USAGE OF BLAST FURNACE SLAG IN MOULDING SAND TO PRODUCE AL-MG ALLOY CASTINGS

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Abstract*:* Now a day, utilization of silica sands for foundry purpose in hundreds of tons. Industrialization and globalization leads to high production rates, which in turn increased the demands in multiples. It is the time to use the materials in an effective way and minimize its utilization by looking for alternative. With this thought find an alternative solution for the future generation for the reduction in usage of moulding sand.

Slag and CO_2 are the byproducts of Blast furnace. Every ton of pig iron produces 0.5-1.8% of Blast Furnace Slag (BFS), based on quality of pig iron and 2.5-3.5% of blast furnace gas. In this work an attempt has been made to replace some portion of sand with slag from the blast furnace by maintaining the same properties. Generally green sand consists of 75-85% silica sand, 11-15% clay, 2-5% bentonite, 4-6% water. These properties of silica sand is varied and balanced with slag in various steps.

With this slag we tried to make moulds with CO_2 process and various mould properties are observed like hardness, permeability, compression and shear strength etc, by using which A1- Mg alloy castings are manufactured and tested.

1. INTRODUCTION

For making castings we need moulds, the moulds are made of wet sands. The name comes from the fact that wet sands are used in the moulding process. There are four main components for making a sand casting mould:

1. Base sand
2. Binder
3. Additives
4. Parting compound

1.1 Base Sands

Base sand is the type used to make the mold or core without any binder. Because it does not have a binder it will not bond together and is not usable in this state. Silica sand is the most commonly used sand because of its great abundance, and, thus, low cost (therein being its greatest advantage). Its disadvantages are high thermal expansion, which can cause casting defects with high melting point metals, and low thermal conductivity, which can lead to unsound casting. It also cannot be used with certain basic metal because it will chemically interact with the metal forming surface defect.

1.2 Binders

Binders are added to a base sand to bond the sand particles together (i. E. It is the glue that holds the mold together). It includes:

Clay and water

A mixture of clay and water is the most commonly used binder. There are two types of clay commonly used, bentonite and kaolinite.

1.3 Additives

Additives are added to the moulding components to improve surface finish, dry strength, refractoriness, and "cushioning properties". Up to 5% of reducing agents, such as coal powder, pitch, creosote, and fuel oil, may be added to the moulding material to prevent wetting (prevention of liquid metal sticking to sand particles, thus leaving them on the casting surface), improve surface finish, decrease metal penetration, and bum-on defects. Up to 2% of iron oxide powder can be used to prevent mould cracking and metal penetration, essentially improving refractoriness. Silica flour (fine silica) and zircon flour also improve refractoriness, especially in ferrous castings. The disadvantages to these additives are that they greatly reduce permeability.

1.4 Over view of slag

Slag is a partially vitreous by-product of smelting ore to separate the metal fraction from the unwanted fraction. It can usually be considered to be a mixture of metal oxides and silicon dioxide. However, slag can contain metal oxides and metal atoms in the elemental form. While slag are generally used as a waste removal mechanism in metal smelting, they can also serve other purposes, such as assisting in the temperature control of the smelting ; and also minimizing any re-oxidation of the final liquid metal product before the molten metal is removed from the furnace and used to make solid metal.

Every ton of pig iron produces four tons of Blast Furnace Slag (BFS) and tons of blast furnace gas. Blast furnace slag can partially substitute basic foundry matrix, i. e., sand as a backup. Present day report shows blast furnace slag can be utilized to a maximum extent of 4% only in cement manufacturing, road material etc. Dumping of used silica sand is also a major problem in terms of transportation and area use of slag can reduce this problem to more than 50% Similarly use of blast furnace gases from the blast furnace stoves can minimize environmental pollution. The chemical analysis of slag is as follows

Constituent	Percentage (%)
FeO	0.21
CaO	36
MgO	8.9
Silica	33.9
MnO	0.19
$8Al_2O_3$	17.5
P_2O_5	0.55
K_2O	0.35
TiO_2	0.55
Bessisity (CaO/SiO_2)	1.02

2. Preparation of Sand and Slag Mould

2.1 Specimen Preparation

a) When preparing a number of specimens from the same sample, replace the lid of the container after weighing out each specimen.

b) Carefully level out the sand surface in the specimen tube before placing under the plunger of the sand rammer.

