STUDYOF MECHANICAL PROPERTIES DURING SANDCASTINGOF ALUMINIUM-1

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ABSTRACT

The effect of runner size, mould temperature, and pouring temperature on the mechanical properties of aluminum alloy part produced through sand casting was investigated. Aluminum alloy scraps of known specification were sourced locally and recycled into cylindrical shapes in a sand mould. Azare foundry sand was used for the production of moulds. The effect of the runner size was studied by tapering the size of the runner towards the mould cavity. The reduced cross-sectional area of the runner is considered. The prepared mould was pre- heated within a temperature range of 25—230 0C. However, pouring temperature was varied within the range of 700—850 0C.The mechanical properties’ aluminum alloy castings studied were hardness, impact and tensile strength. The results showed that the selected process parameters significantly influence the mechanical properties of the aluminum alloy casting. The results of this study can be employed as input data in sand casting process, which is one of commonest manufacturing methods being practiced in developing countries; so that the high volume of the defective castings usually produced will be reduced, thereby making the process less expensive. Metal casting is one of the direct methods of manufacturing the desired geometry of component. The method is also called as near net shape process. It is one of the primary processes for several years and one of important process even today in the 21st century. Today, casting applications include automotive components, spacecraft components and many industrial & domestic components, apart from the art and jewellery items. The principle of manufacturing a casting involves creating a cavity inside a sand mould and then pouring the molten metal directly into the mould. Casting is a very versatile process and capable of being used in mass production. The size of components is varied from very large to small, with intricate designs.

KEYWORDS: Sand Casting Process Parameters, Mechanical Properties, and Aluminum alloy

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1. INTRODUCTION

Aluminium is the most common element in the earth crust and exists as aluminiumoxide . It possesses some peculiar properties such as high resistance to corrosion, ease of fabrication, high thermal and electrical conductivity, low weight and bright colour. Aluminum alloy casting has melting temperature of 660°C and its pouring temperature range is between 649°C -750°C. The knowledge of melting temperature of metals and alloys is necessary to estimate their corresponding pouring temperature (Jain, 1986 and Dieter,1981)). When the pouring temperature is lower than its optimum value, the mould cavity will not be filled because the gate or riser will solidify too rapidly and this will intercept directional solidification. On the other hand, high pouring temperature can cause shrinkage of the casting and mould warping (Grill, 1982; Lindberg, 1997 and Lancer, 1981). Alloys of aluminiumcan be used for packaging in food industries, production of pistons, cylinder heads, sumps of internal combustion engines and electrical cables (Chapman and Martin, 1975 and Lancer, 1981). The ability to significantly alter the properties of Aluminium through modern manufacturing techniques has improved tremendously in recent times. Some of these manufacturing techniques include: casting, forging, extrusion, drawing, welding, just to mention but a few.

To an engineer, the pre-requisite to correct materials' selection for improved service performances are high mechanical properties of such materials. Although different manufacturing methods of engineering components have been developed, the primary aim of each method is to produce components with good mechanical properties. Some of these methods include forging, drawing, rolling, extrusion, etc. The raw materials for most these processes are ingots which are usually produced through casting. Some of the manufacturing methods were developed because of the quest to improve the mechanical properties of the materials especially metals and their alloys (Lancer, 1981 and Donald, 1989). Although, these processes can no doubt result to increase in the mechanical properties of materials such as metals, the cost of setting up these metal working processes is expensive. For example, the three Inland rolling mills in Nigeria settled with the responsibilities of producing rods, wires and pipes have stop productions over ten years now because of the country inability to maintain them. Attempts to bypass some of these processes saw the development of other casting techniques such as pressure die casting, squeezed casting, permanent mould casting, etc. The purpose of this study is to eliminate not only some of the casting defects but bypass most of these manufacturing techniques Casting is a metal object produced by allowing molten metal to solidify in a mould (Sanders, 2001).

The shape of the object is determined by the shape of the mould cavity. Casting as a process involves an interplay between so many parameters such as melting temperature of charge, the mould condition (temperature, moisture content, sand and type of binders used), pouring temperature, and the gating design (i.e. pouring speed, runner size and included gases), the casting size, the type of alloy.

The variation in most of these process parameters from their set values can affect the rate of solidification of the molten metal in the mould and this in turn can affect crystals' formation. In another word, the difference in the microstructure of the casting can result due to the non-uniform cooling of the molten metal in the mould. It is established that to ensure uniform cooling of the molten metal in the mould, the law of uniform flow must be maintained (i.e. constant volume per second flow of the molten metal during the filling of the mould cavity). The task of ensuring that a uniform microstructure is formed in a casting depends on the ability to maintain a law of uniform flow during the feeding of the mould (Sanders, 2001). In casting, especially sand casting, it is difficult to maintain this law because of the difficulty of controlling its process parameters. Therefore, it is difficult to produce a casting with uniform microstructure . The no uniform formation of microstructure in castings can result to poor mechanical properties and this has been one of themain problems with which physical metallurgy is concerned (Whillock et al, 1991 and Ward, l993). Some of the processes developed to eliminate this deficiency include heat treatment (Annealing, quenching, normalizing chemical, low and high temperature thermo-mechanical, etc), forging, rolling, and drawing, just to mention but a few .

To achieve the aim of this study, effect of varying runner size, pouring temperature andmould temperature on the mechanical properties aluminium alloy was studied.

2. LITERATURE REVIEW

Sand casting is a flexible, inexpensiveprocess. Sand is used as the mold material. Thesand grains, mixed with small amounts of othermaterials to improve the mold ability andcohesive strength, are packed around a patternthat has the shape of the desired casting. Productscovering a wide range of sizes and detail can bemade by this method. A new mold must be madefor each casting, and gravity usually is employedto cause the metal to flow into the mold. Asshown below in figure steps of sand casingThe process of sand casting is very old going back to the Bronze Age; the technique haschanged very little since. It involves making a suitable void in compacted sand which is thenfilled with molten metal. This process is best suited to large casting where surface finish is notimportant or which will be machined later. Thin sections are not really suitable as the molten material starts to cool before the mould is completely filled, forming “cold shuts”.

The first stage in sand casting is to make a pattern in wood or metal of the shape to be cast. Thispattern is made slightly larger to allow for shrinkage of the hot metal as it cools down aftercasting. Any part that requires machining after casting would have a machining allowanceincorporated in the pattern. The pattern maker is a very skilled craftsman because as well asmaking the pattern he must have a complete understanding of the actual process of casting. Inmaking the pattern he decides the way the item will be cast. Depending on the shape of the itemthe pattern could be in one or several pieces. If the pattern is split the separate parts are locatedtogether with metal pins or dowels. In deciding which way to cast a particular item the patternmaker would consider several factors such as, which way up to cast it. Molten metal is veryheavy and most of the impurities in the metal float. When the metal is cast the impurities getcarried around the mould with the metal as they have a tendency to float they are likely to bedeposited in one place, either trapped by a narrowing in the shape or floating to the top of thecasting.

