UNIVERSITY OF EDUCATION, WINNEBA

COLLEGE OF TECHNOLOGY EDUCATION, KUMASI

FACULTY OF VOCATIONAL AND TECHNICAL EDUCATION

DEPARTMENT OF DESIGN AND TECHNOLOGY EDUCATION

A COMPARATIVE STUDY INTO THE QUALITIES OF BOTH FOREIGN (INDIA) AND LOCALLY MANUFACTURED CORN MILL PLATES BY ARTISANS AT SUAME – MAGAZINE IN KUMASI

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BY

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(B.Ed TECHNOLOGY EDUCATION)

A THESIS IN THE DEPARTMENT OF DESIGN AND TECHNOLOGY EDUCATION, FACULTY OF VOCATIONAL AND TECHNICAL EDUCATION SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES, UNIVERSITY OF EDUCATION, WINNEBA IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF MASTER OF TECHNOLOGY (MECHANICAL TECHNOLOGY) OF THE UNIVERSITY OF EDUCATION, WINNEBA

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DEDICATION

I dedicate this work to God who provided me with the needed energy and health to go through the programme. May my wife, Pwadam Rebecca and all our children share what has been dedicated to Almighty.

DECLARATION

CANDIDATE'S DECLARATION

I, Christopher Kubetara Yawuliga, declare that the thesis with the exception of quotations and references contained in published works which have been identified and acknowledged, is entirely my own original work and it has not been submitted either in part or whole for another degree elsewhere.

SIGNATURE:................................. DATE:............................

YAWULIGA KUBETARA CHRISTOPHER

SUPERVISOR'S DECLARATION

I hereby declare that the presentation of this thesis was supervised in accordance with the guidelines of supervision of thesis as laid down by the University of Education, Winneba.

SIGNATURE:............................. DATE:..............................

MR. AMOAKOHENE S. K.

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ABSTRACT

The aim of this research was to investigate into the qualities of both locally manufactured (from Suame Magazine in Kumasi) and foreign (India) corn mill grinding plates and to recommend if there are new technologies that could be employed to further enhance their qualities.

The researcher made a brief description of the different forms of casting with more emphasis on sand casting. This was followed with an in-depth literature review of relevant material related to the subject matter. Five (5) corn mill grinding plates, three local and two foreign plates were randomly selected for investigation. The researcher limited the number to five because of financial constraints – the cost of testing and secondly most of the plates had similar qualities. The microstructure of each plate was observed using optical microscope attached to a computer. The qualities of corn mill grinding plates depend on the chemical composition and the casting process used, therefore, the chemical composition of the plates were determined using an emission mass spectrometer.

Additionally, the hardness of each plate was determined using the Leeb hardness tester. It was observed from the results obtained through the various tests on the specimen that the locally produced corn mill grinding plates have a better quality as compared to the foreign (India) in terms of chemical composition and hardness. One significant observation made was that, even samples from the same foundry shop varied in terms of qualities and this was attributed to the uncontrolled charging of raw materials into the furnaces. The researcher strongly recommends capacity building in terms of training from the ITTU to artisans engaged in casting to improve their skills. Further to the above, a concerted effort should be made to ensure that only white cast iron is sorted and fed into the furnaces.

CHAPTER ONE

INTRODUCTION

The following have been discussed under this chapter; Background to the study, statement of the problem, purpose of the study, research questions, scope of the study, methodology. The others include collection of sample, methods of selection, instruments used in the study, analysis of the data and the interpretation of the data.

1.1 Background of the Study

Technology is generally defined as the branch of knowledge that deals with the creation and use of technical means and their interrelation with life, society and the environment drawing upon such subjects as industrial arts, engineering, applied science and pure science.

The manufacture of any engineering component or part makes use of one or a couple of technological processes. The choice or application of a manufacturing process depends on the scientific analysis and the results obtained thereafter.

There are several manufacturing processes of metals such as shaping processes, forging, machining, joining, surface finishing and powder metallurgy. The use of any or a combination of the above processes will depend on several factors. Some of the factors that influence the application of a particular process include; meeting the international standards of the material, the stress analysis and the forces that the component needs to withstand and a host of other factors. The ultimate aim of every engineering design of a component is that the component does not fail in its use, that is, it is able to perform effectively within its limits.

Engineering components are made of many different shapes and the engineer has the herculean tasks of deciding on what method will help reduce the cost of producing that component, not compromising on the quality of that component.

