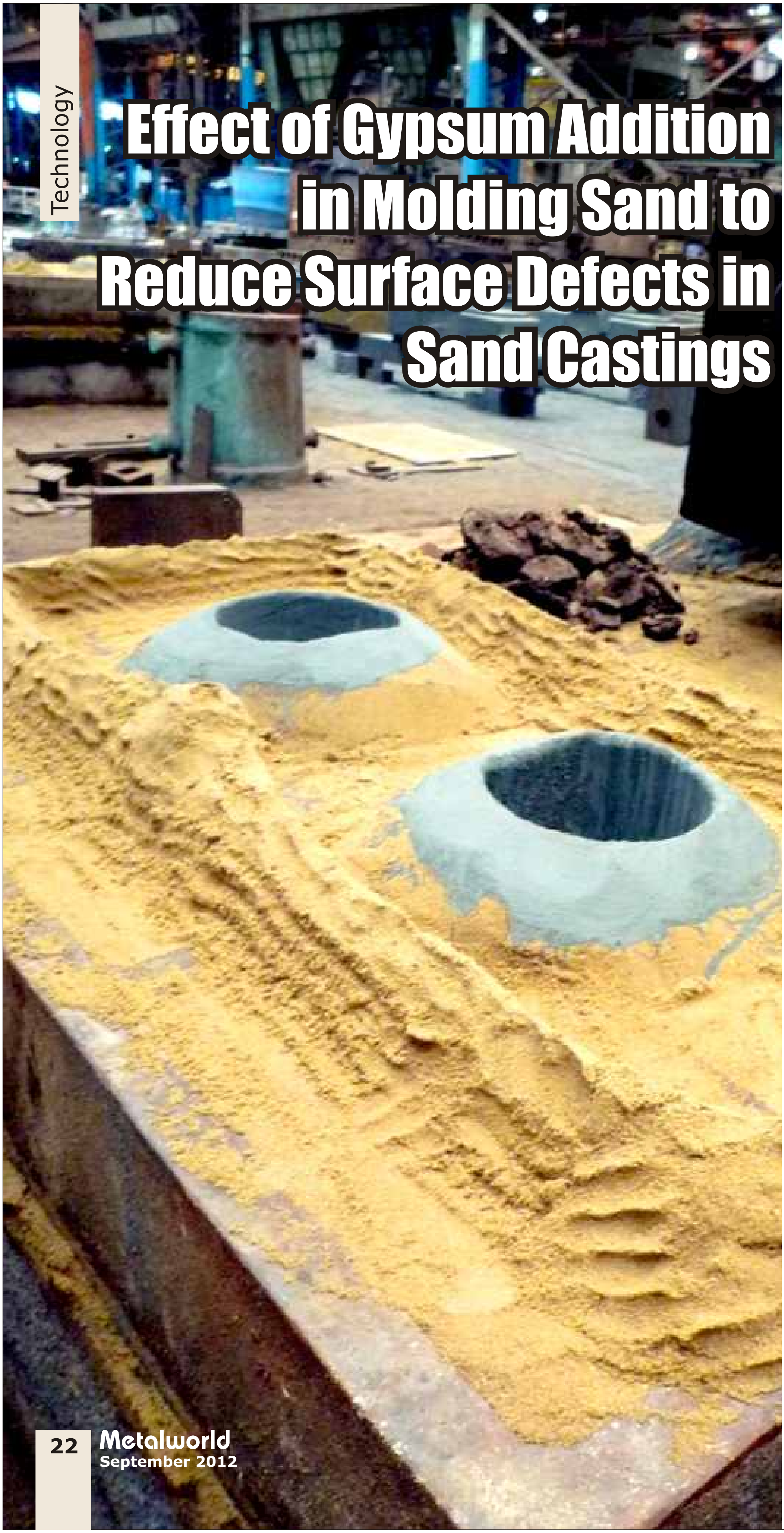

Effect of Gypsum Addition in Molding Sand to Reduce Surface Defects in Sand Castings