Different scholars have made varieties of researches on possible causes of porosity formation in different families of steel. They have made lots of experiments on different mold making materials, mold-metal interface reactions, atmospheric interactions, pouring temperatures, melt handling functions and other surrounding conditions which probably constitute the sources for gas defects. Molten metal is highly reactive material which can make every reaction with nearly all of its surroundings. For instance, its reaction with binders used in mold making for no bake systems usually produces decomposed gases in different levels. Since those gases can be entrapped in a metal and result gas defects, researchers made their studies in some of commonly known binders. [3]

Under practical circumstances castings, like all metallurgical products, contain voids, inclusions and other imperfections which contribute to normal quality impairment. Such imperfections begin to be regarded as true defects only when the satisfactory function or appearance of the product is in question. In such cases, the possibility of salvage, if worse, rejection and replacement should be considered. The decision should be based upon not only the defect itself but also upon the significance in relation to the service function of the casting and the quality and inspection standards being applied. A defect may arise from a single clearly defined cause which enables the remedy to be more specific and straightforward. It may, however, result from a combination of factors, so that the necessary preventive measures are more obscure. All foundry men are familiar with the persistent defect which defies explanation andfinally disappears without clarification of its original cause. Close control and standardization of all aspects of production technique offers the best protection against such troubles. More specific precautions can be taken in those cases where there is a known susceptibility to a particular defect, whilst the radical approach of design modification may need to be considered in the extreme cases which do not respond to changes in foundry technique. Defects can, above all, be minimized by a clear understanding of their fundamental causes. [1] Due to the wide range of possible factors, reasonable classification of casting porosity [2] defects set difficulties. Some scholars classify casting defects based upon their morphology. They prefer identifying defects by direct observation of the defective casting or from a precise description of the defect, involving only the criteria of shape, appearance, location and dimensions. This classification, they assume to be more logical than one based upon causes since it requires no prior assumptions to be made. Others are more comfortable with the classification based upon the causes or origins of the defects. As the researcher in this project believes knowing the cause of a defect is a means to arrive at a best solution to get rid of the defect, the system of classification according to the causes will be adopted throughout this paper. Another scholar, S.Kuyucak[4] has studied the influences of using a pouring cup (a standard gating) and a pouring basin (an alternative gating) on formation of surface quality problems on steel casting due to entrained air. His experiment constitutes two steel wedge-block castings poured from a bottom pouring ladle the first one utilizing a pouring cup and the second, a pouring basin with a dam, with or without a submerged ladle nozzle extension (shroud) into the pouring basin. Prior experiments showed that 30 – 60% air entrainment by volume in a typical ladle bottom pouring operations. [5]The air entrainment and thus surface defects increase with poured metal head height. The second poured blocks with the alternative gating had a lower metal head in the ladle, but the ladle was raised to clear the pouring basin thereby, decreasing the difference in pour heights between the two castings. The average pour heights taken from average metal head in the ladle to sprue base were 45.5” for standard gating and 43.0” for alternative gating. The molds were prepared using silica sand having an AFS grain size of 55 bonded with 4.5 % by sand weight dextrin modified (5 %) sodium silicate (50 % aq.) binder. The heats F5083 and F5085 were meant to be poured with submerged ladle nozzle extension. However, the shrouds started to split longitudinally during pour A and were fully open during pour B. Since use of a shroud is an optional operation, these castings were effectively poured without a nozzle extension. After removing the gates and risers and the castings get cleaned, the experimental conditions and results of cope surface evaluation were given in the following table.

[1]. Peter Beeley, “Foundry Technology”, Butter Worth Heinemann, 2nd ed., 2001
[2]. R. Monroe, “Porosity in Castings”, American Foundry Society, Paper 05-245(04), 2005

[4]. S. Kuyucak, "Sponsored Research: Clean Steel Casting production – Evaluation of Laboratory Castings", American Foundry Society, 2007
[5]. J.S. Campbell, "Principles of Manufacturing Materials and Processes", Tata McGraw Hill Book Co. Inc., New Delhi,1992D.C. Ekey & W.P. Winter, "Introduction to Foundry Technology", McGraw Hill Book Co. Inc., New York, 1958 [6]. John Campbell, "Castings", Elsevier

1.INTRODUCTION TO CASTING.

Casting is basically melting a solid material, heating to special temperature, and pouring the molten metal into cavity or mould, which is in proper shape.Casting has been known by human being since 4^{th} century B.C.

Today it is nearly impossible to design anything that cannot be cast by means of one or more of the available casting processes. However ,as with other manufacturing processes, best results and economy can be achieved if the designer understands the various casting processes and adapts his designs so as to use the process most efficient.

1.1 DEFINITION

In casting involves pouring a liquid metal into a mold, which contains a hollow cavity of the desired shape, and then is allowed to solidify.The solidified part is also known as a casting, which is ejected or broken out of the mold to complete the process. Casting is most often used for making complex shapes that would be difficult or uneconomical to make by other methods.

1.2 TYPES OF CASTING.

- Sand casting
- Die casting
- Investment casting
- Centrifugal casting

1.2.1 SAND CASTING

Sandcasting is used to make large parts (typically Iron, but also Bronze, Brass, Aluminum). Molten metal is poured into a mold cavity formed out of sand (natural or synthetic). The processes of sand casting are discussed in this section, include patterns, sprues and runners, design considerations, and casting allowance In a two-part mold, which is typical of sand castings, the upper half, including the top half of the pattern, flask, and core is called cope and the lower half is called drag. The parting line or the parting surface is line or surface that separates the cope and drag. The drag is first filled partially with sand, and the core print, the cores, and the gating system are placed near the parting line. The cope is then assembled to the drag, and the sand is poured on the cope half, covering the pattern, core and the gating system. The sand is compacted by vibration and mechanical means. Next, the cope is removed from the drag, and the pattern is carefully removed. The object is to remove the pattern without breaking the mold cavity. This is facilitated by designing a draft, a slight angular offset from the vertical to the vertical surfaces of the pattern. This is usually a minimum of 1° or 1.5 mm (0.060 in), whichever is greater. The rougher the surface of the pattern, the more the draft to be provided.