Among the various methods of producing or manufacturing components, casting is one form which is widely employed by both skilled and unskilled castors, small to medium and large foundries.

Casting is a forming technique whereby molten metal is poured into a prepared shape (mould or cavity) and allowed to solidify to take up the shape.

The process was established in the Bronze Age when it was used to form bronze pieces which are now found in museums. Khanna (1972). It is particularly valuable for the economical production of complex shapes ranging from mass produced parts for automobiles one -of -a -kind production of statues, jewellery or massive machinery

Many objects that are used in most spheres of life ranging from very minute parts of machines to very huge housing of industrial machines are cast.

According to Khanna O. P. (1972), the manufacture and use of castings can be traced both in ancient and Medieval history and that the first foundry centre came into existence in the days of Shang dynasty (1766 – 1222 BC) in China.

He also stated that one existing life –sized portrait head of cast Bronze from Mesopotamia antedates about 2250 B. C.

The growing demand of high precision castings and of intricate designs at lower costs helped considerably in the development of Foundry Industry.

Hardly there is any product, today, which does not have one or more cast components. A few applications of foundry products or castings are mentioned below:

In transportation, vehicle cast parts account for more than 90% of an automobile engine and for more than 50% of the total weight of a tractor. Khanna (1972). The other uses of casting include machine tool structures, for example, planer beds, turbine vanes, power generators, mill housings, railway crossings, aircraft jet engine vanes, agricultural machine parts, communication, construction and atomic energy applications.

In Ghana casting has become a household business and has provided many jobs for many people, providing a livelihood for the owner, workers and their dependants.

Many foundries are situated in the big towns in Ghana like Accra, Kumasi, and Takoradi. There are few foundries that are sited in rural areas in Ghana.

Most of the foundries produce household utensils like cooking pots, agricultural components and some industrial components such as milling plates for the corn mills.

The rural electrification programme in Ghana has triggered a high demand for milling plates because of the many milling machines that are springing up in rural communities. Even communities that are not hooked to the national grid have milling machines that run on fossil fuels. The age old form of grinding on rocks in the northern part of Ghana is fast fading out giving way to every grain that is to be turned into flour is taken to the milling machine.

Casting of metal into a component for industrial use is a complex phenomenon and requires very skilled experts in the casting process. Casting involves so many processes and at each stage the services of an expert is needed. For example, the making of the pattern alone has to be carried out by persons who are specialized in the making of patterns. Again, the preparation of the mould is a very difficult process because the nature of the mould will greatly affect the quality of the product. A badly prepared mould will yield a defective cast piece and vice versa.

Metals, both ferrous and non ferrous, have physical, mechanical and chemical properties. When metals are heated they change from solid to liquid state and when allowed to cool they change to solid again. All these processes as they occur in metal, sand and die casting greatly influence the quality of the product.

There are so many advantages of casting as against other forms of shaping of metals but care must be exercised so that the cast product is not ruined with defects, thus making it not safe to use or fail under use in the industry

1.2. Statement of the Problem

Technological advancement all over world has significantly helped manufacturers to improve upon the quality of many products that are used in industry today. In this era of computer, the manufacturer no longer relies solely on his/her experience and knowledge to determine the quality of a product. Computers are used to simulate and generate results which are then used as bases for whatever decisions that the manufacturer will take to ensure that the final product is of high quality. Advanced technology has considerably reduced the margin of error and subsequently reduced the likelihood of a product failing in its use.

In spite of the technological advancement as stated above many products made by sand casting are based on experience gathered over the years in the industry. The researcher investigated into the quality of manufactured (sand cast) milling plates produced at Suame –Kumasi in Ghana and those that are imported from India.

Governments of nations all over the world have institutions established and mandated by law to ensure that whatever product is put on the market for the consumer meets certain obligatory quality standards.

The quality of many items produced locally and others imported have been called to question. Sand cast milling plates are no exception.

The Suame industrial area in Kumasi is well known for its ingenuity in the production of parts of machines which are not only patronized in Ghana but across the boundaries of Ghana. For example indigenes of Togo, Burkina Faso and Benin transact business with Suame industrialists on daily basis.

It therefore behoves on the producers that their artefacts are of the international standards.

In these days of greatly increasing numbers of reliability law suits and the need to conform to regulations issued by Governmental Agencies such as Environmental Protection Agency (EPA), Ghana Standard Authority (GSA), it is very important for the designer and manufacturer to know the reliability of their products used in the industry.

