Foundry Properties of Backing Sand: Some Engineering Studies and Improvements

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***Abstract* - Foundry encompasses the principal activity of making castings. Castings are products of the metal founding industry (Foundry) and are manufactured in a single step from liquid metal without intermediate operations of mechanical working such as rolling or forging. Foundry is an industry utilizing basic simple metallurgical processes with a wide diversity of products. It is the production of shaped articles by pouring molten metal into moulds made of sand ,metal, dies, plaster of parries, candle wax, etc. The greater part of the output of the foundry industry consists of castings made in refractory moulds, chiefly sand casting. Since the properties of the moulding material remains crucial to the production of sound dimensionally accurate castings, its selection and improvement are important. The foundry properties of backing sand are green strength, collapsibility, flowability, refractoriness and permeability. Green strength is the ability to get compacted to a uniform density and facilitating the pattern to be withdrawn without distortion or collapse. Collapsibility is used to describe the readiness with which backing sand will breakdown in cleaning and knocking operations. Flowability defines the ability of the energy from sand compaction to be transmitted throughout the second mass. Refractorines is used to describe the ability of the sand to withstand high temperatures without fusion or other physical changes. Permeability, which forms the main focus of the work reported in this paper, is the ability of the backing sand to allow the stream of gas to pass through the walls of the mould . This can be improved through the increment of the permeability value. In a bid to achieve this increment, venting was carried out on moulds made from two backing sand of different sizes used at the Lagos state university foundry facility. Four different sizes of venting rods were introduced into the moulds and the permeability values were taken. The comparison between the permeability values of the vented moulds vis-à-vis the non-vented moulds showed appreciable increments and also the percentage increments with increase in depth, size of venting rods grain size, and number of venting holes. We conclude that venting increases the permeability values of backing sand, which leads to improved quality of castings.**

Index Terms - Foundry, Backing sand, casting, engineering properties, moulding

INTRODUCTION

Backing sand is reconditioned sand used for ramming main part of mold after pattern has been covered with facing sand. In metal casting, a loose, granular material high in SiO2, resulting from the disintegration of rock. Sand specifically is used to describe the size of grain and not the mineral composition. Diameter of the individual grains can vary from approximately 6 to 270 mesh. Most foundry sands are made up principally of the mineral quartz (silica). This is due to the fact that sand is plentiful, refractory, and cheap; miscellaneous sands include zircon, olivine, chromite, CaCO3, black sand (lava grains), titanium minerals and others. Sand casting involves the production of metal castings in molds and foundry encompasses the process or art of casting metals, comprising the buildings and works for casting metals. Cores and molds used in the casting of iron, steel, copper and aluminum products are created using foundry sand. Most familiar materials such as hardware and hand tools, including girders used in bridge and office buildings had their origins at the foundry. Foundry sand is the second largest industrial use of sand.

Foundry practice is an art of producing castings, casting is one of the oldest and most versatile process of metal shaping. In this process, there are virtually no restrictions to the type of metal or alloy that can be cast, although it is usually beneficial to use alloys designed for castings. Commercial casting alloys include alloys of iron, aluminum, copper, brass etc. There are different forms of casting processes, suitable processes are used for the economic production of wide range of number of castings. This is usually the most economic form of producing components and parts at intermediate range. Good engineering properties and aesthetics of castings allow them to find application in a very wide range of Engineering products and ornamental works. The advantages of casting as a manufacturing process are low tool cost, suitability of wide range of metal to the process, ease of complex shapes creation and design versatility.

SAND CASTING AND FOUNDRY PROPERTIES

This is a most versatile process in the foundry and it is used to produce a wider range of castings than any other casting process. In Nigeria where other processes are virtually absent (especially for high melting point alloys), sand castings constitute a very high percentage of the castings produced locally. The properties of the moulding sand determines to a large extent the type of metal which may be used to cast as well as the properties of the casting produced. A well-prepared moulding sand with the right properties goes a long way in ensuring the production of sound casting.

One of the most important properties of moulding sand is its permeability. This is a term used to define the property of a mold material which allows passage of mould/core gases during the pouring of molten metal. It is the ability of the mould to allow easy escape of gases through its pores. High value of permeability is necessary so as not to obstruct the flow of the liquid metal into the mould. Most backing sand do not possess adequate permeability; to rectify this, the mould is vented by making holes, in the hope to allow for easier escape of gases from the mould cavity.

