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Factors Influencing Characteristics of Sand Core for Water Jacket in Automotive Cylinder Blocks Casting

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자동차 실린더 블록 주조에서 워터 자켓용 샌드 코어 특성에 영향을 미치는 인자

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Abstract The characteristics of the foundry sand were analyzed for water jacket core required to prevent structural deformation from the heat generated in the cylinder bore during the casting of the cylinder block of an automobile. The sand core tensile strength tester, AFS-GFN, and optical microscope were used to evaluate the its properties. If the SiO_2 content is high in the foundry sand, the dimensional defects and veining defects occur due to high temperature expansion. Also, if it is too low, the core breakage, porosities, chemical burn-on defects occur. The particle size index and grain shape influenced the core strength and resin consumption, resulting in fluctuations in defect types. The higher the alkalinity of the dried sand, the lower the core strength. And the more basic, the lower the core strength. At the resin content of 1.6~1.8%, the increase in core strength after 1 hour curing was approximately at its maximum.

Key Words : Sand Core, Water Jacket, Cylinder Blocks, Grain Fineness Number, Core Tensile Strength, Curable Resin

요 약 본 자동차 실린더 블록 주조시 실린더 보어 내에서 발생하는 열로부터 구조적 변형을 방지하는데 필요한 워터 자켓 코어용 주물사의 특성을 분석하였다. 샌드 코어의 특성평가를 위하여 인장강도 시험기, 입도 지수(AFS-GFN), 광학현미경을 사용하였다. 주물사의 SiO_2 함량이 높으면 고온팽창에 의한 치수 불량, 베이닝 불량이 발생하며, 너무 낮으면 코어 파손, 기포, 화학적 소착 등이 발생하였다. 입도 지수와 입형이 코어강도와 레진 소비량에 영향을 미치고, 이로 인한 불량 유형 변화가 발생하였다. 건조사가 염분이 높을수록 코어 강도는 감소하며, 알칼리성일수록 코어 강도가 감소하였다. 레진 함량 1.6~1.8%에서 1시간 경화 이후에 코어 강도 증가는 대략 최대를 보였다.

주제어 : 샌드 코어, 워터 자켓, 실린더 블록, 입도 지수, 코어 인장강도, 수지 경화

1. Introduction

Casting sand is a material that forms an inner/outer shape when casting a cylinder block and maintains its original shape until molten metal is injected and solidified. There are raw sand and

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dry sand for cold box cores, and shell cores are used depending on the purpose[1,2]. The engine cylinder block requires a water jacket that surrounds the cylinder bore and allows coolant to flow around the cylinder casting to cool the bore.

When casting the cylinder head, the core is used to form a water jacket or oil passage, the cylinder head has intake and exhaust ports[3].

In this study, the characteristics of the sand core that can protect the cylinder block from thermal deformation by dissipating combustion heat or heat generated from the cylinder bore was investigated. Based on the results of the study, the factors affecting the sand core characteristics are identified, and the conditions for efficient production are suggested by minimizing defects during cylinder casting.

2. Experimental method

2.1 Raw Sand Analysis for Water Jacket Core

Table 1 shows the results of the component analysis of the two raw materials for evaluating the properties of the foundry sand used within the water jacket core molding of the engine cylinder blocks.

Table 1. Chemical composition of raw sand for core

Composition	Raw Sand for Core(wt%)	
	V-1	A-1
SiO_2	99.7	99.4
Al_2O_3	0.07	0.048
Fe_2O_3	0.04	0.18
CaO	0.02	0.018
MgO	0.01	0.003

We analyzed GFN(Grain Fineness Number) according to AFS(American Foundry Society) standard. Sieve shakers(Laktas Wire Mesh Private Limited) are used for separation and size determination of particles as shown Fig. 1.

Moisture evaluation was performed to determine the percentage of moisture in the molding sand by Moisture Teller(Ridsdale Dieter T).

Fig. 1. Sive shakers for Evaluation of Grain Fineness Number

2.2 Core Molding

Fig. 2 shows the manufacturing process of the core used in the evaluation of the sand properties.

LOI(Loss on Ignition) measured by the weight change of a sample, consisting of weight losses and weight gains when a sample is fired at 982℃.

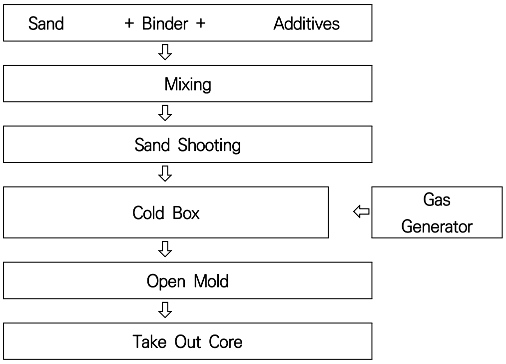

Fig. 2. Core preparing process

Raw sand molding includes weight loss due to volatilization of organic matter, removal of chemically bound water, dissociation of inorganic compounds and weight gain due to oxidation reactions. Therefore, the LOI test was performed according to the AFS standard (AFS 5100-12-S).