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Sand casting is a type of expendable mold casting process. Expendable molds are used only once. Pattern used in the process should be removable from the mold without damage [1]. Sand casting technique can be applied for smaller batch casting production when compared to permanent mold casting and at a very reasonable cost. From castings that fit in the hand's palm to train beds, it can all be done with sand casting process. This method is applicable to almost all the metals and alloys. Four main elements are required in this process. They are casting: pattern, mold, cores, and the part [2]. In this process, sand is mixed with binders, bentonite and water. It is then blended and compacted around the wood or metal pattern halves to produce a mould cavity. Mould is removed from the pattern, assembled with cores, if necessary, and the liquid metal is poured into the resultant cavities. After cooling, moulds are broken to remove the castings. This process is suitable for a wide range of metals, both ferrous and non-ferrous, and different sizes and shape complexities [3]. Sand casting primarily uses green moist sand, and it has almost no part weight limit whereas dry sand has a practical part mass limit of 2300-2700 kg. Minimum part weight ranges from 0.075-0.1 kg. Sand is bonded together using clays, as in green sand molding or chemical binders, or polymerized oils. Sand can be recycled many times in most operations and requires little additional input. The term green sand does not refer to color, but to the fact that a raw sand and binder mixture has been tempered with water. Sand molding is a versatile metal-casting process that provides freedom of design with respect to size, shape, and product quality [4]. Plaster casting is similar to sand molding process except that a plaster is substituted for sand. Plaster compound is composed of gypsum, strengthener and water. Parts were typically made are gears, valves, fittings, tooling, and ornaments. The finished product of plaster casting has a very high surface resolution and fine tolerances. It cannot be used to produce non-ferrous metal castings. Gypsum in the plaster will slowly reacts with the iron and the maximum temperature of plaster casting is limited to 1200°, which limits the material to be cast by using this method. A thin layer of parting film is usually sprayed to the pattern to prevent mold from sticking the pattern, and this step is a necessary one. In this method, the mold box is shaked to allow the filling of the sand in the cavities around the pattern, and it is then dried at the temperature between 120° to 260° [5]. In this work, a simple shape of anvil is used as the mould cavity when performing sand casting process. The molten metal used is tin and stannum castings are made. The physical properties of tin are presented below in Table-1.

TABLE-1 : PHYSICAL PROPERTIES OF TIN	
Name :	Tin
Group :	Metal, carbon group
Density :	7.30 g/cm^3
State :	Solid
Melting Point :	505.168 K (233°C)

Sand Casting Steps and Procedure

Sand casting starts with the following steps, however one must remember that casting process is not only limited to human participation and no special equipments nor machines for the process is being applied.

- A pattern plate is placed on top of the cope and fixes the drag box to the pattern plate and cope using screws. Wipe the pattern plate and the pattern with a parting agent by using a brush. Parting agent is used to avoid the molten metal from sticking on the cavity wall. Place the pattern under the part at the centre on top of the pattern plate and sand is dumped inside the drag box. Then, the sand is rammed.
- Smaller and bigger rammers are used to compress the sand all around in the drag box. Repeatedly it is filled and compressed till it reaches the top of the drag box.
- Cope box is turned upside down and unscrewed. Then, the pattern plate is removed. The parting agent is evenly sprayed throughout the surface of the compressed sand. The upper pattern is aligned to the lower pattern and cope is screwed again.
- Parting agent is applied to the big down gate and small down gates. The gates are placed approximately 10-15mm from the pattern, each on the start and end of the pattern.
- Big down gates serves as a pouring basin and the small down gates serves as the riser. Now repeat the steps on the other cope box.
- After this, both the down gates are removed from the cope box from its bottom. Unscrew the cope box to remove the down gates and pattern. Cope box is then located on the flat surface for making gates, channels, and runners.
- Now the cope box is ready for casting process. Then the molten metal is poured into the mold till it is fully filled. Then, it is allowed to solidify and the final casting is extracted after some time by loosening the bolts from the cope box.
- Casting is then cleaned by removing the sand around its surface. Gates and runners are removed by using a hacksaw blade.

(I) Now the casting is ready for observation. All the defects found on the casting will be recorded in detail and it should be analyzed for improvement.

