GISS Technology: Principle and Applications in Die Casting

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Abstract. In the past, there have been a lot of effort to solve gas and shrinkage porosity defects in die casting. The common solutions are vacuum technology, jet cooling technology, and application of squeeze pins. However, these solutions often increase the die casting production costs. A new solution that has recently been introduced worldwide is GISS Technology. This technology applies the superheated slurry casting process. Gas and shrinkage porosity defects can be reduced. Furthermore, the production costs are lowered due to die life extension, cycle time reduction, melting energy reduction, and lubrication usage reduction. This paper describes the principle of GISS Technology, and selected applications and case studies are also be presented.

Introduction

Currently, there are several aluminum die cast parts that have requirements of no porosity for leak-tight and structural applications. The key porosity defects in die casting are entrapped gas porosity from turbulent flow and shrinkage porosity. The current methods to reduce entrapped gas porosity defect are die design optimization and applying vacuum technology. For shrinkage porosity, several die casters implement jet cooling technology and local squeeze pins. These current methods have been widely used; however, they often result in increased production costs. Another known technology that can effectively reduce porosity defects is semi-solid metal technology. However, the technology has not been widely applied in the die casting industry due to some limitations such as the limitations of the alloys that can be used, and the need to make modifications to the die design and production machines. A new solution that has recently been introduced in the die casting industry is GISS Technology. This technology involves preparing and casting superheated slurry so that any alloys can be used and existing dies can be used without any modifications. Gas and shrinkage porosity defects can be significantly reduced. In addition, production costs are lowered from die life extension and cycle time reduction.

GISS Technology

This new technology, called GISS Technology, involves a process for preparing and casting slurry with a low superheat temperature. The process, see Fig. 1 (a), comprises the steps of:

Step 1: Placing a probe into the melt to remove a controlled amount of heat.

Step 2: Vigorous convection by injection of inert gas bubbles is applied to the melt to assure nearly uniform cooling of the melt to the temperature slightly above the liquidus temperature and also to create solid nuclei.

Step 3. The probe is then rapidly removed from the melt when the desired solid fraction is reached.

Step 4: The melt is quickly transferred to a mold for casting into parts or a shot sleeve for injection into a die cavity.

Fig. 1 (b) shows the GISS Unit which is the commercial add-on unit used to produce slurry for the die casting industry.

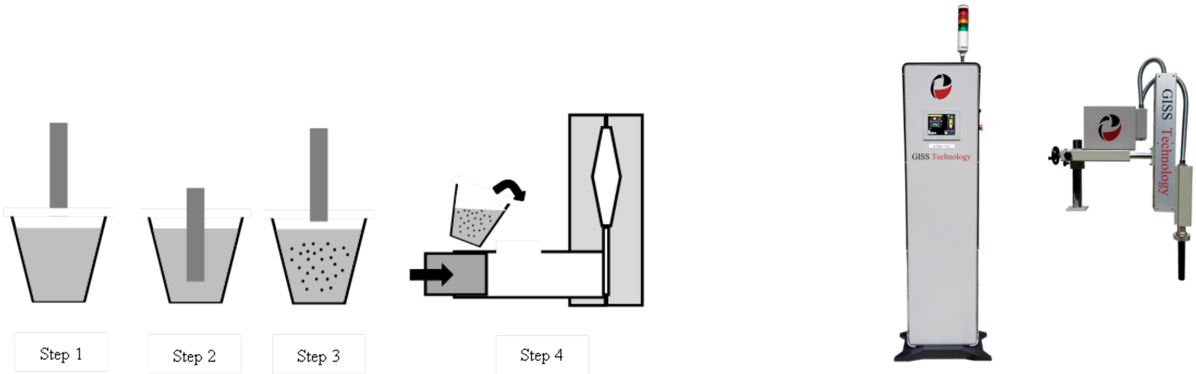


Fig. 1. (a) Illustration of the GISS slurry casting process [1] (b) GISS Unit used in commercial applications [2].

