Improvement of the Heat Checking Resistance of Casting Dies by Shot-Peening

Tadanobu Oyama[1], Yuji Kobayashi[1], Toshihiro Kitagawa[2], Noki Yokoi[3] and Yasushi Hiraoka

1 SINTOKOGIO, LTD., JAPAN
2 Daido Amistar Co.,Ltd, JAPAN
3 Daido Steel Co., Ltd

Abstract
In this study, heat treatment and shot-peening conditions were examined for the purpose of improving the heat checking resistance of casting dies.
Nitriding was selected as heat treatment and the two-stepped shot-peening process was used to apply a residual stress after removing the compound layer generated by nitriding.
By manufacturing actual die-cast products and evaluating the damage caused to the dies, it was found that the heat check resistance of nitrided dies is much higher than that of non-nitrided ones.

Keywords
Shot peening, Die-casting, Heat check, Nitriding.

Introduction
Die-cast products are widely used for automotive parts and electric appliances and manufactured with dies made of a high strength material.
Cracks called "Heat checking" is generated on die surface by thermal fatigue caused by repeated heating by molten metal and cooling by mold lubricant.
In these days, the die casting cycle time has been shortened to reduce the cost, which has increased the thermal stress applied to die surfaces.
In this study, the heat treatment (nitriding) and shot-peening combined process was examined for the purpose of improving the heat check resistance of casting dies.

Specimens and shot-peening conditions
Die specimen manufacturing method:
A higher strength material should be used to prevent heat checking. However, high strength means high hardness. Dies made of a harder material are inferior in toughness and need to be toughened to some degree to eliminate the possibility of large cracks. Therefore, heat checking should be effectively prevented by only reinforcing the surfaces and the most frequently used heat treatment at the present is nitriding.

However, ordinary gas nitriding generates a compound layer with poor toughness as shown in Fig.1 and heat checks in this layer are known to grow to the nitrogen diffused layer.
Then, we invented a process as shown in Fig.2. First, the surface rigidity of the material is improved by nitriding. The compound layer generated at this time is removed during the first shot-peening step. Then, the exposed nitrogen diffused layer is shot-peened. This process is called Aminit DS.
Table 1 shows the first and second shot-peening conditions. Specimens were shot-peened using a Sinto Kogio's gravity shot-peening machine MY-40.