C) In CO_2 process sand is leveled up to correct height and then pass the CO_2 through the specimen

d) Never use which has already been rammed up once to form a specimen.

e) Always ensure that the height of a specimen is correct, that is within the tolerance specified.

f) Reject any specimen which shows any sign of damage.

g) Green sands should be tested immediately; dried or baked sands as soon as they have cooled in desiccators and with cured sands the length of time between curing and testing should be stated when reporting results.

h) Any deviation from standard ramming practice should be reported with results.

2.2 Sieve Analysis

A sieve analysis (or gradation test) is a practice or procedure used (commonly used in civil engineering) to assess the particle size distribution (also called gradation) of a granular material. The size distribution is often of critical importance to the way the material performs in use. A sieve analysis can be performed on any type of non-organic or organic granular materials including sands, crushed rock, clays, granite, coal, and soil, a wide range of manufactured powders, grain and seeds, down to a minimum size depending on the exact method. Being such a simple technique of particle sizing, it is probably me most common.

Sieves

Mechanical Shaker

Fig 1: Sieve Shaker

2.3 Sand Rammer

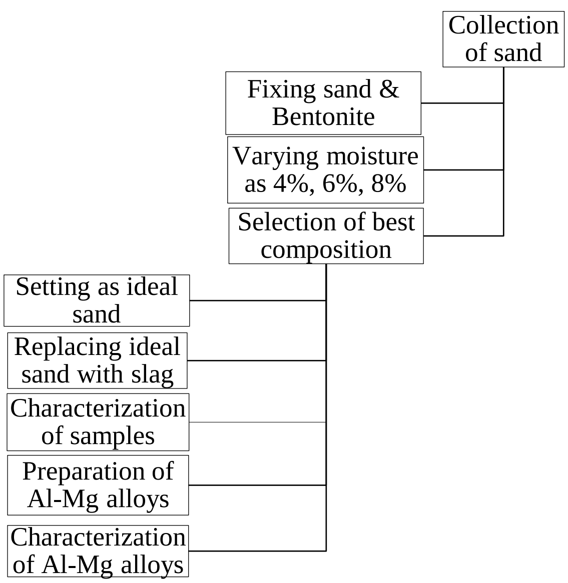
Fig 2: Sand Rammer

Sand rammer consists of calibration sliding weight actuated by cam, a cup to accommodate specimen tube below ram head, a specimen stripper to strip compacted specimen out of specimen tube, a specimen tube to prepare the standard specimen of 50 mm diameter by 50 mm height or 2 inch diameter by 2 inch height for an AFS standard specimen. The sand rammer machine can also be used by filling the specimen tube with sand so that it is level with the top of the tube, and, by compacting the sand within the tube with a three-ram compaction to whatever height is the result of the three rams, compute a percent compatibility of green sand. The cam is actuated by a user by rotating the handle, causing a cam to lift the weight and let it fall freely on the frame attached to the ram head. This produces a standard compacting action to the pre-measured amount of sand. The object for producing the standard specimen is the have the specimen become 2 inches high (plus or minus 1/32 inch) with three rams of the machine. A rammer is mounted on a base block on a solid foundation, which provides vibration damping to insure consistent ramming. After the specimen has been prepared inside the specimen tube, the specimen can be used for various standard sand tests such as the permeability test, the green sand compression test, the shear test, or other standard foundry tests.

Used for sand types

- Green sand
- Oil sand
- C02 sand
- Raw sand i. e. Base sand i. e. un-bonded sand.

2.4 Methodology Chart



2.5 CO_2 MOULDING PROCESS

CO_2 moulding process has many advantages over other forms of sand moulding. But it is not more economical to do than green sand moulding, but moulds can be made to much closer tolerances, which can reduce machining time of castings, this will only appeal to commercial operators, and not be of much concern to the hobby caster, where time taken to do a certain process is not important.