There is no specific guideline for carrying out venting. Hence the practice varies across foundries, which may be attributed to the lack of understanding of the effects of venting on permeability. The aim of the work presented in this paper was to study how venting affects the permeability of moulding sand by studying effects of variation in the parameters affecting venting such as cross sectional area; depth and distribution of vent holes.

EXPERIMENTAL

Four venting rods of diameters 1mm, 3mm, 5mm and 7mm were used. One end of the rods was sharpened and configured to allow for easy entrance into sand. Five different venting depth positions were marked on both ends of the venting rods. Jigs were prepared using cardboard material allowing for uniformity, constant distribution of venting holes and to ensure that the holes are evenly distributed and equally spaced. Backing sand was collected from the foundry of the Lagos State University, Lagos Nigeria.

Sand was prepared by sieving and riddling, two different sizes, the first being 180μm + 25Oμm and the second, 355 μm - 450 μm. Utilizing the facility at the Federal Institute of Industrial Research Oshodi, a 150 gram of sample was weighed and then filled into a slipping post of 2m diameter. The sand was then rammed three times to have it compacted. The stripping post was inverted over the electronic permeability measuring machine to obtain the original value of the sand before venting. Using the prepared jigs venting holes were then made to the sand sample while slipping past. The sharpened end of the rods was used first for easy penetration into sand. The other unsharpened end of the end of the rods was also used for completeness (see Figure 1).

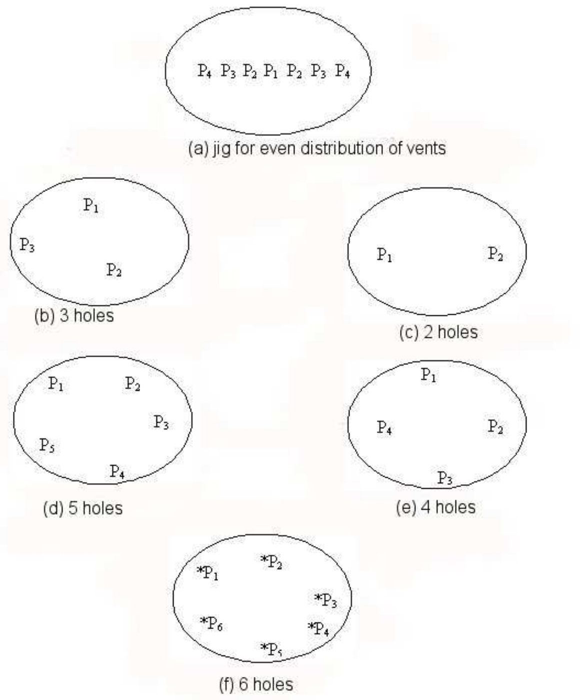

FIGURE 1 PREPARATION AND CONFIGURATION OF JIGS SHOWING THE LAYOUT USED FOR EVENLY DISTRIBUTED VENTS (A) AND FOR THE 2 – 6 HOLES SHOWN IN (B), (C), (D), (E) AND (F).

DETERMINATION OF PERMEABILITY, MOISTURE AND CLAY CONTENTS: Methods of laboratory measurement of permeability and related foundry properties have been reported [1, 2, 3, 4, 5]. Permeability in some cases involving wells, is determined by flowing air along the long axis of the plug, thereby obtaining the horizontal component of permeability if the well was drilled vertically. For the present work we use an available permeability measuring machine to obtain measurements. Grain size has been reported to have effect on permeability. coarse-grained sandstones sometimes have permeability values greater than values found in medium and fine-grained sandstones. In unconsolidated sands, grain size is highly correlated with pore-throat size and hence is highly correlated with permeability. The permeability of each vent hole at different diameter and depth was then recorded. Each hole's permeability reading was repeated thrice to test for reproducibility and ± 5% accuracy was obtained. The green compression strength of each sand sample was measured after venting.

The AFS standard was used in the determination of moisture content. A 50g specimen of sand is weighed and put in specimen tube. This is rammed three times until a height of 5.04 cm is attained and is indicated on the sand rammer. If the specimen does not fall within this range it is rejected. For determining the moisture content, the weighed 50g sample is poured into flask, one spoonful of calculus carbide is added and the flask is tightly closed. The flask is shaken vigorously and the moisture content is read from the visible dial gauge. In determining the clay content the weighed sample is poured into a wash bottle. 47 ml of water is added with 25 ml of sodium pyrophosphate. The sand-washer is used to aggregate the sand for 5 minutes. The bottle is washed by using additional water and allowed to settle for 10 minutes. The water in the flask comprising now a mixture of water and clay is siphoned. The procedure is repeated until eh water becomes clear. The sand is dried in the furnace and the weight of the clay is obtained.