Surface Defects in Anvil Castings

Surface defect is a crucial problem in castings. During the experiment, three types of casting defects have been identified. They are metallic projection, cavities and rough surfaces. These defects share a common condition as they are found on the casting surface. These are categorized together for the ease of solving and complete considerations. Hence, solution obtained will be compromising and effective for these defects. Formation of a smoother and lesser moisture mould's surface will increase the complexity of making the mould, and cause extra consumption of time and work force towards the process. Partial contribution of surface cavity is due to the moisture content present in the sand. Surface reaction of water vapor with other elements in the molten gives rise to metal oxides and atomic hydrogen which diffuses into the molten metal. Hence, cavities are formed on the casting surfaces. In order to remove the moisture in the sand, sand can be baked and cured in an oven before use. However, this can easily yield to excessive removal of moisture in greensand. Moisture and clay present in the sand penetrates inside to create a film of a fixed and defined composition [6]. Excessive moisture removed from the sand will in turn leads to a fragile structure in the sand mould and the mould cavity can easily fall apart. Separation of necessary part in the sand mould means to remove the moisture on the molten contact area only. Removal of moisture is done by using a dryer at 120°F and this will partially removes the moisture on the cavity surface. The heating process is shown below in Figure-1. The reason for heating the cavity surface to 120°F is that the clay should not adhere to the sand over 130°F. Bonding capacity of sand, bentonite-water mixer starts reducing above 50°C and becomes non-existing above 70°C [6].

Figure-1 : Heating Process to Remove Moisture at 120°F

During the heating process, both the upper and lower mould cavity has been heated by a dryer to a temperature at 120°F. In solving the problem of excessive moisture in the greensand, it is always suggested to dry the green sand in order to remove the moisture before the casting process. Surface roughness in the mould cavity can be controlled by controlling the grain size of the greensand and finer grain size will create more intimate contact and lower permeability [6]. Metallic projection occurrence is contributed by the air bubbles lodged within the casting closer to the pattern surface. Hence in curbing these problems, a material film is made on the cavity-molten contact. The material to be mixed into the green sand requires carbon content to be added in order to improve the surface finish. However, for this case study, gypsum is chosen instead of carbon powder.

Reasons for Adding Gypsum in Moulds

In this study, quantity of gypsum added in the sand varies from 3%, 4%, 5% & 10%. The reasons for adding gypsum in the moulding sand is presented below in Table-2.

A simple experiment has been conducted to test the binding effects, otherwise called as mould ability of the sand. Variation of mould ability with varying % addition of gypsum is presented in Table-3. Moving across from 10% to 3%, gypsum in the greensand, mould ability has been

TABLE-2 : REASONS FOR GYPSUM ADDITION IN THE MOLDING SAND	
Factors	**Reasons for Adding Gypsum in Moulding Sand**
Accessible	Easily Attainable
Accuracy	Good dimensional accuracy and surface finish can be attained. Capability to make thin cross-sections in casting.
Molten Material	Limited to Non-ferrous alloys.
Absorbance	$CaSO_4 \cdot ½H_2O + 1½\ H_2O \rightarrow CaSO_4 \cdot 2H_2O$ Gypsum absorbs moisture effectively.
Melting Point	1460°C, which makes it stable at high temperature.
Quantity	Fines content to be added into the green sand influences the binder requirement significantly; and it should be kept below 3%. In this case study 3% of gypsum from total weight of the film material is added in the green sand.

found to be decreasing. In other words, greensand will lose its ability to bind as the quantity of gypsum increases. It has been found that 3% has indeed proves to be too much. However, this experiment was a successful one and despite at a certain level of difficulty. Figure-2 shows a discardable film in the greensand containing gypsum. The picture at the left indicates the sectioned side view and the picture at the right indicates the top view.