In the GISS technology, a small fraction of fine solid nuclei is created in the melt even though the bulk liquid melt is at the temperature slightly above the liquidus temperature. Fig. 2 shows the microstructure of the slurry having about 3-5% fine solid particles.

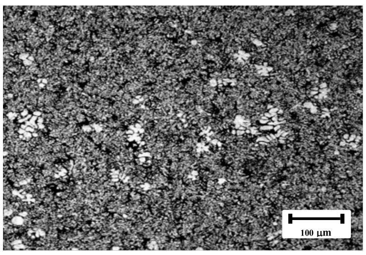


Fig. 2. Optical micrograph of the rapidly quenched slurry with about 3-5% fractions of finely distributed solid nuclei in the matrix of the rapidly solidified melt [3].

Porosity Defect Reduction

Reduction of Gas Porosity. Since the slurry has higher viscosity than liquid metal, the flow of the slurry into the die cavity is less turbulent. This results in less entrapment of gas. Thus, gas porosity can be minimized and the reject rates can be reduced using slurry casting technology. Janudom et al. reported the flow behaviors of the slurry compared with liquid metal [4], see Fig. 3. They found that by controlling the solid fraction and flow speed, entrapped gas porosity can be significantly reduced.

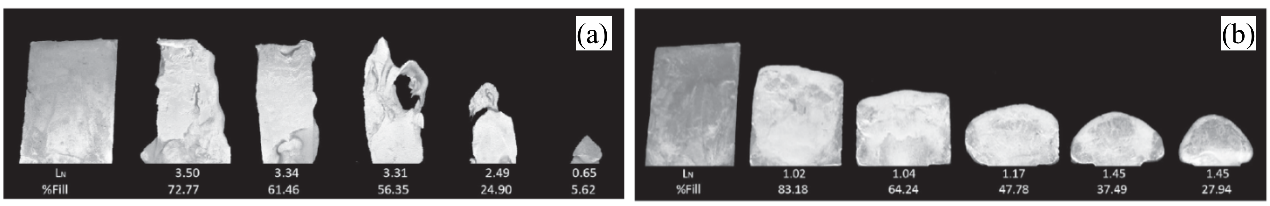


Fig. 3. Flow behavior of an aluminum melt into a die casting in (a) liquid casting and (b) slurry casting [4].

Reduction of Shrinkage Porosity. Slurry has pre-existing fine solid particles, which effectively act as nuclei. So, after the slurry fills the die cavity, these solid particles will spontaneously grow larger to fill the die cavity so that shrinkage porosity can be significantly reduced. This results in less reject rate and higher part quality. Fig. 4 shows the reduction of shrinkage porosity with the use of the GISS slurry casting technology.

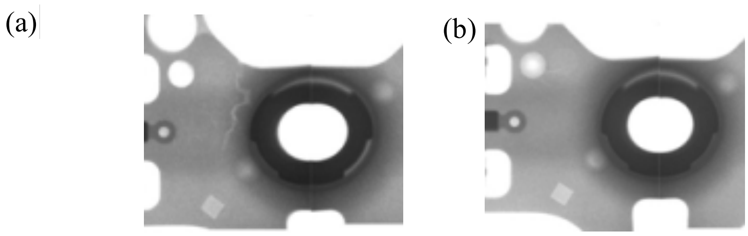


Fig. 4. X-ray results illustrating the shrinkage porosity reduction benefit of GISS Technology. (Courtesy of Summit Steering Wheels Co., Ltd.) [2].

Production Cost Reduction

Die Life Extension. Since slurry has some portion solidified, it has significantly less heat content than superheated liquid metal. The die surface will therefore be heated up to a lower temperature and will then require less cooling. This lower temperature difference helps extend the die life significantly. From mass production results, the die life has been extended to 2-4 times the die life of conventional die casting. This will significantly save the die making and maintenance costs.