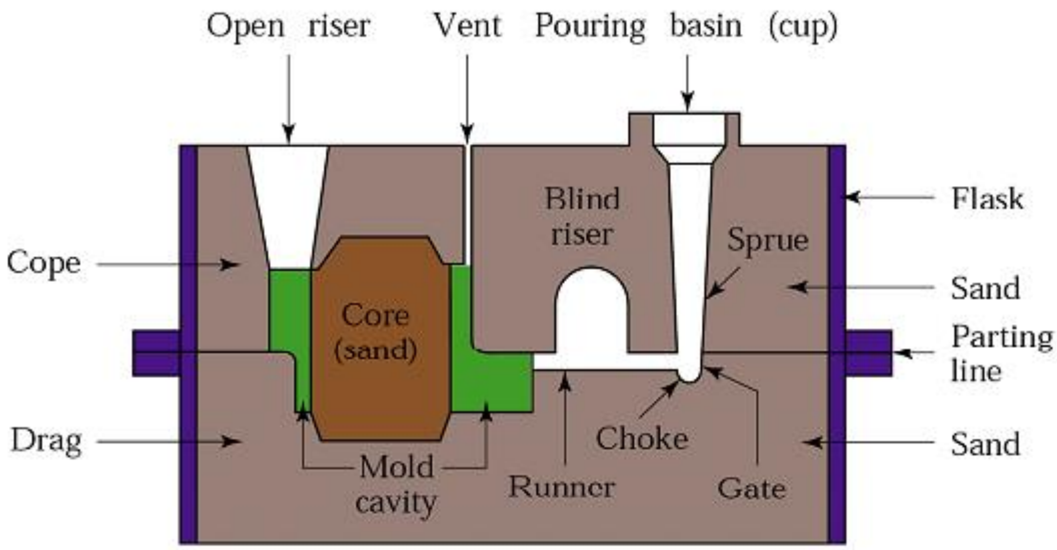


Fig 1:Sand casting

3.1 Type of Mould
3.3.1.1 Permanent mould
3.3.1.2 Temporary mould

3.3.1.1 Permanent mould casting

Permanent mold casting is metal casting process that employs reusable molds("permanent molds"), usually made from metal. The most common process uses gravity tofill the mold, however gas pressure or a vacuum are also used. A variation on the typicalgravity casting process, called slush casting, produces hollow castings. Common castingmetals are aluminum, magnesium, and copper alloys. Other materials include tin, zinc, andlead alloys and iron and steel are also cast in graphite molds.

3.3.1.2 Temporary Mould casting

This mould are destroyed at the time of removing casting from them.There are many type of temporary mould which are mentioned below.

Type of Temporary Mould

Greensand mold

Greensand molds use a mixture of sand, water, and a clay or binder. Typicalcomposition of the mixture is 90% sand, 3% water, and 7% clay or binder. Greensand moldsare the least expensive and most widely used.

Skin-dried mold

A skin-dried mold begins like a greensand mold, but additional bonding materials areadded and the cavity surface is dried by a torch or heating lamp to increase mold strength.Doing so also improves the dimensional accuracy and surface finish, but will lower thecollapsibility. Dry skin molds are more expensive and require more time, thus lowering theproduction rate.

Dry sand mold

In a dry sand mold, sometimes called a cold box mold, the sand is mixed only with anorganic binder. The mold is strengthened by baking it in an oven. The resulting mold has highdimensional accuracy, but is expensive and results in a lower production rate.

No-bake mold

The sand in a no-bake mold is mixed with a liquid resin and hardens at roomtemperature.

3.3.2 Moulding Sand

Molding sand is more than just sand. Typically it is a fine grade of sand (mine is 110grit sand blasting sand), clay binder and something to moisten it. There are two types of molding sand namely natural sand and synthesis sand.

3.3.2.1 Properties of Moulding Sand

A large variety of molding materials is used in foundries for manufacturing molds andcores. They include molding sand, system sand or backing sand, facing sand, parting sand,and core sand. The choice of molding materials is based on their processing properties. The properties that are generally required in molding materials are:

Refractoriness

It is the ability of the molding material to resist the temperature of the liquid metal tobe poured so that it does not get fused with the metal. The refractoriness of the silica sand ishighest.

Permeability

During pouring and subsequent solidification of a casting, a large amount of gases andsteam is generated. These gases are those that have been absorbed by the metal duringmelting, air absorbed from the atmosphere and the steam generated by the molding and coresand. If these gases are not allowed to escape from the mold, they would be entrapped insidethe casting and cause casting defects. To overcome this problem the molding material mustbe porous. Proper venting of the mold also helps in escaping the gases that are generatedinside the mold cavity.

Green Strength

The molding sand that contains moisture is termed as green sand. The green sandparticles must have the ability to cling to each other to impart sufficient strength to the mold.The green sand must have enough strength so that the constructed mold retains its shape.

Dry Strength

When the molten metal is poured in the mold, the sand around the mold cavity isquickly converted into dry sand as the moisture in the sand evaporates due to the heat of themolten metal. At this stage the molding sand must posses the sufficient strength to retain theexact shape of the mold cavity and at the same time it must be able to withstand themetallostatic pressure of the liquid material.

Hot Strength

As soon as the moisture is eliminated, the sand would reach at a high temperaturewhen the metal in the mold is still in liquid state. The strength of the sand that is required tohold the shape of the cavity is called hot strength.

Collapsibility

The molding sand should also have collapsibility so that during the contraction of thesolidified casting it does not provide any resistance, which may result in cracks in thecastings.Besides these specific properties the molding material should be cheap, reusable andshould have good thermal conductivity.

Thermal stability

Heat from the casting causes rapid expansion of the sand surface at the mould-metalinterface. The mould surface may crack, buckle, or flake off (scab) unless the moulding sandis relatively stable dimensionally under rapid heating.

3.3.1.2 Sand Testing

Moisture Content test

Moisture is an important element of the moulding sand as it affects many properties.To test the moisture of moulding sand a carefully weighed sand test sample of 50g is dried ata temperature of 1050 C to 1100 C for 2 hours by which time all the moisture in the sandwould have been evaporated. The sample is then weighed. The weight difference in gramswhen multiplied by two would give the percentage of moisture contained in the mouldingsand. Alternatively a moisture teller can also be used for measuring the moisture content. Inthis sand is dried by suspending the sample on a fine metallic screen and allowing hot air toflow through the sample. This method of drying completes the removal of moisture in amatter of minutes compared to 2 hours as in the earlier method.