Figure-2 : A Discardable Film in the Greensand Containing Gypsum

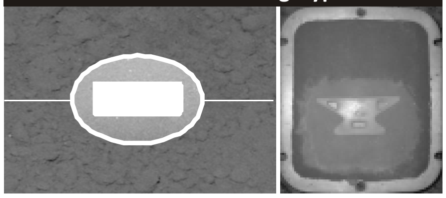


TABLE-3 : MOULDABIITY Vs GYPSUM ADDITION		
Greensand (7g)	**Gypsum (g)**	**Mould Ability**
3%	0.21 gm	Low
4%	0.28 gm	Considerably Low
5%	0.35 gm	Easily fall off
10%	0.7 gm	Unusable

The percentage of gypsum added in the greensand has made the mould cavity harder and casting removal easier. So, extraction of casting is made easier and cavity dimensions are left undisturbed. This is a benefit to the casting mould because of the additives added. Figure-3 shown below indicates the mould condition after and before the casting process is performed.

Results and Discussion

Figure-4 (a) and (b) indicates the casting surface after and before gypsum addition. Figure-5 (a) indicates the presence of metallic projection on casting surface before gypsum addition, whereas, Figure-5 (b) indicates casting surface after gypsum addition and it is free from metallic projection. Casting after improvement shows that it is completely free from any metallic projections.

Figure-3 : Easy Extraction from the Greensand Mould

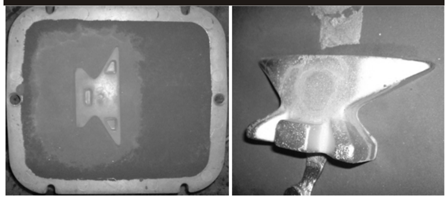


Figure-4 : (a) Casting Surface After Gypsum Addition & (b) Before Gypsum Addition

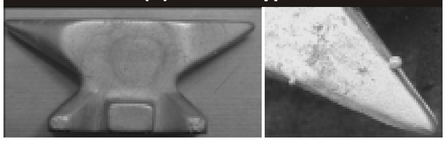


Figure-5 : (a) Casting Surface After Gypsum Addition

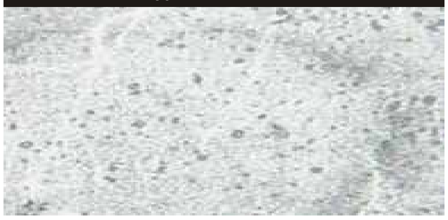
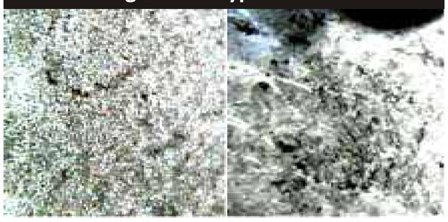


Figure-5 : (b) Indicates Rough Surface in Casting before Gypsum Addition



In terms of surface roughness and cavities, gypsum addition has successfully improved surface roughness and reduced the cavity formed on the casting surface. Figure-6 (a) indicates the casting surface finish after gypsum addition, and Figure-6 (b) indicates the surface before gypsum addition. Figure-6 (a) clearly shows the improvement of smooth surface and reduction in surface cavity. Reason for the reduction in cavity is most probably contributed by the usage of recycle material and possibilities of porosities are contributed by the contaminants reacted during high temperature during the release of gaseous entrapment.

Figure-6 : (a) Casting Surface without Camera Flash at the Left

Figure-6 : (b) Casting Surface without Camera Flash at the Right

Measurement of surface roughness is done by using a profilometer and the data is presented in Table-4. Measurement of the surface roughness was performed by taking two of the smoothest and roughest surface to represent the total average value for the entire casting surface.

Further proof on surface improvement can be obtained through the observation of casting surface by optical microscopy. Figure-7 (a) shown below at the left side indicates the surface finish after improvement and having a denser grain structure, after gypsum addition.