According to Khama (1972), in casting, quality is one of the keys to the survival of the Foundry industry today. To implement an effective quality assurance programme, it is most important to understand how to select and apply available high-tech testing and measuring equipment.

1.3 Purpose of the Study

The goal of this study was to.

i. assess the quality of milling plates produced by sand casting by artisans in Suame Kumasi,

ii. compare and contrast the quality of locally produced milling plates as against that of imported milling plates,

iii. find out the materials (metals) used to produce the plates,

iv. identify the common defects that users of the plates encounter,

v. Recommend if there are any new technologies that can help to improve the quality of sand cast milling plates.

1.4 Significance of the Study

The significance of the study was to help develop a scientific knowledge based document that can be used to improve the quality of locally produced milling plates.

It was also aimed at helping the users of the plates distinguish between quality plates from others thus improving their businesses.

Besides, the study sought to help the general public in that quality plates will reduce the likelihood of flour contamination with its health hazards.

In addition, it will reduce the cost of running the mills and consequently those who patronize their services will be made to pay less.

The research has helped to unearth and recommended good sand casting practices that will effectively improve upon the quality of locally produced milling plates.

1.5. Research Questions

In an effort to achieve the purposes of the study the answers given to the following research questions were tested after collecting and collating the data.

i. Was there any significant difference between the locally sand cast milling plates and the foreign milling plates?
ii. Were there any regular defects that users of locally sand cast milling plates encounter?

1.6. Scope of the Study

The study covered ten (10) foundries that perform sand casting within the Suame industrial area in Kumasi in the Ashanti Region of Ghana.

Samples of sand cast milling plates from the foundries as well as users of the plates were collected and their properties analysed. Both the foreign and the locally produced milling plates were produced using sand casting method.

1.7. Methodology

This chapter gives an account of how the samples were collected for the research and analysed. It looked at the target group, how the groups were selected and as well as how the results that were obtained from the research were analyzed.

The chapter has been put under the following sub-headings:

i. population,

ii. collection of sample,

iii. methods of selection,

iv. instruments employed in the selection process,

v. analysis

1.8. Population

The term population refers to a set of individuals (subjects) or events having common observable characteristics in which the researcher is interested.

They included foreign and local milling plates.

1.9 Collection of Sample

The study of an entire population to answer specific question(s) was made difficult in terms of money, time and resource. Therefore a sub-set of subjects, in this case, locally manufactured corn mill grinding plates and foreign corn mill grinding plates were selected.

A sample is a small sub-set of the population that will be chosen to be studied. A total of ten (10) foundries in Suame Kumasi who perform sand casting of milling plates were chosen for the study. In addition, two foreign corn mill grinding plates from India which were produced by sand casting method were chosen for the study.

1.10 Methods of Selection

Both locally manufactured and foreign corn mill grinding plates were randomly selected to give every plate from the foundries an equal chance of being selected. Another reason for the random selection was that the plates had similar qualities.

1.11 Instruments Used for the Study

The study was an experimental one and data was collected using the following;

i. Emission mass spectrometer which was used to check the chemical composition of the various plates,

ii. Leeb hardness tester MH180 which tested the hardness values of each plate and converted those values from one scale to the other;

iii. Labpol Duo and Twin disc machine used for polishing specimen for testing

iv. Lecia DM 1000 machine attached to a computer used for checking the microstructure of specimen.

1.12 Analysis of the Data

The scientific data which was collected through the various tests on the specimen was analyzed based on the results.

1.13 Interpretation of the Data

The interpretation of the data was done using tables of percentages and bar charts.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter will take into account the following: history of casting, both in Ghana and in the world, forms of casting, that is, sand casting, die casting, shell casting, plaster mould casting, investment casting and permanent mould casting.

Some metals that are used in casting are steels, cast irons, aluminium alloys, copper alloys and zinc alloys. Advantages of sand casting over other methods, causes and defects in casting are also discussed.

2.1 Definition of Casting

Of all the manufacturing processes; perhaps casting is the oldest and it is as important today as it was in primitive days (Khanna 1972). Casting is a process of pouring liquid or viscose material into a mould and allowing to solidity.

