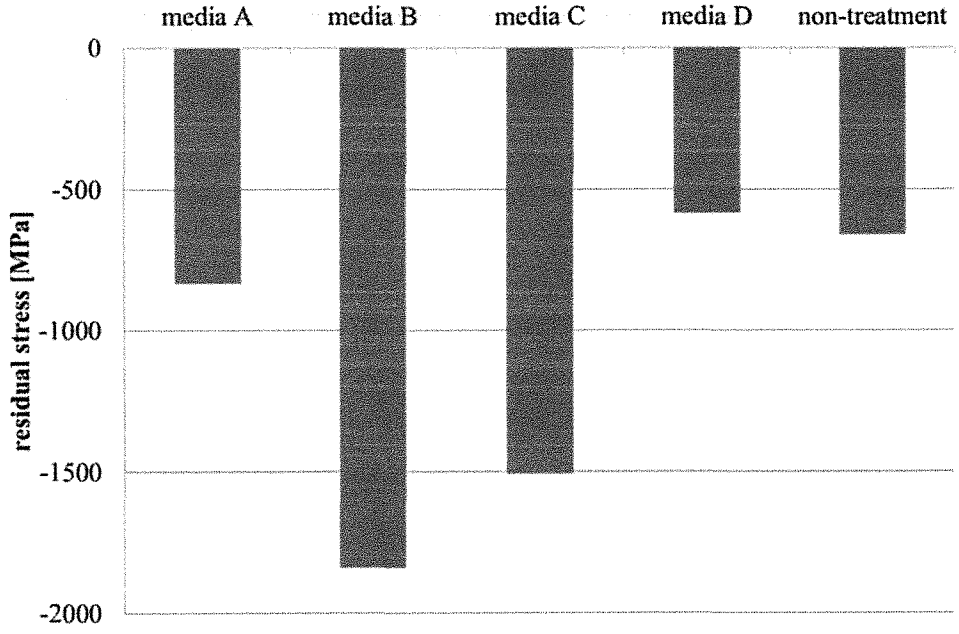


Fig.1 Residual stress of external surface.

Shot peening to water cooling hole
Evaluation of residual stress

Shot peening should be applied to top and inside wall surface of hole. Therefore, rotating nozzle with ricochet plate was developed. Fig.2 shows photograph of nozzle. [6]
Fig.3 shows dimension of the specimen. Specimens are made of SKD61. They are applied nitrising same as specimen of pre experiment. After shot peening, specimen were cut by micro cutter for measuring of residual stress.

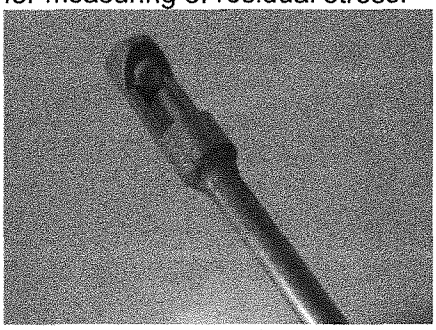


Fig.2 Nozzle tip

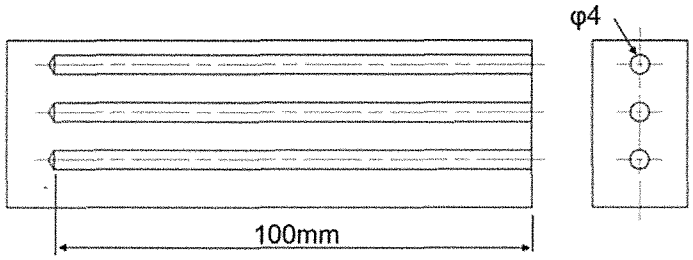


Fig.3 Dimension of specimen

Same medias were used that were used in pre experiment.
Fig.4 shows surface residual stress after processing shot peening by 1200HV media that is changed coverage. "1T" means any time.
From Fig.4, there is proportional relationship between coverage and surface residual stress.
Fig.5 shows surface residual stress after processing shot peening by 1350HV media that is changed coverage.