Results Analysis and Discussion

The results obtained show the variation of permeability with depth of venting and with changing diameter of the venting rods. It is shown, using specimens 1 and 2, that the permeability of the sand increases with depth of the venting holes (see Figure 2) as well as for increasing number of venting holes in the jig.

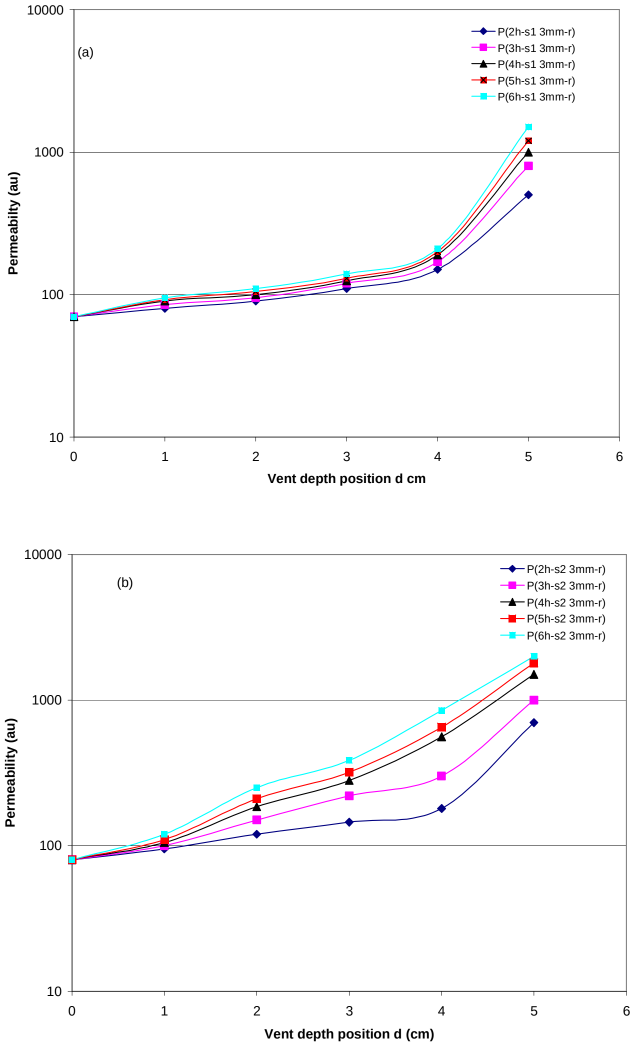

FIGURE 2 PERMEABILITY MEASUREMENTS AT DIFFERENT VENT DEPTH POSITIONS FOR 3MM SIZE ROD USING DIFFERENT JIG CONFIGURATIONS OF HOLES FOR SAND SPECIMEN 1 (TOP) AND SPECIMEN 2 (BOTTOM).

Some changes can be observed in the permeability of the moulding sand as the number of holes increases. As the number of holes increases, the compression strength of the sand decreases. This results from the fact that venting weakens the compression strength of the mould. Increasing the depth of the venting holes leads to increased permeability of the sample. It must be noted that there was a significant increase in permeability when the depth of the vent hole was almost at a maximum, a condition almost resulting in bursting in the cavity of the mould. The compression strength of the mould was observed to decrease by ~ 50% (from 40 to 22KN/m3) as the diameter of the venting rod increases. The results of the sand tests which were compared with those obtained from standard specifications tables show that the permeability of the sand produced for each test (70 — 200AFS) was suitable for casting; (i) medium and heavy brass or cast iron, (ii) Casting of steel green sand and (iii) casting steel dry sand facing.

The effect of grain size of sand on permeability is important. The two sieves (70 AFS and 80 AFS) were use to prepare two specimens for study. Coarse sand have less density and greater void spaces. Fine sand is more compact. Based on permeability alone, results showed that the sand to be suitable for preparing mould to be used for casting of heavy and medium cast iron, green sand and steel dry facing sand. It was found that it would be necessary to increase the low clay content or the amount of bentonite added. The constant area option was investigated and used in comparison of permeability values obtained. This involved using different sizes of venting rods and different number of venting holes to explore same are of venting on the specimen and allow for comparison with reference to effect on permeability (see Fig 3). Values obtained for each corresponding area are shown to be same, for example those for 3 mm diameter. Venting rod with 5 holes approximates 5 mm diameter venting rod with 4 holes. In the same vain, 7 mm diameter venting rod approximates a rod with 1 hole in area.