Permeability test

The permeability number, which has no units, is determined by the rate of flow of air,under standard pressure, through a 2 x 2-in. rammed AFS cylindrical specimen.The grain size, shape and distribution of the foundry sand, the type and quantity of bonding materials, the density to which the sand is rammed and the percentage of moistureused for tempering the sand are important factors in regulating the degree of permeability. Anincrease in permeability usually indicates a more open structure in the rammed sand, and if the increase continues, it will lead to penetration-type defects and rough castings. A decreasein permeability indicates tighter packing and could lead to blows and pinholes.

Clay Content Test

A known amount of dried molding sand mixed with a pyrophosphate solution isstirred with a high-speed mixer for 5 min. Water is added to the top level line, and themixture is allowed to settle for 5 min. before the top 5 in. of the water is siphoned off. Theprocedure is repeated until the water above the sample is clear. The sand then is dried, andthe weight loss is recorded as Clay.Clay may contain active clay, dead clay, silt, seacoal, cellulose, cereal, ash, fines andall materials that float in water. Only the active clay gives active bonding capacity to thesystem.

4.Melting Equipment

4.1 Cupola Furnace

A Cupola or Cupola furnace is a melting device used in foundries that can beused to melt cast iron, ni-resist iron and some bronzes. The cupola can be made almost anypractical size. The size of a cupola is expressed in diameters and can range from 1.5 to 13 feet(0.5 to 4.0 m). The overall shape is cylindrical and the equipment is arranged vertically,usually supported by four legs. The overall look is similar to a large smokestack.The bottom of the cylinder is fittedwith doors which swing down and out to 'dropbottom'. The top where gases escape can be open orfitted with a cap to prevent rain from entering thecupola. To control emissions a cupola may be fittedwith a cap that is designed to pull the gases into adevice to cool the gasses and remove particulatematter.The shell of the cupola, beingusually made of steel, has refractory brick and refractory patching material lining it. Thebottom is lined in a similar manner but often a clay and sand mixture ("bod") may be used, asthis lining is temporary. Finely divided coal ("sea coal") can be mixed with the clay lining sowhen heated the coal decomposes and the bod becomes slightly friable, easing the opening upof the tap holes. The bottom lining is compressed or 'rammed' against the bottom doors. Somecupolas are fitted with cooling jackets to keep the sides cool and with oxygen injection tomake the coke fire burn hotter.

5 Electric Furnace

Electric furnace is used for heating purpose in various industrial productionprocesses. Electric furnaces are used where more accurate temperature control is required.There are three types of electrical furnaces namely: (1) Induction Heating Furnace

(2)Resistance Heating Furnace and (3) Arc furnace depending upon the method of heatgeneration.Induction heating furnaces and arc furnaces are beyond the scope of this projectprofile. The scope of this project profile is confined to the resistance heating furnace only. Inresistance heating furnaces, the resistance heating

The heating elements used are Nichrome wire, Kanthal wire or Graphite rods dependingupon the temperature requirements. The unit proposed in this project profile envisagesmanufacturing furnaces to a maximumtemperature of 1000
OC and only up to 50 kWpower rating. In this case, Kanthal wire is used.The temperature is controlled using thermostatsand the temperature is monitored bythermocouples. The heating chamber isconstructed by M. S. Sheets and channels and forthermal Insulation, fire clay bricks and refractorybricks are used

Operation

Scrap metal is delivered to a scrap bay, located next to the melt shop. Scrap generallycomes in two main grades: shred (white goods, cars and other objects made of similar light-gauge steel) and heavy melt (large slabs and beams), along with some direct reduced iron(DRI) or pig iron for chemical balance. Some furnaces melt almost 100% DRI.The scrap is loaded into large buckets called baskets, with 'clamshell' doors for a base.Care is taken to layer the scrap in the basket to ensure good furnace operation; heavy melt isplaced on top of a light layer of protective shred, on top of which is placed more shred. Theselayers should be present in the furnace after charging. After loading, the basket may pass to ascrap pre-heater, which uses hot furnace off-gases to heat the scrap and recover energy,increasing plant efficiency.

The scrap basket is then taken to the melt shop, the roof is swung off the furnace, andthe furnace is charged with scrap from the basket. Charging is one of the more dangerousoperations for the

EAF operators. There is a lot of energy generated by multiple tonnes of falling metal; any liquid metal in the furnace is often displaced upwards and outwards by thesolid scrap, and the grease and dust on the scrap is ignited if the furnace is hot, resulting in afireball erupting. In some twin-shell furnaces, the scrap is charged into the second shell whilethe first is being melted down, and pre-heated with off-gas from the active shell. Other operations are continuous charging - pre-heating scrap on a conveyor belt, which thendischarges the scrap into the furnace proper, or charging the scrap from a shaft set above thefurnace, with off-gases directed through the shaft. Other furnaces can be charged with hot(molten) metal from other operations.After charging, the roof is swung back over the furnace and meltdown commences.The electrodes are lowered onto the scrap, an arc is struck and the electrodes are then set tobore into the layer of shred at the top of the furnace. Lower voltages are selected for this firstpart of the operation to protect the roof and walls from excessive heat and damage from thearcs. Once the electrodes have reached the heavy melt at the base of the furnace and the arcsare shielded by the scrap, the voltage can be increased and the electrodes raised slightly,lengthening the arcs and increasing power to the melt. This enables a molten pool to formmore rapidly, reducing tap-to-tap times. Oxygen is also supersonically blown into the scrap,combusting or cutting the steel, and extra chemical heat is provided by wall-mounted oxygen-fuel burners. Both processes accelerate scrap meltdown.

5.**Melting & Pouring**

Many foundries, particularly ferrous foundries, use a high proportion of scrapmetal to make up a charge. As such, foundries play an important role in the metal recyclingindustry. Internally generated scrap from runners and risers, as well as reject product, is alsorecycled. The charge is weighed and introduced to the furnace. Alloys and other materials areadded to the charge to produce the desired melt. In some operations the charge may bepreheated, often using waste heat.In traditional processes metal issuperheated in the furnace. Molten metal is transferred from the furnace to a ladle and helduntil it reaches the desired pouring temperature.The molten metal is poured into the mould andallowed to solidify.

5.COPE AND DRAG

Used for sand casting with pattern.