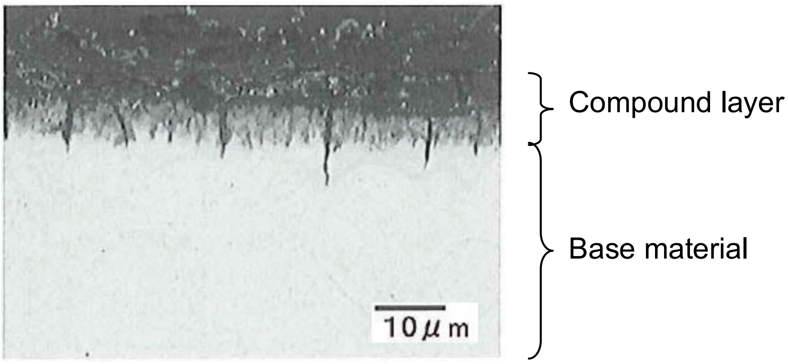

Fig.1 Sectional structure of surface of nitrided parts

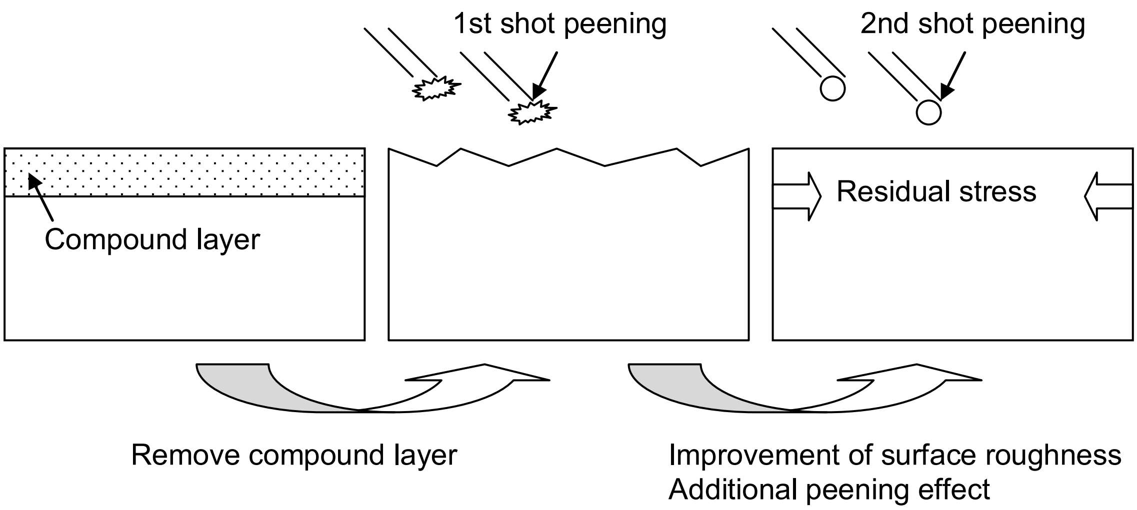

Fig.2 Peenig process (Aminit DS)

Table 1. Shot-peening conditions

Shot-peening conditions	1st shot peening	2nd shot peening
Media	Alundum	Amo beads
Media size	#150	φ50μm
Air pressure (MPa)	0.3	0.45

Heat checking test

A heat checking test was performed as a laboratory test to evaluate the heat checking resistance of specimens manufactured with the Aminit DS process.

Fig.3 shows an overview of the heat check test method. Specimens were prepared as H13(SKD61, 44HRC).

The heat checking specimens were evaluated for residual stress distribution (Fig.4) and surface roughness (Fig.5). The values obtained with gas sulphonitriding and salt bath nitriding are also shown for reference.

According to Fig.4, the compressive residual stress, approximately -1500MPa, was observed at surfaces of specimens manufactured with the Aminit DS process. For salt bath nitrided specimens, on the other hand, a compound layer generated at the surface obstructed the surface residual stress measurement.