2.3 Properties Analysis of Dry Sand

The properties of the dried sand were measured in terms of composition, particle size(AFS 1105-12-S), particle shape, pH(AFS 5113-00-S), ADV(Acid Demand Value), LOI(Loss On Ignition), and moisture(AFS 2216-00-S) according to the AFS standards. The acid demand value (ADV) tester measures the amount of basic substances present in sand that dissolves in a dilute acid solution. The reaction to harden the resin acts as an acid catalyst and the acid is very weak, so the presence of a basic substance that can neutralize the weak acid will delay the curing reaction. ADV test was performed according to the AFS standard (AFS 1114-00-S).

The Acid Demand Value Test Kit(Simpson Technologies) includes a two titrating burette, digital magnetic stirrer, specialized stir wedge, heavy duty stand, beaker, dual self-zeroing burette kit, (pH/mV) temperature meter with electrode arm kit and electrode.

2.4 Tensile Strength Testing of the Water Jacket Core

Tensile strength test was measured in a state in which the collected sample was put into a cold box tensile curing machine and amine gas (N, N diethylmethyamine) was blown to cure the catalyst. The tensile strength of the prepared sand core samples was measured by SWY universal sand strength testing equipment as shown Fig. 3. As shown Fig. 4, the tensile strength tests were performed according to the AFS standard (AFS 3301-08-S).

Two resin mixtures (ECO 700, ECO 900) were used as the curing agents.

Fig. 3. sand core strength testing machine.

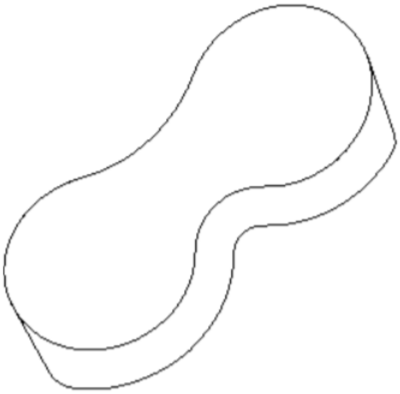

Fig. 4. Standard specimen of tensile strength test for core sand

A sample was put on the tensile strength machine and gradually loaded until it was broken, and its strength could be recorded. the tensile strength at room temperature and that of samples holding at 35℃ and humidity of 90% RH for 30, 60, 90 min. were measured.

3. Results And Discussion

3.1 AFS Grain Fineness Number of Foundry Sand for Water Jacket Core

The optimal grain fineness number (GFN) in a sand core is determined by the type of metal poured, pouring temperatures, casting products (light vs. heavy castings) and required surface finishing. Once the optimum fineness level has been determined, maintaining a consistent grain structure becomes an important factor in the quality of the final casting[4].

Fig. 5 shows core defect rate as grain size(GFN) variation.

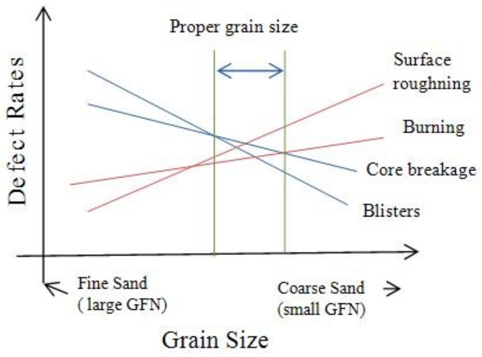

Fig. 5. Core defect rate as grain size(GFN) variation

Table 2. Casting effect according to the properties of dry sand

Factors	Standards	Impact on casting
Component	≥SiO_2 90%	The higher SiO_2 content, the higher core strength, and there is a risk of veining.
AFS-GFN	58~64	GFN and grain shape affect core strength and resin consumption, and defect types fluctuation occur.
Grain Shape	Rouded, Suangular	
pH	4~7	alkalinity decrease core strength.
ADV	≤ HCl cosumption 15cc	higher salinity the core strength decrease.
LOI	≤ 1.0%	The higher the organic substance and moisture content, Core strength decrease.
Moisture	≤ 0.2%	

If the sand is too fine or has a higher GFN, it is less permeable and can lead to gas defects.

Sand with low or too coarse GFN produces high permeability and can cause metal penetration, rough surface finish, burn-in and burn-on defects[5,6].

3.2 Casting Effects with the Raw Sand Properties

As shown in Table 2, the size, size distribution, and shape of the sand grains are important in controlling the quality of the mold.

Most mold aggregate are mixtures of fresh and recycled sand, which contain not only recycled mold sand, but also core sand.

Proper sand particle size, shape and distribution seems to be important to control these factors, as the sand particle shape contributes to the amount of surface area, and the particle size distribution affects the permeability of the mold.

The optimal sand shape for making the core was rounded grains, because rounded grains have a low surface area to volume ratio and require the least amount of binder[7,8].

As shown in Fig. 6, Since the angular sand has the largest surface area, more mulling, bonding and moisture were required. In addition, since sand is decomposed by heat and mechanical shock, the amount of sand is increased according to the angle of the sand, so the shape seems to be a very important factor.