5.1 Gating System

The gating system serves many purposes, the most important being conveying theliquid material to the mold, but also controlling shrinkage, the speed of the liquid, turbulence,and trapping dross. The gates are usually attached to the thickest part of the casting to assistin controlling shrinkage. In especially large castings multiple gates or runners may berequired to introduce metal to more than one point in the mold cavity. The speed of thematerial is important because if the material is traveling too slow it can cool beforecompletely filling, leading to mis-runs and cold shuts. If the material is moving too fast thenthe liquid material can erode the mold and contaminate the final casting. The shape andlength of the gating system can also control how quickly the material cools; short round orsquare channels minimize heat loss.The gating system may be designed to minimize turbulence, depending on thematerial being cast. For example, steel, cast iron, and most copper alloys are turbulentinsensitive, but aluminum and magnesium alloys are turbulent sensitive. The turbulentinsensitive materials usually have a short and open gating system to fill the mold as quicklyas possible. However, for turbulent sensitive materials short sprues are used to minimize thedistance the material must fall when entering the mold. Rectangular pouring cups and taperedsprues are used to prevent the formation of a vortex as the material flows into the mold; thesevortices tend to suck gas and oxides into the mold. A large sprue well is used to dissipate thekinetic energy of the liquid material as it falls down the sprue, decreasing turbulence. Thechoke, which is the smallest cross-sectional area in the gating system used to control flow,can be placed near the sprue well to slow down and smooth out the flow.

5.1.1 Runner & Sprue

The molten material is poured in the pouring cup, which is part of the gatingsystem that supplies the molten material to the mold cavity. The vertical part of the gatingsystem connected to the pouring cup is the sprue, and the horizontal portion is called therunners and finally to the multiple points where it is introduced to the mold cavity called thegates. Additionally there are extensions to the gating system called vents that provide the pathfor the built up gases and the displaced air to vent to the atmosphere.The cavity is usually made oversize to allow for the metal contraction as itcools down to room temperature. This is achieved by making the pattern oversize. To accountfor shrinking, the pattern must be made oversize by these factors, on the average. These are linear factors and apply in each direction. These shrinkage allowance are only approximate,because the exact allowance is determined the shape and size of the casting. In addition,different parts of the casting might require a different shrinkage allowance. See the casting allowance table for the approximate shrinkage allowance expressed as the Pattern Oversize Factor.

5.1.2 Riser

A riser, also known as a feeder, is a reservoir built into a metal casting mold to prevent cavities due to shrinkage. Most metals are less dense as a liquid than as a solid so castings shrink upon cooling, which can leave a void at the last point to solidify. Risers prevent this by providing molten metal to the casting as it solidifies, so that the cavity forms in the riser and not the casting. Risers are not effective on materials that have a large freezing range, because directional solidification is not possible. They are also not needed for casting processes that utilized pressure to fill the mold cavity. A feeder operated by a treadle is called an under feeder.

6 Cleaning & Finishing.

Cleaning

After degating, sand or other moulding media may adhere to the casting. Toremove this the surface is cleaned using a blasting process. This means a granular media willbe propelled against the surface of the casting to mechanically knock away the adhering sand.The media may be blown with compressed air, or may be hurled using a shot wheel. Themedia strikes the casting surface at high velocity to dislodge the molding media (for example,sand, slag) from the casting surface. Numerous materials may be used as media, includingsteel, iron, other metal alloys, aluminum oxides, glass beads, walnut shells, baking powderamong others. The blasting media is selected to develop the color and reflectance of the castsurface. Terms used to describe this process include cleaning, blasting, shot blasting and sandblasting.

Finishing

The final step in the process usuallyinvolves grinding, sanding, or machining thecomponent in order to achieve the desireddimensional accuracies, physical shape and surfacefinish.Removing the remaining gatematerial, called a gate stub, is usually done using agrinder or sanding. These processes are usedbecause their material removal rates are slow enough to control the amount of material. Thesesteps are done prior to any final machining.After grinding, any surfaces that require tight dimensional control aremachined. Many castings are machined in CNC milling centers.

4. Casting defects and their remedies

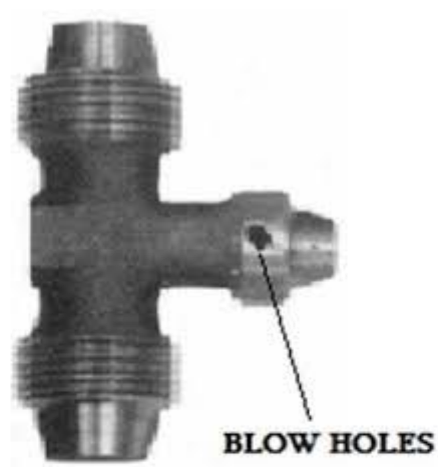
At present, casting defect analysis is carried out using techniques like historical data analysis, cause-effect diagrams, design of experiments, if-then rules (expert systems), and artificial neural networks (ANN). They are briefly explained in this section.

4.1.1 SHRINKAGE FAULTS:

- Shrinkage faults are faults caused by improper directional solidifications, poor gating and risering design and inadequate feeding.
- Solidification leads to volumetric contraction which must be compensated by feeding. If this compensation is inadequate either surface shrinkage or internal shrinkage defects are produced making the casting weaker.
- Shrinkage faults can be reduced by providing proper gating system, pouring at correct temperature and taking care of directional solidification.These are the common sand casting

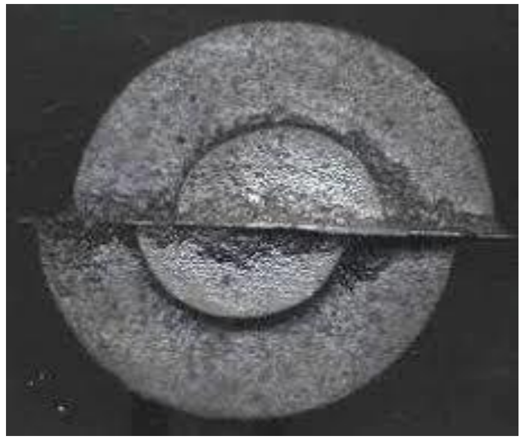
defects on the surface and inside of cast iron and cast steel parts.

1. **Blowhole** is a kind of cavities defect, which is also divided into pinhole and subsurface blowhole. Pinhole is very tiny hole. Subsurface blowhole only can be seen after machining. Burning-on defect is also called as sand burning, which includes chemical burn-on, and metal penetration.
2. Sand inclusion and slag inclusion are also called as scab or blacking scab. They are inclusion defects. Looks like there are slag inside of metal castings.



3. **Mold Shift**

   This is due to operator error: not aligning the mold correctly.Most flasks have alignment pins to prevent this, but I never installedthem on my 6x6 set so I have to guess at it.



4. **Porosity**

This is an investment casting. Different from sand casting, but defects still happen allthe same. In this case, it was either gas or slag (but the area doesn't have the right appearancefor slag). Come to think of it, it could be gas from the mould, but that's just a thought. In anycase, the area in question is on the right, where it looks rough (the area on the left appears tobe a broken section of the mould, which might've contributed to the next listed defect). Thereare actually a few pinholes which you can see light clear though in the porous area.