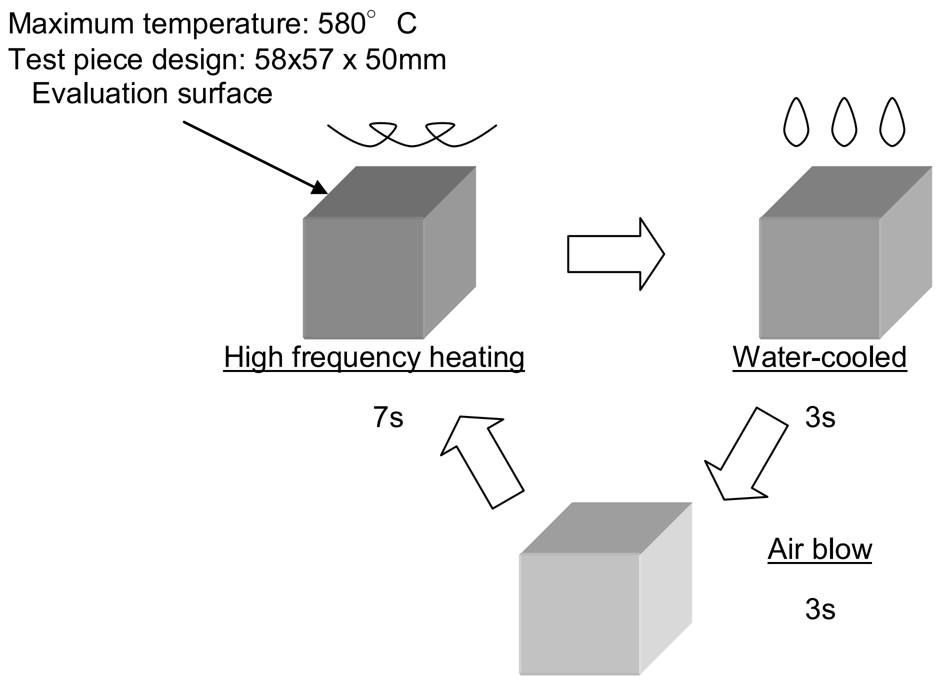

Fig.3 Experimental method of evaluation of heat chek resistance

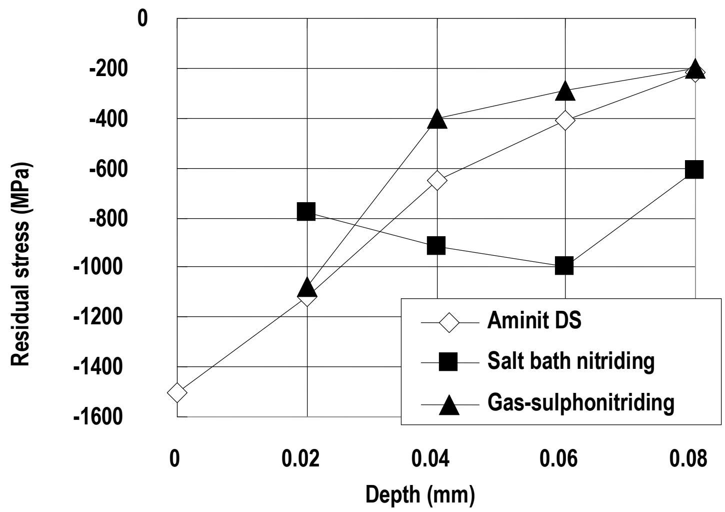

Fig.4 Residual stress distribution

As shown in Fig.5, the surface roughness obtained with the Aminit DS process is almost equivalent to that of unpeened specimens. In addition, the micrographs of their cut sections show that the surface compound layer has been completely removed.

Results of heat checking test

Fig.6 shows textures of heat-checking surfaces observed after 30,000 cycles of heat checking test around the centers of specimens, which were subject to the highest thermal stress during the test.

A number of heat checking were observed with unpeened and salt bath nitrided specimens but no heat check was visually recognized with specimens manufactured with the Aminit DS process. It is found from this fact that the Aminit DS process has a great effect to prevent heat checking.