But as green sand gets more difficult to find or make, then this form of mould and core making can be of great benefit for the hobby caster.

CO_2 Advantages:

1. A reduction in fuel costs due to the elimination of core drying ovens etc.
2. A reduction in the number of mould boxes required for making moulds.
3. Cores and moulds are gassed or hardened in situ, lessening the labor involved in mould making.
4. Because moulds are hardened with patterns in position, a high accuracy is achieved. With careful moulding practice some castings can be produced with tolerances very close to shell moulding.
5. The low cost of equipment required for CO_2 ·
6. Existing pattern making equipment can be used.
7. One of the biggest advantages for the hobby metal caster when using this system, is the total elimination of moisture from the moulding sand (providing it has been stored correctly) the only expense you might encounter is the cost of the CO_2 cylinder, regulator. Hoses and hand held applicator gun or nozzle. The CO_2 system is one of simplicity, which greatly improves casting quality in the home foundry.

Fig 3: Specimen preparation using CO_2 Process

3. Properties of Sand and Slag Mould

Precautions:

a) Handle the specimens carefully.
b) Always test three specimens and report the average result.
C) For research work never use the same specimen for two different tests.
d) Always follow the instructions with regard to rate and method of applying load to specimens.

Fig 4: Prepared Specimen

3.1 Green Hardness Tester

This instrument is designed for measuring the surface hardness of green sand moulds and green cores. The test is similar to the brinell hardness test. Softer the mould surface, greater the penetration of the probe into the mould. The hardness number indicated is the measurement of the depth of penetration of the probe in thousands of an inch. A mould offering no resistance to penetration has a zero hardness reading and one which completely resists penetration has a hardness reading of 100.

Fig 5: Hardness Tester

Description

The tester has a dial gauge, calibrated in thousands of an inch, which is operated by a spring loaded probe of 1/2" radius. The bottom dial bezel can be rotated and the pointer held in any position by pressing the locking button. The instrument can be carried in the pocket and is most useful for checking the degree or uniformity of ramming of a mould.

Table 1: Hardness test results

Percentage of slag	Heardness
100% Green sand	73.25
CO2 Process (0% slag)	75.58
10% Slag	72.48
11% slag	72.64
12%slag	72.86
13% Slag	73.34
14% Slag	74.98.
15% Slag	75.84
16% Slag	76.29
17% slag	77
18%slag	77.98
19% Slag	78.68
20% Slag	80.54
30%slag	81.83
50% Slag	83.72
70% Slag	86.62
100%slag	89.33

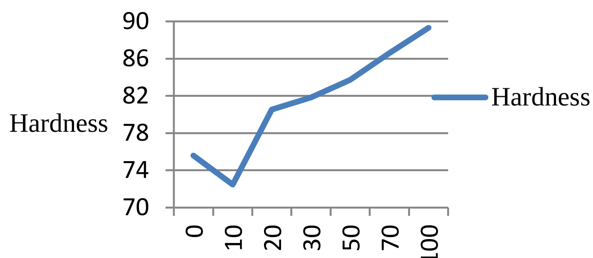


Fig 6: Hardness test graph

3.2 Hand Operated Universal Sand Strength Machine

The universal sand strength machine together with appropriate accessories will determine the compression, shear, tensile, transverse and splitting strengths of moulding and core making materials by means of dead weight loading.

Fig 8: Universal Sand Strength testing machine

DESCRIPTION

This consists of three major parts: frame, pendulum weight and pusher arm. The pusher arm is motivated by means of a small hand wheel which through a gear box rotates a pinion engaged in a rack on the quadrant. The pendulum weight swings on ball bearing and can be moved by pusher arm via a test specimen from a vertical position through 90, to a horizontal position, with a consequent increase of load on the test specimen. A magnetic rider is moved up a calibrated scale by the pendulum weight and indicates the point at which specimen collapse occurs. The machine is calibrated in KN/m2 for 50 mm diameter and 50 mm height standard sand specimens. The accessories required for the determination of shear, dry, tensile, transverse and splitting strengths are described separately.