Cycle Time Reduction. With less heat content of the slurry, this means it takes less time to wait for the solidification of the casting parts. So, the die closing time can be shortened. In addition, it takes less time to cool the die by spray and air blow. Therefore, the total cycle time is reduced by 10-20%. This cycle time saving results in improved productivity and less production cost.

Applications and Case Studies

Bühler, Switzerland. GISS Technology has been tested at Bühler with two commercial alloys, 226 and SF6. This study has demonstrated several benefits of GISS Technology, including less porosity, lower cast temperature, lower cycle time, and lower closing force with same quality as standard die casting (SDC). Fig. 5 shows the die casting machine and the part design used for this study. Fig. 6 shows that at the same applied pressure, GISS process yields less porosity for both alloys. In addition, it demonstrates that to achieve the same porosity level, less applied pressure or, consequently, less closing force, is needed. Mechanical property results are also found to be similar for processes and both alloys. Fig. 7 shows the property data of 226 alloy as a representative. The results of this study demonstrate that lower production costs through die life extension and cycle time reduction can be achieved with lower porosity and similar mechanical property using GISS Technology.

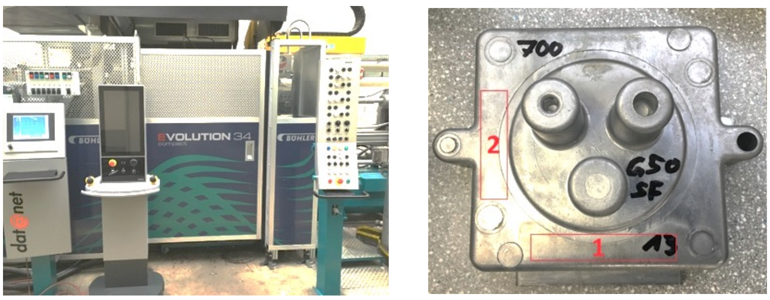


Fig. 5. The die casting machine and part used in this study (Courtesy of Bühler, Switzerland).

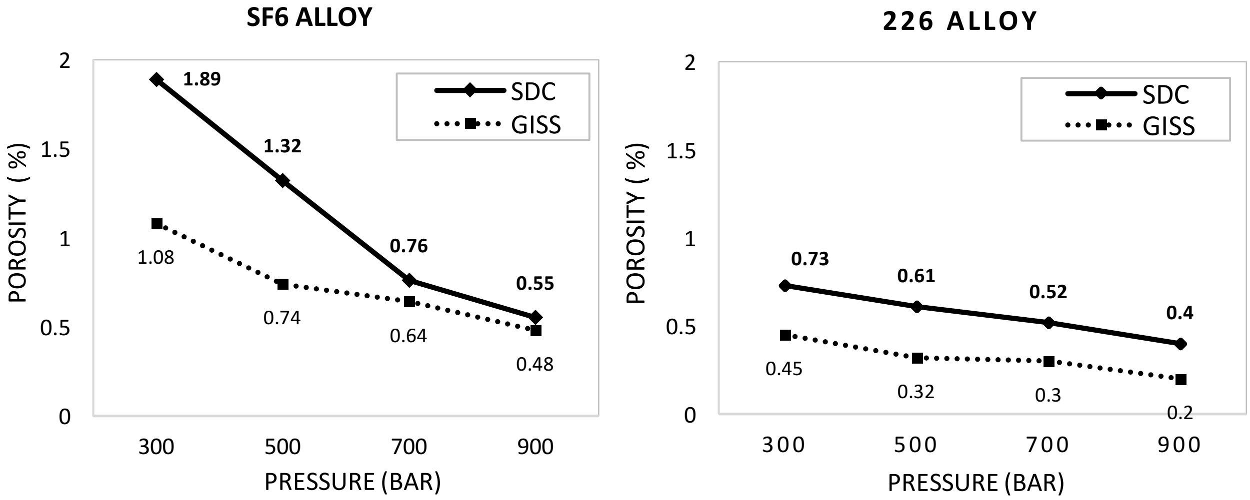


Fig. 6. Pressure-Porosity Diagram of SDC vs GISS Technology (Courtesy of Bühler, Switzerland).