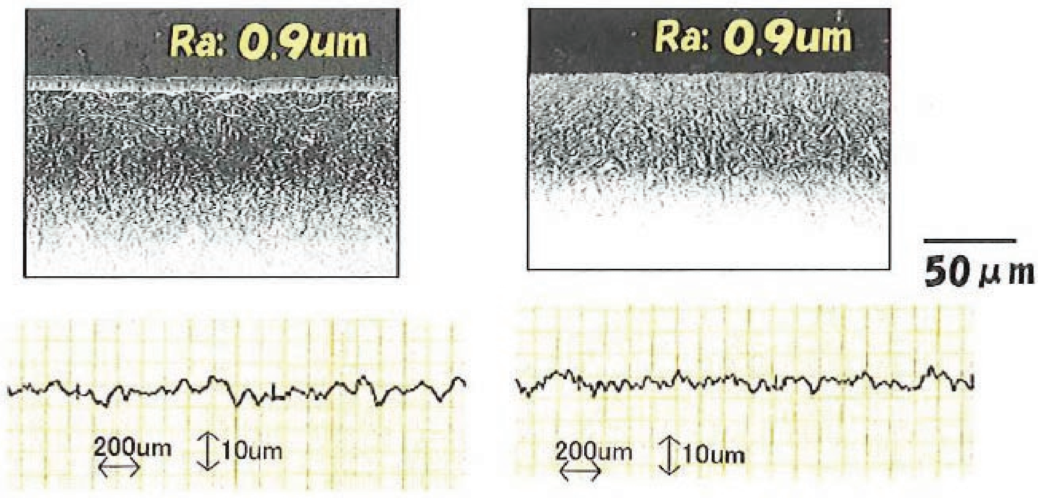

Fig.5 Surface roughness

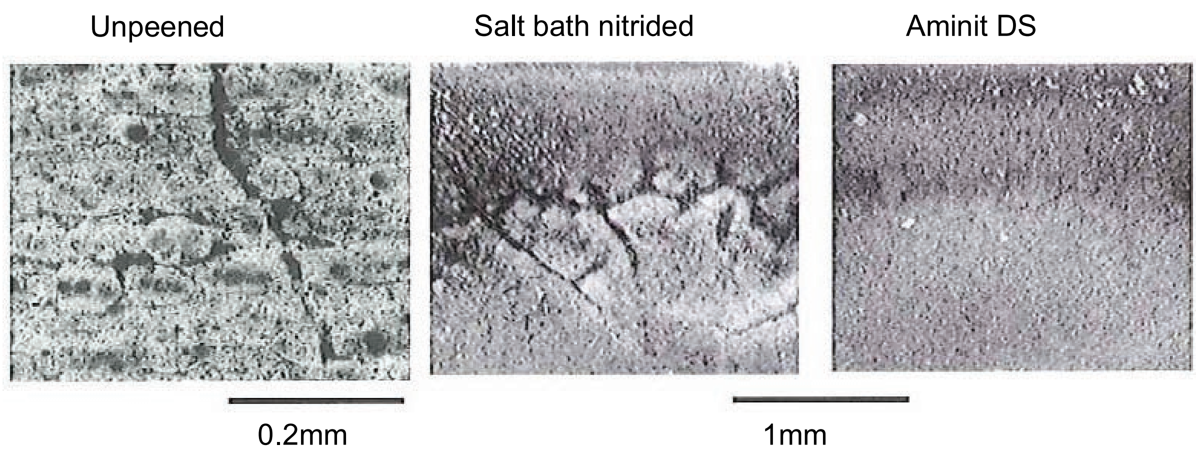

Fig.6 Surface texture after experiment

Casting experiment for shot peened dies

Dies were manufactured to the dimensions shown in Fig.7 and actually used for casting to determine their heat checking resistance.

The following three features were incorporated into the shape of the die specimens.

(1) A simple, easily testable shape simulating actual dies
(2) A thick casting with a large sectional area (aiming to raise the die temperature)
(3) A protrusion beside the pouring gate (aiming to concentrate stresses at the corner)

Table 2 shows details of the specimens and Table 3 shows testing (casting) conditions.
The die manufacturing process consists of “rough machining,” “quenching and tempering,” “finishing” and “Aminit DS.”
A just quenched and tempered die and a salt bath nitrided one were also used for comparison.