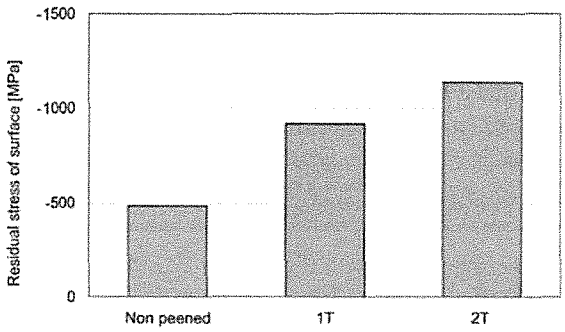


Fig.4 Surface residual stress by 1200HV

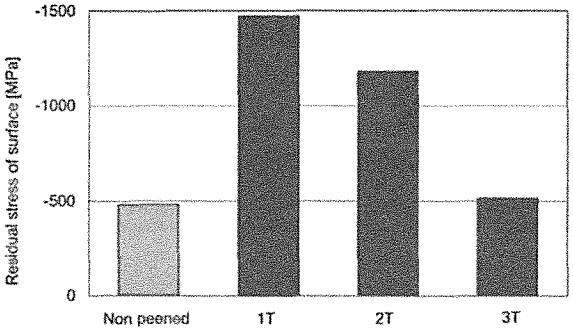


Fig.5 Surface residual stress by 1350HV

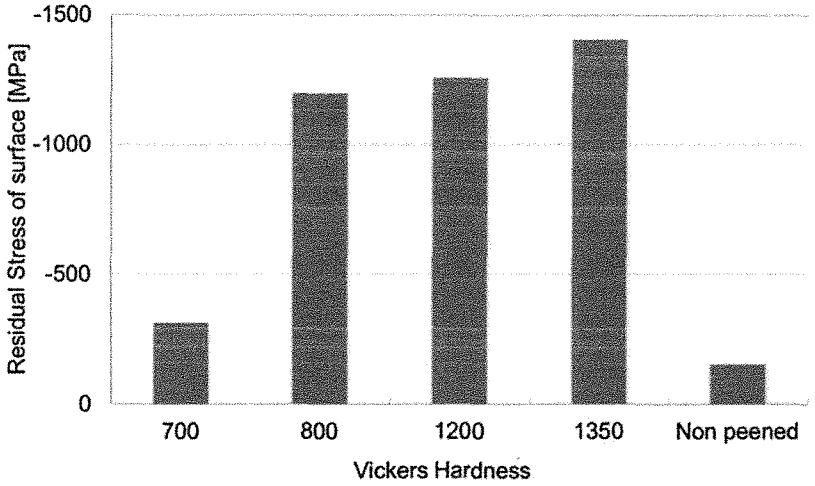


Fig.6 Surface residual stress of the side surface

From Fig.5, there is proportional relationship between coverage and surface residual stress. The compressive residual stress value decreases as the coverage increases. After investigating, the surface is erosion.
Fig.6 shows the surface residual stress of the side surface. On each media, the shot peening condition is optimized. Maximum residual stress is obtained when highest hardness media were used.

Change of the tool mark

The tool mark may become the stress riser point that is caused by a cyclic heat change.
Changes of the tool mark are evaluated by profile curve and photograph.
Tool marks were evaluated by profile curve before and after shot peening.
The figure is an appearance photograph of the specimens which I prepared.
Fig.7 shows dimension of the specimen. The diameters of holes are 5mm, 8.5mm, 11.5mm.
The material is same as previous experiment.