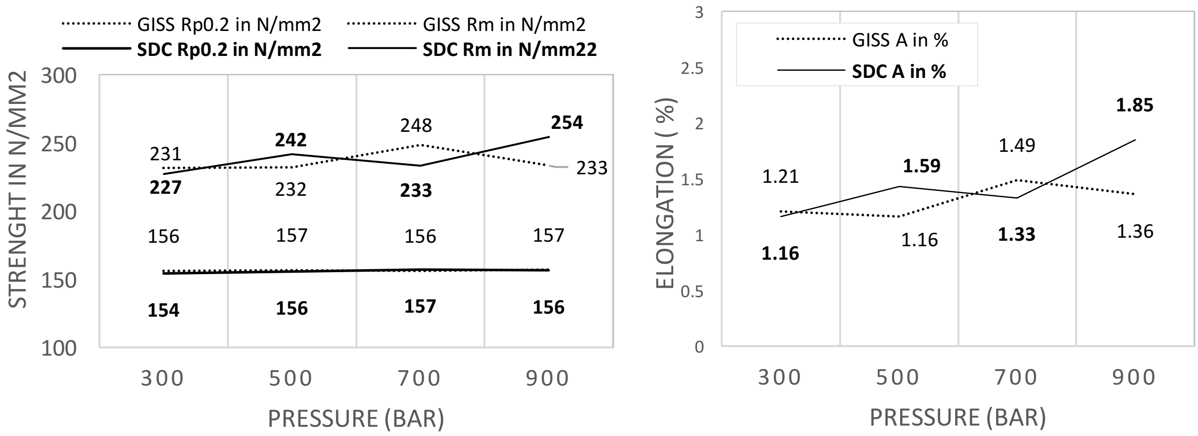


Fig. 7. Strength and elongation data of the 226 alloy produced by SDC and GISS processes (Courtesy of Bühler, Switzerland).