Table 2. Chemical composition of die material

	C	Si	Mn	Cr	Mo	V
H13(SKD61)	0.4	1.0	0.4	5.2	1.2	0.8

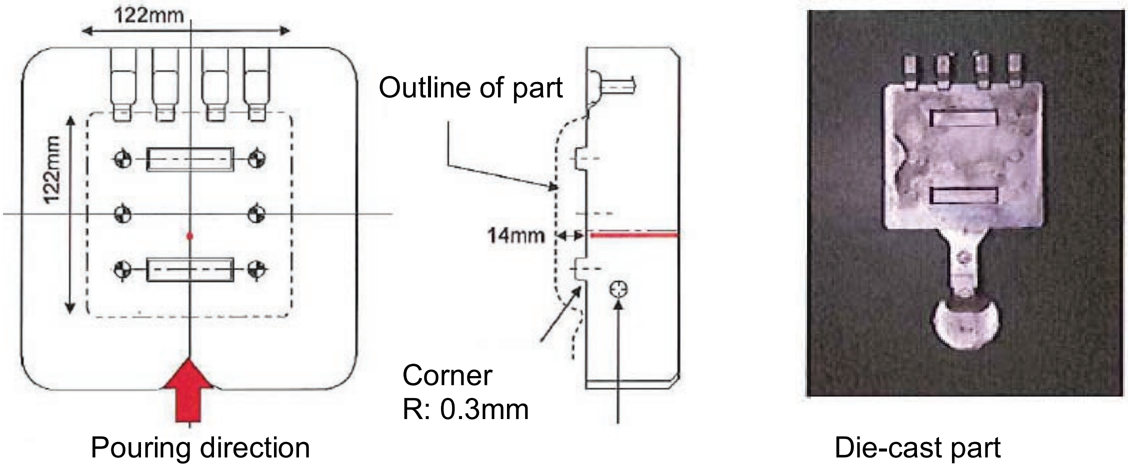

Fig.7 Design of die and Die-cast part

Table 3. Die casting conditions

Aluminum alloy	ADC-12		Injection speed	1.6m/s
Alloy weight	600g		Casting pressure	65Mpa
Alloy temperature	700° C		Injection time of parting agent	3s

Results of casting experiment

Fig.8 shows photographs of die surfaces used for 5,000 casting cycles.

The heat checking resistance of the salt bath nitrided die seems to be slightly better than that of the unpeened one while the Aminit DS processed die has much fewer heat checking.

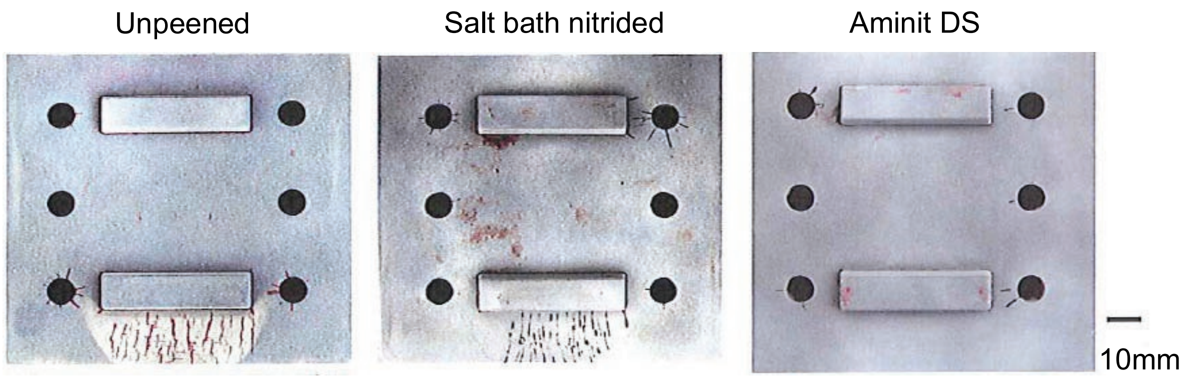

Fig.8 Surface damage after experiment

Discussion and Conclusions

As a result of a study to prevent heat checking on die surfaces and optimize the material and heat treatment and shot-peening conditions, a two-stepped shot-peening process has been developed where the compound layer generated by nitriding is removed by the first shot-peening step, and the surface is shot-peened by the second step in order to apply compressive residual stress.

According to a heat checking test and an evaluation of damage to the dies actually used for casting, the newly developed process was found to have a great effect to prevent heat checking.

References

[1] T. Kitagawa and Y. Hiraoka and Y. Kobayashi, *Complex surface treatment, improving heat-checking –resistance for die casting mold " AMINIT DS"*, Die and Mould Technology , Vol. 25 No.27(2010), pp 118-129.

[2] S. Nakahama, *Technologies to improve the casting die life ,* Die and Mould Technology , Vol. 25 No.4(2010), pp 48-51.

[3] Y. Naoki and K. Inoue, Casting Technology Conference proceedings, (2008), pp 220.