5. **Slag Inclusions**

During the melting process, flux is added to remove the undesirable oxides andimpurities present in the metal. At the time of tapping, the slag should be properly removedfrom the ladle, before the metal is poured into the mould. Otherwise any slag entering themould cavity will be weakening the casting and also spoiling the surface of the casting.

6. **Gas pockets**

Gas pockets come from gas dissolving in the melt then coming out when itsolidifies. This usually manifests itself as a rough surface on areas exposed to air or pocketsof varying size in the cross-section of the metal. Gas comes from melting too long or heatingtoo hot, 'stewing' the metal using an unusually oxidizing or reducing flame in the furnace,getting water in the melt, and the alignment of the Moon with the Earth and Sun. A goodidea is to recycle scrap into ingots as a first step since the scrap might be wet, oily or paintedand will add gas to the melt. The gas comes out in the ingots, not your casting.

7. **Swell :**

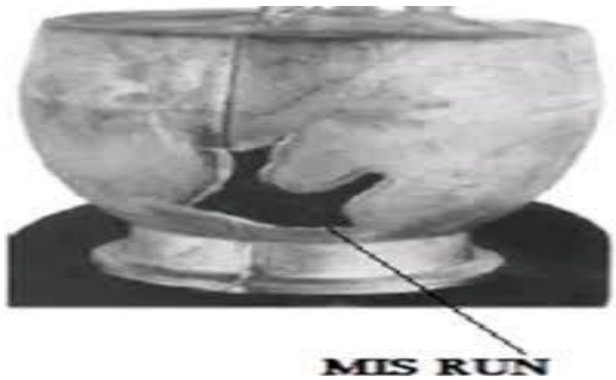
Under the influence of metallostatic forces, themould wall may move back causing a swell in thedimensions of the casting. As a result of the swell, thefeeding requirements of the casting increase which shouldbe taken care of by the proper choice of risering. The main cause of this defect is improper ramming of the mould.

8. **Drop:**

An irregularly shaped projection on the cope surface of a casting is called a drop.This is caused by dropping of sand from the cope or other overhanging projections into themould. An adequate strength of the sand and the use of gaggers can help in avoiding the drops.

9. **Misrun:**

Many a time, the liquid metal may, due to insufficient superheat,start freezing before reaching the farthest point of the mould cavity. Thisdefect is called Misrun.



10. **Hot tears:**

Since metal has low strength at higher temperatures, anyunwanted cooling stress may cause the rupture of the casting. Thebetter design of casting avoids this defect.

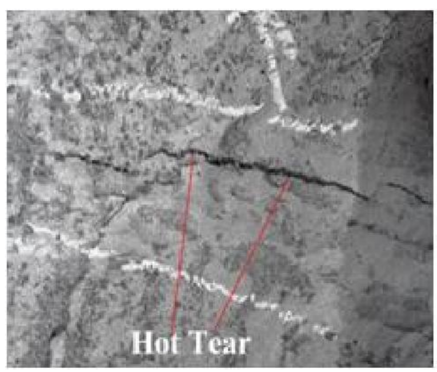


Fig . hot tears

11. **Cold shut:**

For a casting with gates at its two sides, the misrun may show up at the centre of thecasting due to non fusion of two streams of metal resulting in a discontinuity or weak spot incasting.Above two defects are due to lower fluidity of the molten metal or small thickness of the casting. The fluidity of the metal can be increased by changing the composition of moltenmetal or raising the pouring temperature. The other causes for these defects are large surfacearea to volume ratio of the casting, high heat transfer rate of the mould material and back pressure of the gases entrapped in the mould cavity due to inadequate venting.

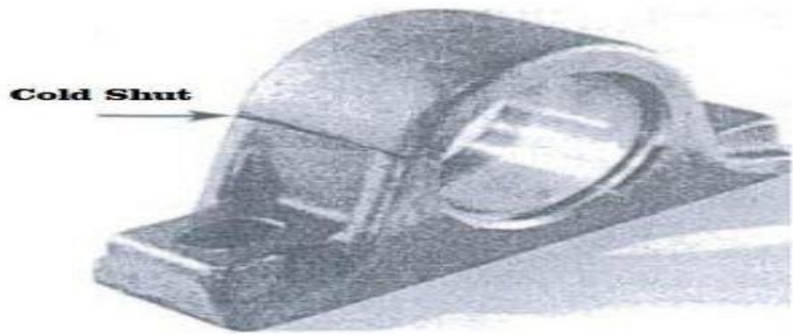


Fig .cold shut

4.1 PRESENT APPROACHES FOR ANALYSIS OF CASTING DEFECTS

Cause- effect diagram is one of the approaches to enumerate the possible causes. When all possible causes are known to us, the operating conditions are verified and applied to determine the potential cause item by item. As the primary factors are identified, they are further examined to find the specific problems that cause the defects. After the particular cause has been identified, remedies are suggested to eliminate the defects.

2.MATERIALS AND METHOD

2.1 Materials/Equipments

Aluminiumscraps , cope and drag, cylinderical rod pattern, Sodium chloride – Potassium chloride powder, Graphite crucible, Electric resistance furnace, sand, Mould, pattern, Rammer, Tensile and hardness testing machine.

2.2. METHODS

2.2(a) Preparations of the Mould

At first, moulding sand was produced by adding water to Azare foundry sand of known specification (Tokan et al 2004). Mould boxes (i.e. drag and cope) were produced using wood. The drag was placed on aa flat wooden board and then a cylindrical pattern placed on the board. The moulding sand was added to the pattern and rammed, properly. When properly rammed, the mould box containing the pattern was turned upside down and the parting sand was applied. The cope was place on the drag and care was taken to ensure proper alignment. The positions of the gate and the riser were located using circular pipes; and then the moulding sand was added again. When properly rammed, the cope was removed and then the pattern was removed. A runner of cross-sectional area, 380mm2 (i.e. 38mm wide and 10mm deep) and 208mm2 (i.e. 26mm wide and 8mm deep) was produced. This process was repeated for other runner sizes. Then the assembled moulds were placed in a furnace and preheated to temperatures of 37°C, 150°C, 190°C , and 230°C for holding time of 35 minutes.