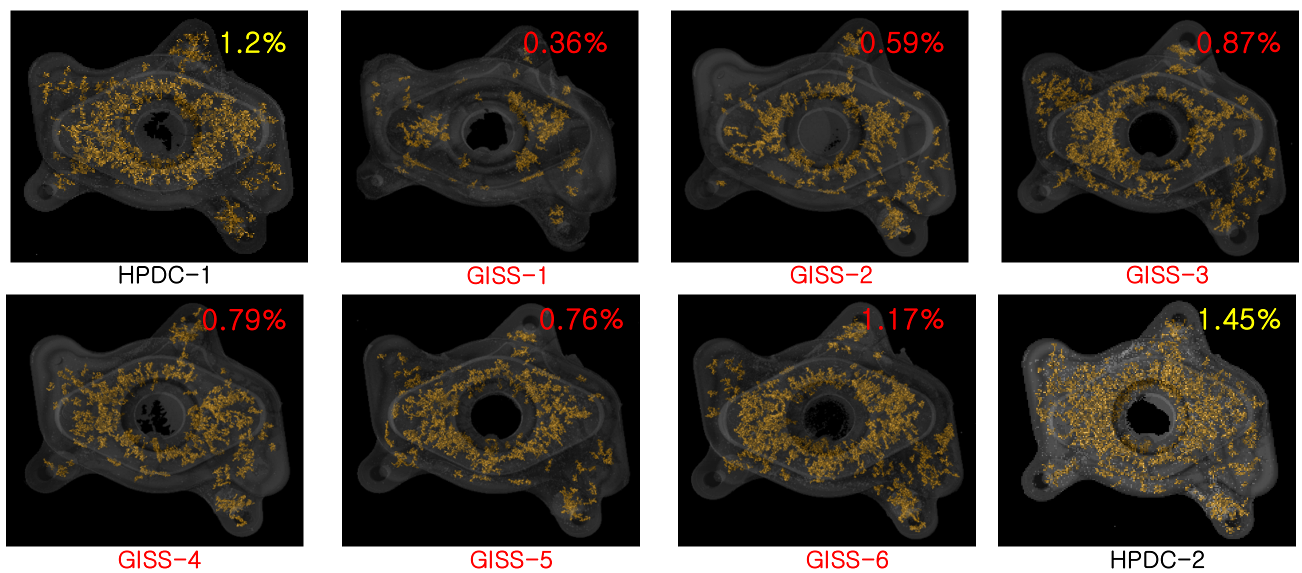


Fig. 8. Comparison of porosity level measured by CT scan of fuel pump bracket (Courtesy of Hyundai Motor Company, Korea).

Hyundai Motor Company, Korea. The R&D Center at Hyundai Motor Company (HMC) in Korea has been working with GISS Technology since 2015. An example which can be disclosed is the fuel pump bracket. A study to optimize the process parameters using GISS has been carried out with six GISS conditions and two HPDC conditions. The results of CT scan show that with the optimum condition of GISS, the porosity level is significantly reduced from 1.2% to 0.36%, as shown in Fig. 8. This study also shows that the microstructure of GISS samples have finer primary and silicon phases, as shown in Fig. 9.

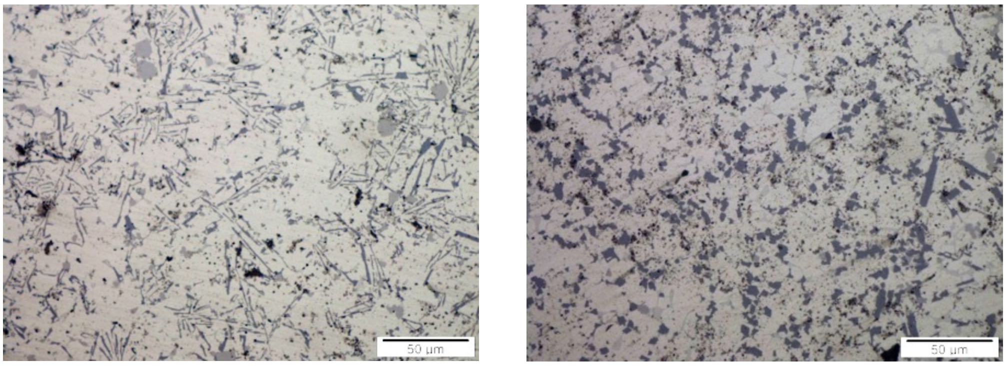


Fig. 9. Comparison of microstructure of ADC12 cast by HPDC (left) and GISS (right) processes (Courtesy of Hyundai Motor Company, Korea).

Sundaram Clayton Limited, India. The benefits of GISS Technology in mass production for production of leak-tight automotive parts have also been demonstrated by Sundaram Clayton Limited in India. Fig. 10 shows the effect of GISS in reduction of porosity at thick sections. The CT scan and cross-section photos clearly show that GISS samples have significantly less porosity. In mass production, the benefits of GISS are then realized with the reduction of leak-related reject from 15,000 ppm to about 4,700-6,024 ppm, or about 60-69% improvement, as shown in Fig. 11.

CT Scan *Cross-Section*

Fig. 10. CT scan and cross-section photos of HPDC (left sample) and GISS (right sample).