Percentage of slag	Shear strength (kg/cm2)	Compression Strength (kg/cm2)
100% Green sand	0.1825	0.2225
CO2 Process (0% slag)	0.1984	0.2846
10% Slag	0.1759	0.1945
11% slag	0.1803	0.2193
12%slag	0.1879	0.2248
13% Slag	0.1901	0.2387
14% Slag	0.1962	0.2519
15% Slag	0.2039	0.2798
16% Slag	0.2157	0.2968
17% slag	0.2197	0.3016
18%slag	0.2463	0.3096
19% Slag	0.2831	0.3186
20% Slag	0.2968	0.3315
30%slag	0.3682	0.3852
50% Slag	0.4018	0.4268
70% Slag	0.3852	0.3741
90%slag	0.3496	0.3062
100%slag	0.2849	0.2836

Table 4: Shear and Compression strength Results

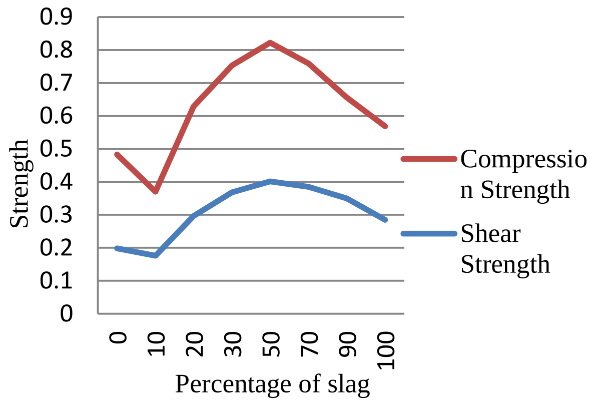


Fig 9: Shear and compression strength test graph

3.3 PERMEABILITY METER

Permeability is a property of foundry sand with respect to how well the sand can vent, i.e. how well gases pass through the sand. The permeability is commonly tested to see if it is correct for the casting conditions.

Fig 6: Standard permeability meter

Affecting factors

The grain size, shape and distribution of the foundry sand, the type and quantity bonding aterials, the density to which the sand is rammed, and the percentage moisture used for tempering the sand are important factors in regulating the degree permeability.

General principle

Permeability is defined by the AFS as the physical property of moulded sand which allows gas to pass through IL It is determined by the measuring the rate of blow of air through the metric standard rammed specimen under a standard pressure.

The general formula for the calculation of permeability may be expressed as follows:

P= (V*h) / (P * A * T)

Where

P= Permeability number

V= Volume of air in ml passing through the specimen

h= Height of test specimen in cm

P= Pressure of air in cm of water

A= Area of cross section of specimen in cm2

T= Time in minutes

Since the standard method requires that 2000ml of air should be forced through a specimen 50mm (5. 0 cm) and 50mm diameter.

Percentage of slag	Permeability
100% Green sand	98.75
CO2 Process (0% slag)	97.68
10% Slag	96.29
11% slag	96.68
12%slag	96.92
13% Slag	97.18
14% Slag	97.79
15% Slag	98.25
16% Slag	98.74
17% slag	99.06
18%slag	99.46
19% Slag	99.83
20% Slag	100.25
30%slag	101.87
50% Slag	103
70% Slag	107.41
100%slag	119.35