Fig 2: mould making

2.2(b) Preparation of the Charge

The analysis of the aluminum alloy that was used for this work was done at the foundry shop of the National Metallurgical Development Centre (NMDC) Jos, Nigeria. High purity aluminum electrical wires (i.e scraps) obtained from the Northern Cable Company (NOCACO), Kaduna, was charged into a graphite crucible kept in electric resistance furnace. It is free from dust and contamination. The Silicon and Iron contents were kept constant. 0.01% sodium chloride- potassium chloride (Nacl-Kcl) powder was added to the charge. This can minimize the oxidation of aluminium by excluding oxygen and creating a protective atmosphere inside the furnace.

2.2(c) Preparation of pattern

Fig3: Pattern of a connecting rod

2.2(d) POURING OF METAL

Metal is then poured into the mould through pouring basin.

Fig4. pouring

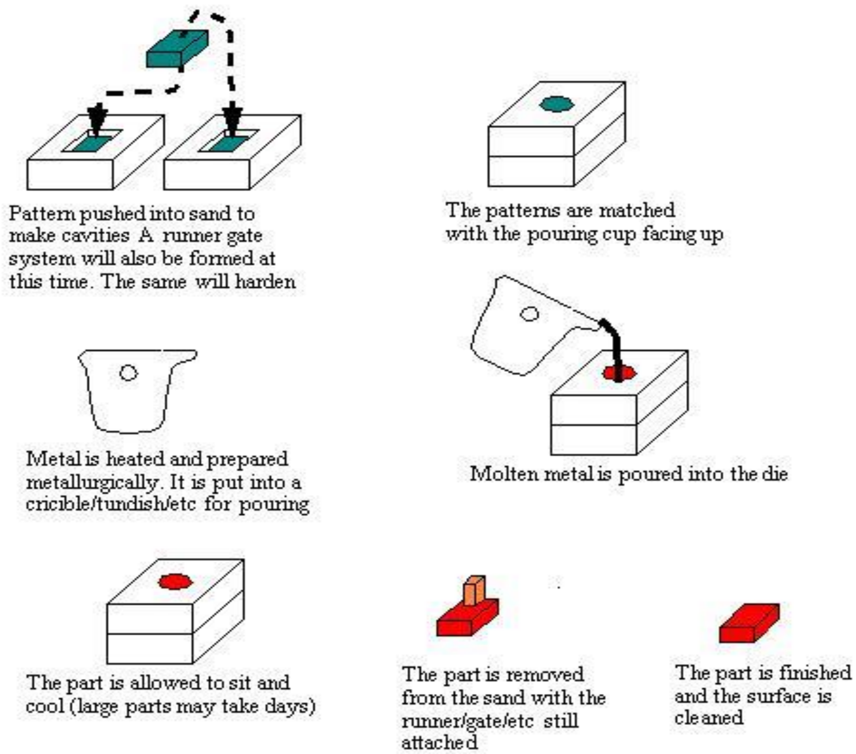


Fig: 5 Pouring Process

2.2(e) FRETTLING AND ANALYSING DEFECTS.

After pouring and solidification of mould product is taken out and defects are analyised.

Fig . frettling

Fig.6 Defects of Casting

3.FUTURE WORK

3.1 Testing of mechanical properties.

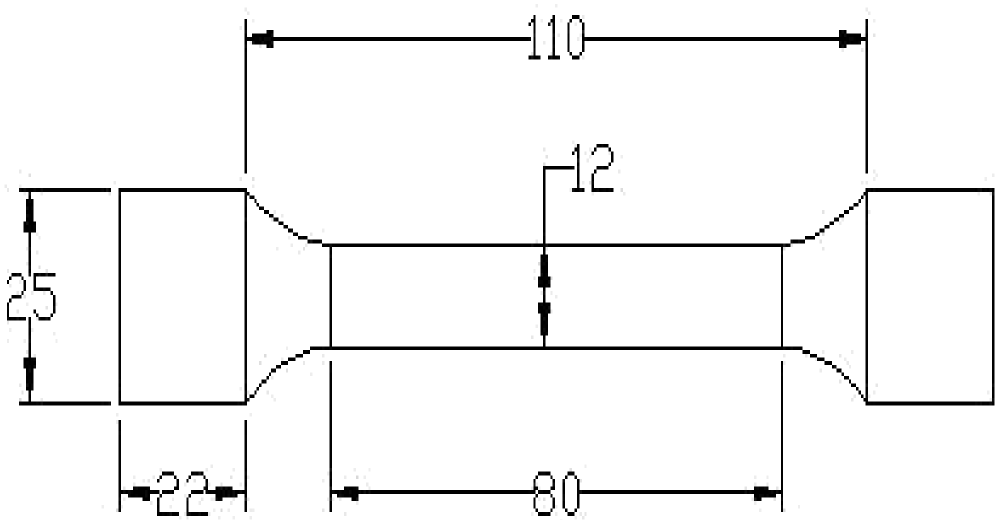


Fig7: specimen for tensile test

3.2 Specimen for Impact Test

The specimens for impact test were machined to specifications using a milling machine (figure 2). The equipment used for this test was the impact testing machine, WOLPERT, model RW 30115.The capacity of the machine is I50J. The pendulum was raised to the maximum height and the test piece was placed horizontally at the specimen holder. The pointer's reading was noted. The pendulum was released and strikes the specimen at the notch. The pointer's reading was noted again. The difference between is the energy that made the specimen to fail. This process was repeated for other specimens. The impart strength of the specimen was determined as follows: Impart Strength = energy expended/cross – sectional area of the specimen.

Fig. 8: specimen for impact test

Fig9: impact test zoom view

3.3 Specimen for Hardness Test

.Specimens for hardness test were produced (Figure 3).The Rockwell method was adopted. A standard block of hardness of 101.12 HRB, a minor load of 10kg and a major load of 100kg were used respectively. A hand wheel was used manually to raise the spindle towards the interior until the small needle has made this full turn which signals the application of the pre-load to the exact zero setting of the scale ring of the dial gauge. The application of the test load and the release were effected by means of a motor drive

eccentric. The motor stopped automatically after the test was completed. It was carried out in 7.5 seconds and the reading was taken for each specimen at different points on the specimen. The hardness is determined by the depth of indent produced by a steel ball. The correct indenter and a selected pre-load stop of 100kg at 10kg was 5mm. The test specimenwas placed on the test table