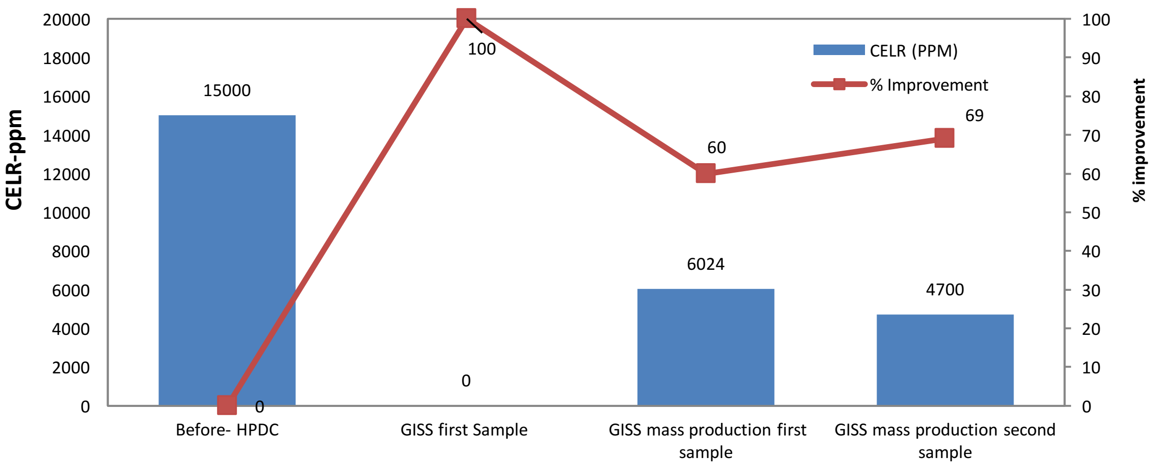
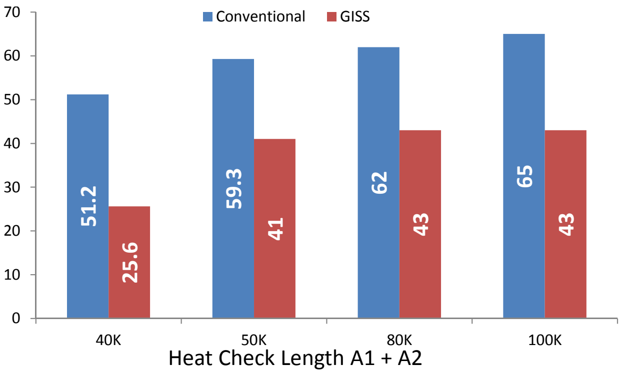
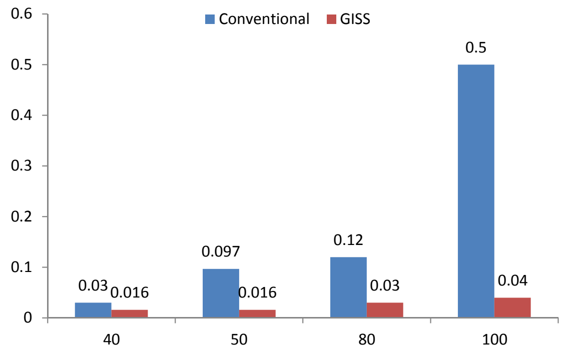


Fig. 11. Die cast parts using GISS Technology (Courtesy of Sundaram Clayton Limited).

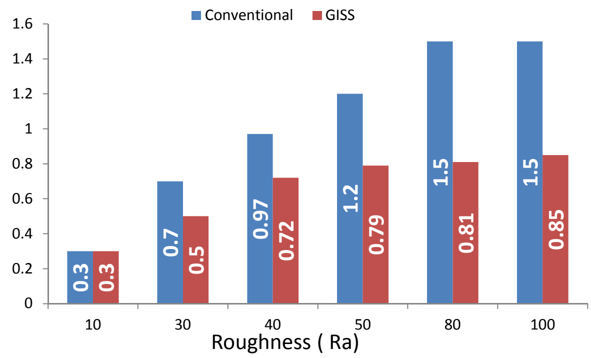
A Leading Bicycle Manufacturer. A study to demonstrate die life extension using GISS Technology has been conducted by a leading bicycle manufacturer. The heat check length, pitting height, part roughness, and insert hardness were monitored every 10,000 shots during the mass production up to 100,000 shots. The results are given in Fig. 12. The results show the surface condition of the die using GISS is better than the die using normal liquid, as shown in Fig 13. Other benefits such as the cycle time reduction of 16%, rejection reduction to about 1%, energy reduction of 18%, and die lube reduction of 73% have also been reported.