Comparing the permeability of different sand samples, it can be observed that the sand had different permeability trends despite the fact that they were subjected to the same condition of venting. This may emphasize the need to know the properties of the mould sand before effective venting method is applied. All in all, however, it is established that venting favours permeability.

For the 2 hole jig configuration permeability values follow the same pattern and is shown to increase somewhat steadily for the different sizes of rod used. In the case of the jigs with 4 and 6 holes, the onset of increase comes earlier and are much more pronounced. Although these are preliminary results, it is not clearly understood why this is the case and why the response for the 5mm and 7mm rods are so different with the higher values as observed. Further works are continuing with the data and theoretical models are being examined to explain this observation. Relationships have been obtained for the fractional increase in permeability as a function of the venting depth and also for original permeability (see Figure 4).

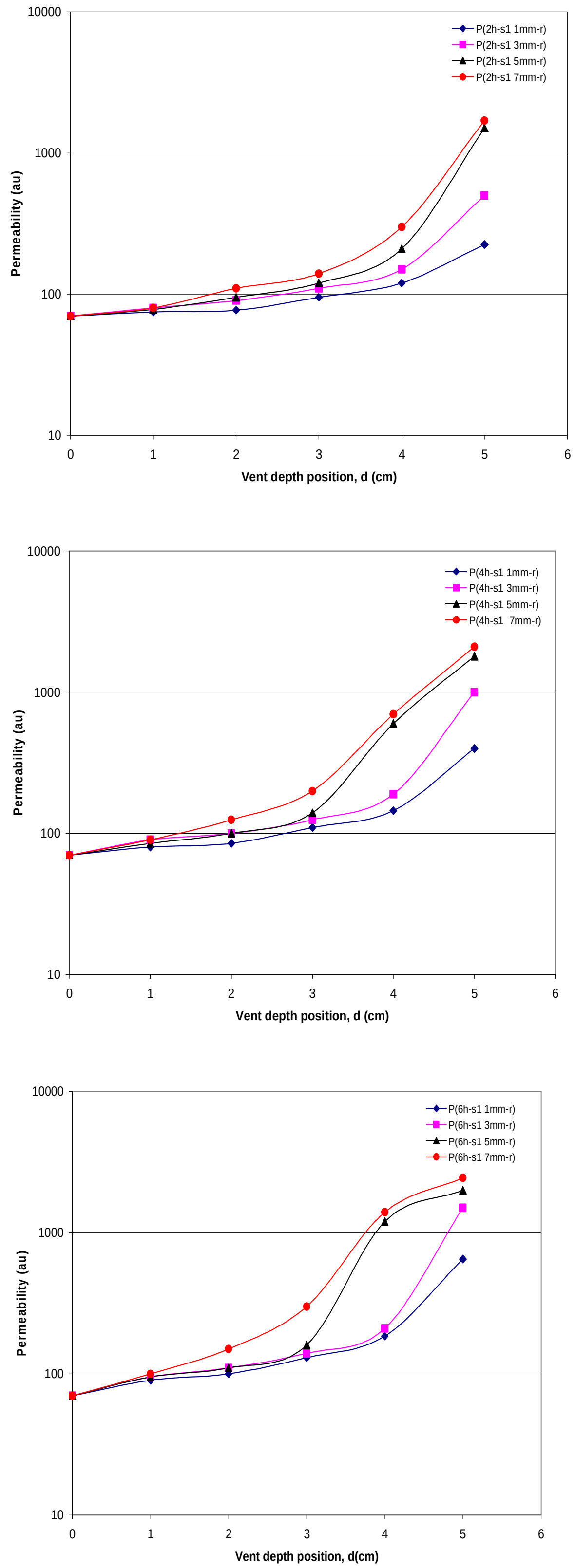

FIGURE 3 PERMEABILITY DEPENDENCE ON VENT DEPTH POSITION FOR VARYING SIZES OF RODS IN THE RANGE 1MM TO 7MM, USING FIRST SAMPLE (SPECIMEN 1) AND DIFFERENT JIG CONFIGURATIONS OF 2 HOLES (TOP), 4 HOLES (MIDDLE) AND 6 HOLES (BOTTOM).