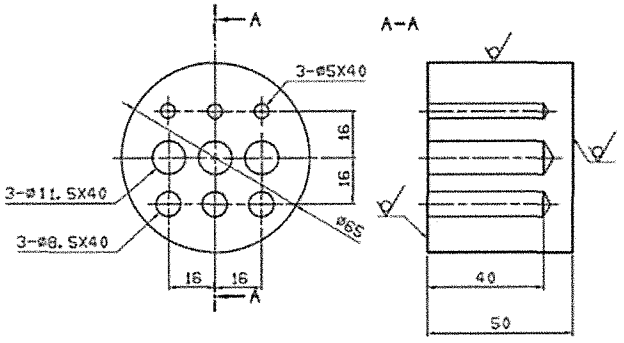
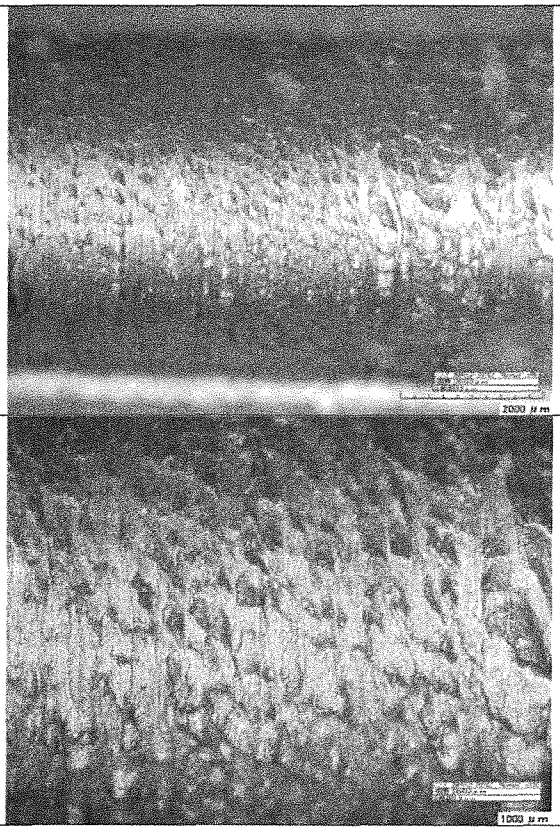
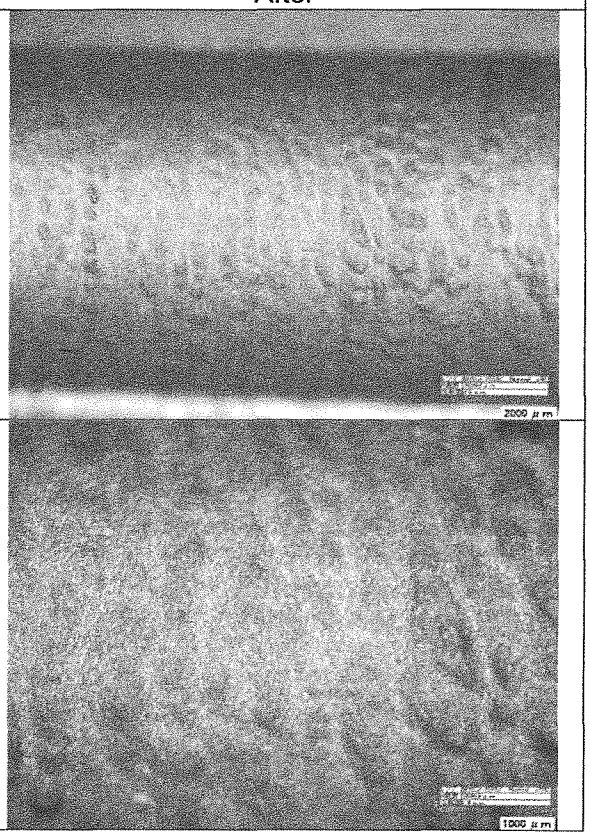


Fig.7 Dimension of specimen for tool mark

Table4 The surface of before and after shot peening

Before	After
	

The tool mark cannot be removed after shot peening. But, the edge can be smashed.

Evaluation on actual production

Fig.8 shows photograph of inside of water cooling hole that was used in actual production. Both die used same cycles. Non peened die was judged to replace.