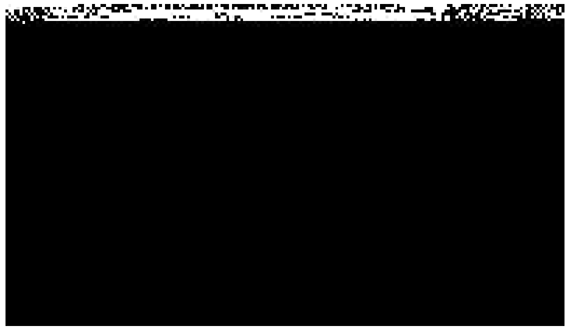


Fig 10: Specimen for hardness test

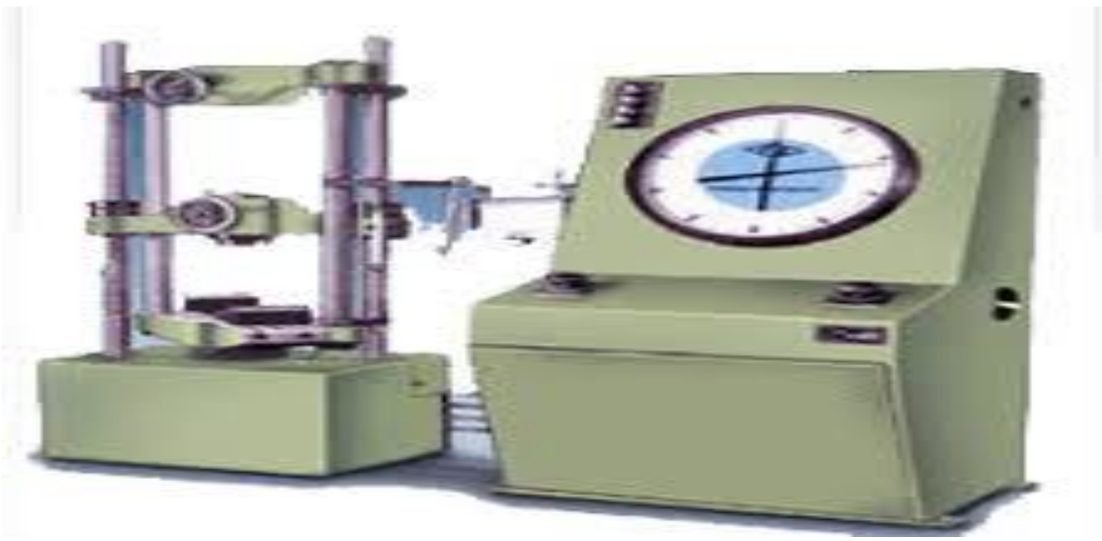


Fig 11: Universal Testing machine

From literature review, the following formulas were used to determine Ultimate strength and percentage elongation (%) respectively (Donald, 1989).

% Elongation = (L-L0)........................... (1)

Where: L = Final length after fracture; L0 = Gauge length

Ultimate Strength = Maximum Load................................ 3

Original cross- sectional area

4.READINGS TABLE

Table 2:Solidification time and mechanical properties at different mould temperature

Mould Temp (^{0}C)	Solidification time (min)	Impact Strength (J/mm^2)	UTS (N/mm^2)	Hardness (HRB)	Percentage Elongation (%)
25	-	-	-	-	-
150	-	-	-	-	-
190	-	-	-	-	-
230	-	-	-	-	-

Table 3:Solidification time and mechanical properties at different pouring temperature

Pouring Temp (^{0}C)	Solidification time (min)	Impact Strength (J/mm^2)	UTS (N/mm^2)	Hardness (HRB)	Percentage Elongation (%)
700	-	-	-	-	-
750	-	-	-	-	-
800	-	-	-	-	-
850	-	-	-	-	-

Table 4: Solidification time and mechanical properties at different runner size

Runner size (mm^2)	Solidification time (min)	Impact Strength (J/mm^2)	UTS (N/mm^2)	Hardness (HRB)	Percentage Elongation (%)
100	-	-	-	-	-
180	-	-	-	-	-
285	-	-	-	-	-
315	-	-	-	-	-

6.RESULTS AND DISCUSSIONS

The chemical composition of the recycled Aluminum alloy scraps is presented in Table 1.The results of the effect of mould temperature, pouring temperature, and runner size on the mechanical properties and solidification times of aluminium alloy parts are shown in tables 2, 3, and 4 respectively. Also, graphs of process parameters versus mechanical properties and solidification times were plotted (figure 4, 5, and 6).

From table 2, it is observed that an increase in mould temperature resulted to decrease in solidification time and impact strength. However, for the same increase in the mould temperature, the ultimate strength, hardness, and percentage elongation increased. The ultimate strength was the most affected. For example when the mould temperature was increased from 37oC to 150oC, the ultimate strength increased from 29.50N/mm2 to 49.30N/mm2. Perhaps the decrease in the solidification time resulted to formation of uniform grains structure during recrystallization. Also the decrease in the solidification time must have resulted to uniform filling of the mould cavity, eliminating some of the casting defects such asblow holes and shrinkage which would have caused decrease in the mechanical properties (Grill, 1982 and Jain, 1986).

From the graphs of fig. 5, it is observed that the increase in the pouring temperature caused decrease in the impact strength also. For example when the pouring temperature was increased from 800oC to 8500C the impact strength decreased from 0.31J/mm2 to 0.30 J/mm2. Again, increasing the pouring temperature caused increase in the time of solidification, ultimate strength, hardness, and percentage elongation though the increase these mechanical properties are not as significant as in the cast of mould temperature. For instance, increases in the pouring temperature from 800oC to 850oC, the ultimate strength increased by 3.20N/mm2. The small increase in the ultimate strength may be because of the trapped gases such as hydrogen resulting from the burning of the crystals during melting.

Also from table 4, it is observed that increasing the runner size towards the mould cavity produced corresponding decreases in the solidification time other mechanical properties for this alloy. The decrease in the mechanical properties may be as result of non-uniform crystal structure formed because of the decrease in the solidification time (Llewellyn, 1997). Since the velocity of molten metal going in the mould cavity is decreased, the filling of the mould cavity is delayed resulting to non-uniform solidification of the molten metal and this can results to non- uniform microstructure formation within the solidified casting(i.e. coarse and fine grain structure within the casting)

7. CONCLUSION

1. It is discovered that the mould and pouring temperatures significantly affect the mechanical properties of sand casted aluminium alloy. Ultimate strength, hardness, and elongation increased with increased the mould and pouring temperature. The increased in the ultimate strength is more than that of hardness and elongation.

2. Decreasing the runner size resulted to increase in the solidification time, ultimate strength, hardness and elongation. That is, if the runner's size towards the mould cavity is made smaller than the one towards the sprue, both solidification time and the mechanical properties of the alloy will increase.

3. For this alloy, the pouring temperature to achieved improved mechanical properties ranges from 800oC – 850 oC. Also for the casting of this size, the runner's size should not exceed 100mm2.

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