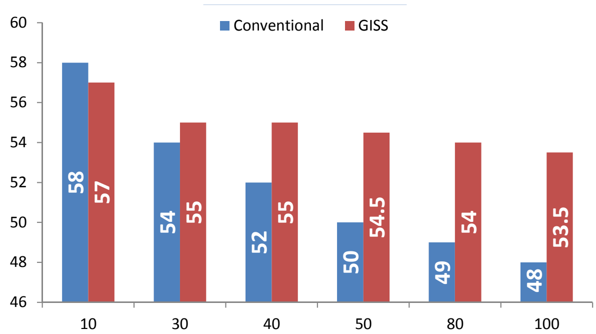
(a) Heat check length



(b) Pitting height

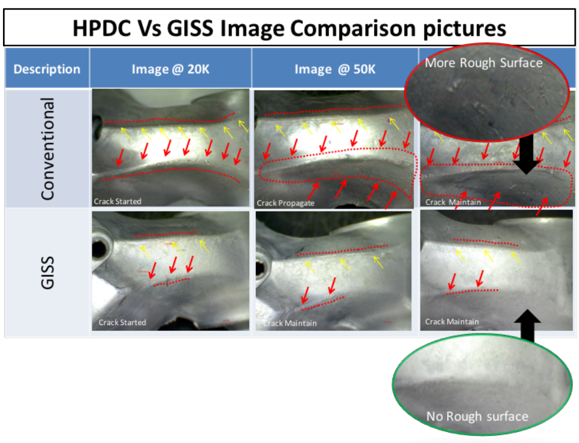


(c) Part surface roughness



(d) Insert hardness (HRC)

Fig. 12. Die conditions using conventional die casting (left column) and GISS (right column).



Measurement Indicator	Target	Conclusion Report			
		Mar-17 10K	Apr-17 20-30K	May-17 40K	Jun-17~ Aug-17 50K ~ 100K
(3) Cycle Time Reduction	15%-20%	16% 38s ➔ 32s	16% 38s ➔ 32s	16% 38s ➔ 32s	16% 38s ➔ 32s Final Cycle Time 32s
(4) NC Reduction	< 5%	1.73%	1.48%	0.9%	1.02% Overall NC 1.3%
(5) Energy(Gas) Reduction	15%	18% 8➔6.5m3/hr	18% 8➔6.5m3/hr	18% 8➔6.5m3/hr	18% 8➔6.5m3/hr Energy used 6.5m3/hr
(6) Die Lube Reduction	15%	38% down 34cc➔ 21cc	65% down 34cc➔ 12cc	73% down 34cc➔ 9cc	73% down 34cc➔ 9cc Final Die Lube vol 9cc

Fig. 13. Part surface quality comparison and GISS benefit indicators.

GISSCO Co., Ltd., Thailand. GISS Technology is being used to develop high performance products with wrought aluminum alloys such as 7075 and 6061 alloys at GISSCO. Both slurry die casting and slurry squeeze casting processes are being used. Examples of components being developed are shown in Fig. 14. High mechanical properties, good anodized surface quality, and small production machines and dies are the key benefits of the GISS Technology for these applications. Current results show 7075-T6 brake caliper parts have the ultimate tensile strength of 450 MPa, and elongation of 7%.

Fig. 14. Examples of color anodized wrought aluminum parts being developed by GISSCO Co., Ltd. (Courtesy of GISSCO Co., Ltd., Thailand).

Summary

GISS slurry casting technology is a new technology for aluminum die casting industry. It is aimed to improve the casting quality by reducing porosity and also lower the production costs. The technology applies the superheated slurry casting principle. Gas porosity and shrinkage porosity rejects can be significantly reduced by applying the GISS Technology with the current die design and die casting machines. In addition, because of the low heat content of the slurry, die life is extended and the cycle time is substantially reduced. Consequently, the casting quality is improved with reduced production costs.

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