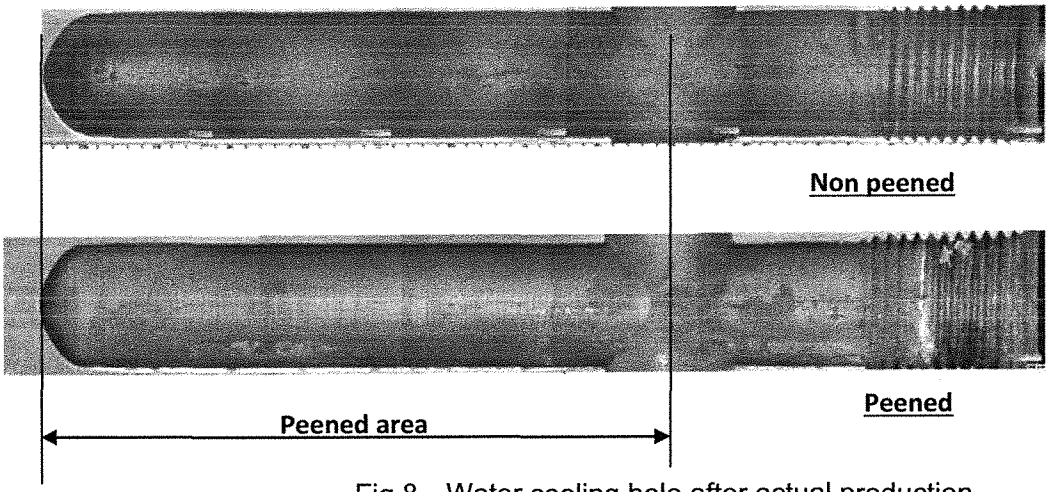


Fig.8 Water cooling hole after actual production

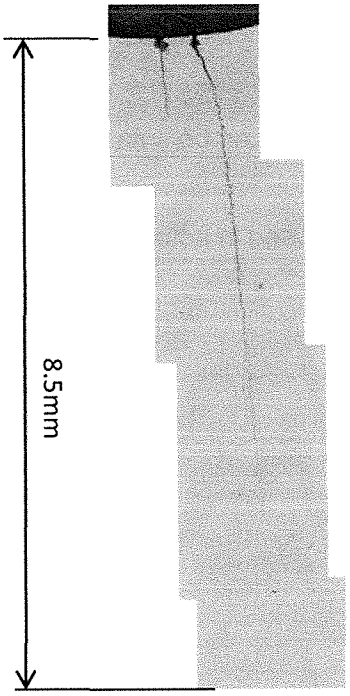


Fig.9 Cross sectional observation of non peend hole

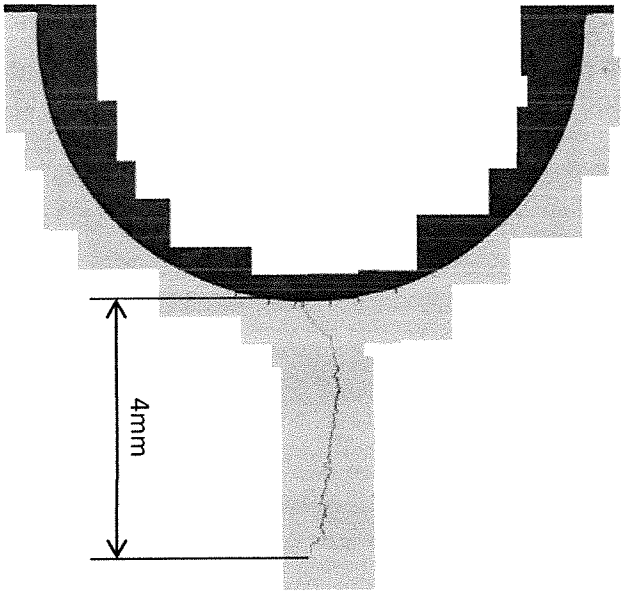


Fig.10 Cross sectional observation of peened hole

In the case of non peened hole, one big crack is appered. But, multipl small cracks was appered on the peened surface.
Fig.9, Fig.10 shows cross sectional observations of peened surface and non peened surface.
In the case of non peened, crack initiate to 8.5mm length. On the other hand, multipl small crack and long crack were appered. Long crack initiate to 4mm length. The life time can be estimate double.
Therefore, the die life time expand by residual stress that is induced by shot peening.

Conclusion

1. 1500MPa residual stress can be induced on the surface of water cooling hole that was heat hardened by shot peenig.
2. Expanding of die life that was applied shot peening can be confirmed on actual production.

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