Figure-8 shown above is the microscopic images, (a) having more

TABLE-4 : SURFACE ROUGHNESS RESULTS					
Surface Roughness of Casting (R_a)	**Smooth**		**Rough**		**Average Value**
From Raw Material	6.05 µm	6.16 µm	16.15 µm	11.86 µm	**10.055 µm**
Conditioned Mould Cavity without Heating (Random Trial)	5.84 µm	4.38 µm	8.79 µm	7.69 µm	**6.675 µm**
Conditioned Mould Cavity with Heating (Controlled Parameters)	1.64 µm	1.78 µm	2.25 µm	3.53 µm	**2.3 µm**

Figure-7 : (a) Casting Microstructure After Gypsum Addition Magnified at 50X

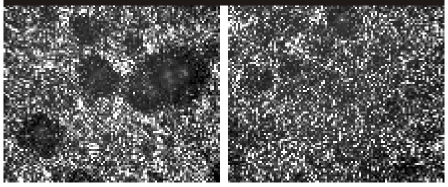


Figure-7 : Casting Microstructure After Gypsum Addition Magnified At 50x

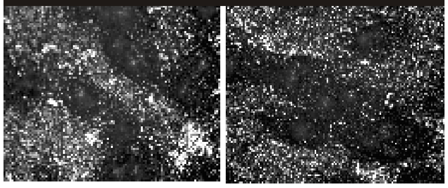
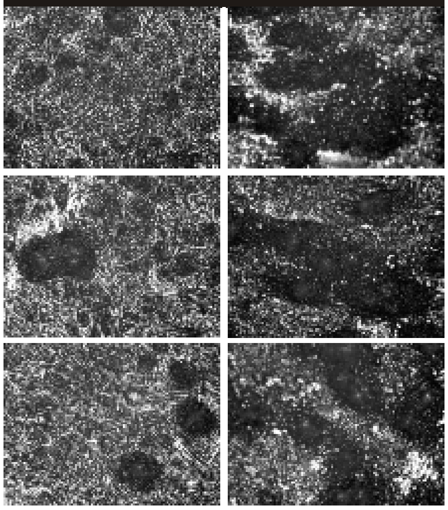


Figure-8 : (a) Microscopic Images Under 50X Magnifications for the Improved Casting Surface and (b) Showing the Reduction of Surface Cavities



(a) (b)

continuous surface cavities than the one in (b) and also shows the dramatic reduction in surface cavity formation. Comparison of both surface roughness yields to an improvement of 77.13%. Figure-9 shown below is a comparison made between the casting surfaces with bare eye observation, and also indicates improved surface on the left and before improvement on the right.

$$\frac{\text{(Raw-Conditioned Heating Capacity) Data } \mathbf{RA}}{\text{Raw Data } \mathbf{RA}} \times 100\%$$

Calculation on Improvement %

$$10.055 - 2.3 = 7.755$$

$$\frac{7.755}{10.055} * 100 = 77.13\%$$

Figure-9 : Comparison between Castings Surface with Bare Eye Observation Indicates Improved Surface on the Left and before Improvement on the Right.

Figure-10 : Comparison of Parting Line Area and Surface Finish Improvement After Gypsum Addition, (left Side) and before Improvement (Right Side)

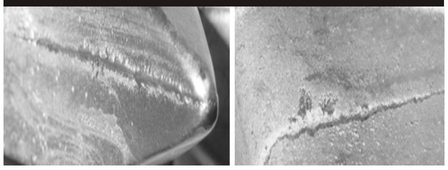


Figure-10 shown above focus the parting line area in the casting. The left side of the picture indicates the improvement done on casting after gypsum addition, whereas, the picture displayed at the right side indicates the flash formation on the casting parting line area. Flash formation on the parting line area will be followed by extra removal process.

Conclusions

The application of gypsum in the greensand mixture has reduced the casting surface defects and also improved surface finish. Metallic projection has been completely removed from the casting surface, and there is no formation of metallic projection detected through bare eye inspection throughout the casting surface. For verification and improvement, various tests have been

carried out to investigate the casting outcome which includes the running surface testing with a profilometer and optical microscopy observation. Besides, a simple experiment was carried out to determine the quantity of gypsum to be added in the greensand.

Suggestions for Future Work

Further study should be repeated on the microstructure on castings. Impact of gypsum addition on the surface area should be identified and studies. Because it is potential diffusion might affect the physical properties of casting material. Finally, it is recommended to study the effect on the addition of different additives, instead of using gypsum as an additive in the greensand. Another material should be used to study the effect of mixture between greensand and additives towards the surface finish formed. Calcium carbonate is a secondary choice to be concerned as it does not contain sulfur and applicable to ferrous metals and alloys.

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