Fig. 7 shows the bench life is the usable time of the mixed sand after mixing sand and resin, and it is used to manufacture the core by the cold box method, and the longer the time, the better the production.

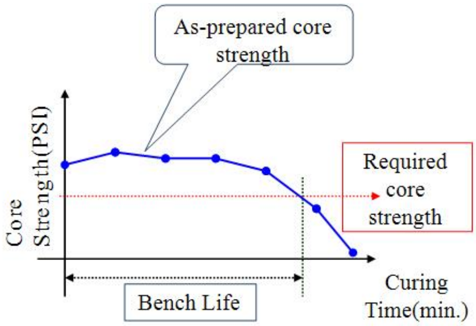

Fig. 7. Bench life in the curing time vs. core strength

The final tensile strength was the average of five samples, respectively. The distribution of green sand is related to the physical properties that can be developed by the green sand system, and has an effect on the dry core strength. The particle size distribution was found to have an effect on the amount of bonding required and the surface finish of the casting. Therefore, screen analysis had to be performed on washed and dried sand systems[9,10]. A comparison of the dried sand screen analysis and the washed sand screen analysis indicates that a large amount of agglomeration occurs in the green sand system.

The factors affecting the moisture demand of the sand core were the type and amount of clay, and the type and amount of additives contained in the green sand mixture. The moisture content of the green molding sand had to be kept within a narrow range. LOI (Loss on Ignition) determines the total amount of combustible substances in the green sand, and the green sand samples were fired at 982 ℃ by volatilization until a constant weight was reached. The amount of gaseous material in the green sand influenced the casting results. A high LOI could cause gas defects such as pinholes, scabbing and blows, so control was required. In steel castings, it was found that a high LOI caused carbon pickup from the casting surface, and a low LOI resulted in poor cast peeling and a rough casting surface[11,12].

3.3 Properties Analysis of Dry Sand

When the casting is poured into the mold, the sand adjacent to the hot metal quickly loses water as steam. Therefore, dry sand must have the strength to withstand erosion and the metal static pressure of the molten metal. Otherwise, the mold could become large, so it had to show sufficient strength[13].

Fig. 8 shows Changes in core strength according to resin content and curing time.

It was found that the tensile strength of core sand had an effect on the amount of resin added, but the raw sand composition at V-1 and A-1 did not have a significant effect[14,15].

Therefore, It is considered important to manage organic substance such as grassroots debris and insect carcasses which mixed in the sand collection process[16].

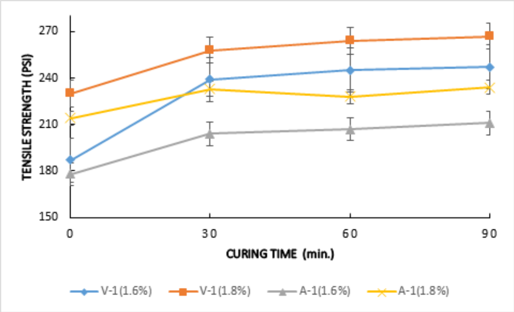

Fig. 8. Changes in core strength according to resin content and curing time

Fig. 9 is a water jacket core made using V-1 and A-1 raw sand, and Fig. 10 is a test sample showing the strength and dimensional stability of the core.

Industrially, the water jacket core of the cylinder block requires a minimum tensile strength of 100 PSI with the core manufactured without curing time.

Fig. 9. Two types water jacket core prepared from V-1 and A-1 raw sand

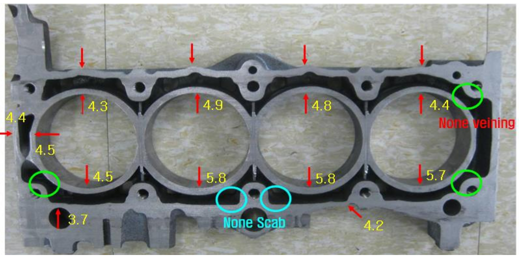

Fig. 10. Cross sectional image of manufactured water jacket core

4. Conclusions

Therefore, the sample proposed in this study appears to have the strength that can be applied to the production site without maintaining the curing time.

The raw sand that satisfies the tensile strength of 100 PSI and economical efficiency of dried sand was V-1. The compositional effect was insignificant compared to the amount of the resin and the curing time in the range of Al_2O_3 0.05-0.07, F_2O_3 0.04-0.2 and MgO 0.003-0.01 wt%.

In order to obtain sufficient core strength to allow handling and handling work in cylinder block casting, the raw sand's particle size index, grain shape, pH, alkalinity, acid demand value, ignition loss, moisture, and organic substances must be sufficiently managed. The sand core curing conditions suitable for the water jacket of the cylinder block for preventing casting defects were a curing time of 30 minutes or more and a curing catalyst of 1.6%, respectively.

In a future study, we will try to optimize the relationship between heat flow and structural deformation by simulating combustion heat and heat dissipation in the cylinder block bore.

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