Table 3: Results of permeability test

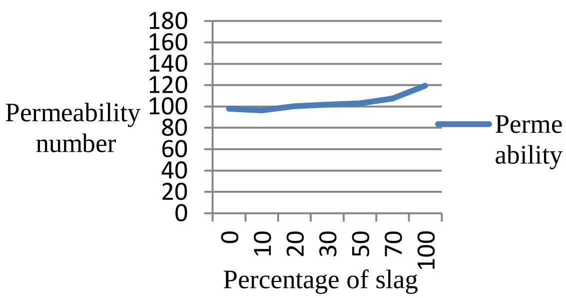


Fig 7: Permeability Test Graph

4. Casting of Ai-Mg Alloys with Various Proportions of Sand and Slag

4.1 Procedure for Preparation of Al-Mg Alloy

Here in this work we have used A1-Mg alloy to make casting. In order to make this casting we have made use of 90% A1 and 10% Mg. Aluminium is taken into crucible and is heated until it reaches its melting point of 660^{o} c. Magnesium is dipped into molten Aluminium along with a coverall (which prevents from oxidation) with the help of graphite plate until Mg is completely mixed with the Aluminium. The molten metal is carefully carried and is poured into moulds. After few minutes the castings are carefully ejected from the moulds. Casted alloys are characterized using Rockwell hardness test and surface finish is observed. Chemical composition of casted alloys is as follows

Type of Alloy	Magnesium (%)	Aluminium (%)
Alloy 1	5	Balance
Alloy 2	10	Balance

Table 6: Chemical Composition of Casted Alloys

4.2 Characterization of Al-Mg Casted Alloys

The hardness of the casted Alloys Rock Well Hardness scale is used.

Rockwell Scale

The most Rockwell scale is a hardness scale based on the indentation hardness of a material. The Rockwell test determines the hardness by measuring the depth of penetration of an indenter under a large load compared to penetration made by a preload. There are different scales, which are denoted by a single letter, that use different loads or indenters. The result, which is a dimensionless number, is denoted by HRX where X is the scale letter.

When testing metals, indentation hardness correlates linearly with tensile strength. This important relation permits economically important non-destructive testing of bulk metal deliveries with lightweight, even portable equipment, such as hand held Rockwell hardness tester.

Table 1: Various Rockwell Scales

Scale	Abbreviation	Load	Indenter	Use
A	HRA	60kgf	120 diamond cone	Tungsten carbide
B	HRB	100kgf	1/16 inch diameter steel sphere	Aluminium brass and soft steel
C	HRC	150kgf	120 diamond cone	Harder steel
D	HRD	100kgf	120 diamond cone	
E	HRE	100kgf	1/8 inch diameter steel sphere	
F	HRF	60kgf	1/16 inch diameter steel sphere	
G	HRG	150kgf	1/16 inch diameter steel sphere	

4.3 Rockwell Hardness Test Results for Al-Mg Casted Alloy

Percentage of slag	Heardness
100% Green sand	66
10% Slag	66.92
11% Slag	66.71
12% Slag	66.54
13% Slag	66.28
14% Slag	66
15% Slag	65.79
16% Slag	65.43
17% Slag	64.96
18% Slag	64.58
19% Slag	64.18
20% Slag	63.86
30%slag	60.84
50% Slag	58.71
70% Slag	56.33
100%slag	55.94

Table 8: Rockwell Hardness Test Result

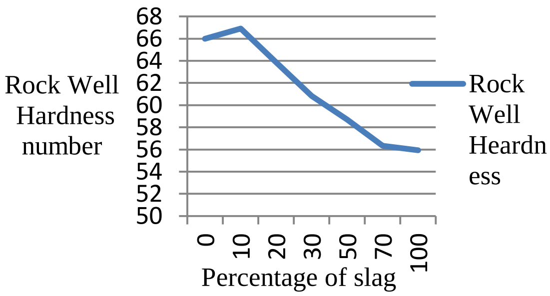


Fig 12: Rockwell Hardness graph

Conclusions

- From the above results we can conclude that around 13-15% of slag can be mixed with sand in the preparation of mould.
- As the percentage of slag increases the hardness of the moulds made through CO_2 process is increasing. But this high hardness is not required, since poor collapsibility. Hence 13-15% of slag can be recommended.
- Surface finish of the casted products is poor, so we have to provide more machining allowance. Hence we can't go beyond 15% of slag.
- It is observed that the moulds made with slag have more permeability than the sand moulds.
- With this work we can say that the waste CO_2 gas coming from blast furnace is used in CO_2 moulding process.
- The slag from the Blast furnace is channeled out at 1430 ° C. so this slag is used for casting non-ferrous metals like aluminium (since they have low melting temperature 660 ° C) and is not preferable for casting steel (since high melting temperature 1539°C)

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