In the case of the result presented using specimen 2, quasi similar shapes showing a gradual increase in permeability is shown for jigs with 3 and 5 holes and rods of sizes up to 7mm. Beyond 4 cm depth, there appears to be a decrease (tailing off) of the permeability. This after-effect is still the subject of our future study involving a number of specimen samples.

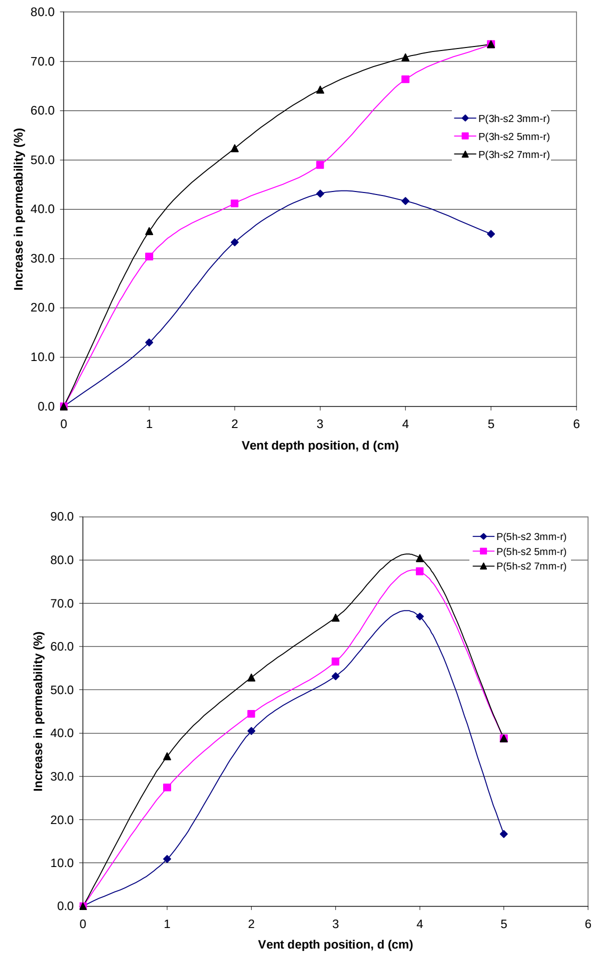

FIGURE 4 INCREASE IN PERMEABILITY AS A FUNCTION OF VENT DEPTH POSITION FOR 3 HOLES (TOP) AND 5 HOLES JIG CONFIGURATION FOR SPECIMEN 2 SAMPLES.

For a given specimen, the permeability curves tends to display similar trend for different sizes and number of vent holes. From this it could be concluded that the number of holes for venting does not seriously affects the permeability.

The gradient of the curve at vent depth position shows a much slower rate of increase of permeability between 1cm and 3 cm ~ 7.5 for speciment. Whereas between depth position 4 cm and 5 cm there seems a factor of ~ 5 increase in this value. This suggests that venting is important at greater depth for increased permeability of sample.

Conclusion

The percentage increment in permeability of moulding sand increases with increase in depth size of venting rod, grain size and number of venting holes. By keeping the depth and size of vent rod constant, the permeability is improved. This is achieved by increasing the number of holes. The sand used was found to be as good as those sands currently employed in some Nigerian Foundries for the casting of heavy brass or iron, steel green sand and steel dry facing sand. Permeability is found to be dependent on number of holes, depth of vent, position or distribution of vents on the jig and diameter of venting rods. Engineering properties of systems such as backing sand is useful in understanding materials applicable n everyday life. This facilitates knowledge and technology transfer and should encourage active collaboration between industries and engineering research institutions including universities. This should will in no small measure contribute to improvement in engineering education especially in developing countries. In manufacturing processes especially in relation to sands some effects have been studied and reported [6, 7, 8, 9]. Sand with improved foundry properties could find use in the making of computers, consumer products, communications equipment., manufacturing industries, automobiles and by the military in some cases involving the fabrication of micro systems.

Acknowledgment

The authors would like to thank the management and staff of the Federal Institute of Industrial Research Oshodi, Lagos, Nigeria for use of facility. We would also like to express our gratitude to colleagues in the School of Electrical and Mechanical Engineering and the School of the Built Environment at the Faculty of Engineering at both the University of Ulster and Lagos State University for use of equipment and helpful discussions of the results.

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