2.2 History of Casting

From the beginning of the Christian era, many societies in Ghana used ceramics for their infrastructure, tools and equipment for their socio-economic and cultural activities. Examples of these are not hard to come by (a) iron smelting and iron smithing furnaces; (b) copper working hearths and crucibles; (c) cloth spinners' spindle whorls (d) discs used by gold merchants for weighing gold dust (e) sculptures used by 12^{th} – 18^{th} century Koma – Bulsa and 17^{th} – 18^{th} century Akan for funerary ceremonies (f) stoves (g) smoking pipes, and (h) a great variety of vessels used for cooking, serving food, convenience storage and drinking of water and bathing.(www.ghanaculture.gov.gh retrieved 27/7/2012).

Since about 2500BC Pharaonic Egyptian potters used the wheel for shaping pots and used high temperature kilns for baking their wares. On the other hand Ghana's potters have always used local raw materials and simple tools for pottery productions. Present day traditional Ghanaian potters are still unwilling to adopt the potters wheel and firing kiln. They believe that even their industry is a religious gift handed down to them by their ancestors and should not be tainted by modern adaptations, even if modern tools and techniques will make for greater efficiency and productivity.

The development of Ghana from the stage of the small "Nyame Akuma" village to the stage of the early town and chiefdom and then to the stage of empire such was developed by Akwamu and Asante took over 3000 years. Each turning point was marked by the introduction of new or improved technology or industry.

There is little doubt that the introduction of iron technology was a crucial factor in the foundation-laying process of modern Ghana. Iron being much tougher and having more versatile material than either copper or "Nyame Akuma" greenstone it became very popular with early Ghanaian historic communities from the beginning of the Christian era when expanding population demanded increasing output of hunting, agricultural, architectural and industrial equipment.

Recent studies on early African iron metallurgy have shown that ancient iron technologists were acquainted with non-scholastic metallurgy chemistry and subtleties of iron technology which enabled them to produce traditional steel products quite often superior to the iron wares manufactured in European factories of the time (www.ghanaculture.gov.gh retrieved 27/7/2012).

The origin of Ghanaian iron technology is still shrouded in mystery. The available facts show that the earliest-known iron extractive industries were operating in the Begbo and Bono Manso areas of Brong Ahafo around A.D. 100-400 and that the Brong ancestors of Bonoso near Wenchi installed a similar industry around A.D 700-1000. According to archaeological studies, between 1400 and 1700AD, the International Commercial Metropolis of Begbo was operating probably the largest iron metallurgical installations known so far in West Africa, which have left behind numerous mounds of which represent ruins of smelting and smithing furnaces and slag waste products. Here the locals turned out numerous iron implements for the populace of middle Ghana. (www.ghanaculture.gov.gh retrieved 27/7/2012).

Similarly archaeological investigations conducted along coastal Ghana at Cape Coast University, Asebu and the Shai hills, and also in Northern Ghana location at Buipe, Lakpasere, Yendi Dabari, Komaland and Gambaga show that these areas were prolific in iron production during the period AD 700-1700. Oral historic recordings in Asante state that in the past probably about three to four centuries ago, several Adanse communities such as Edubiase, Fomena, Dompoase, Akrokeri, Akrofrom and Bodwesanwo regularly produced iron blooms for manufacturing hoes, cutlasses, knives, axes, animal traps etc and that Edubiase was celebrated as the “Birmingham of old Adanse”. Similar traditions recorded in the Denkyira townships of Ayamfure, Dunkwa, Mudaso and Kyekyewere-Nyameso to mention a few had vigorous iron industries operating there during the last few centuries. (www.ghanaculture.gov.gh retrieved 27/7/2012).

Written documentations of iron technology by European visitors to Ghana confirm the information obtained from ethno-histories and archaeological sources. For example Peter De Marees who visited the Elmina region around 1600, Olfert Dapper (1670) who also visited the coastal lands and Thomas Bowditch who led an expedition to Kumasi in 1817- these and a host of other European visitors described a variety of iron products made locally to serve the needs of builders, farmers, craftsmen, gold miners, household keepers, and soldiers.

Around 3500 BC the ancient Egyptian became acquainted with the knowledge that when copper metal is heated in a crucible to a temperature of about 1100^{0}C it melts into fluid state and that it can then be shaped by pouring into a mould of stone or clay previously cut to the exact shape of an artefact or it can be cast by the "lost wax" method. There is archaeological evidence that during the period 1000BC – A.D 1500, some centres around Akjout in Mauritania Republic and others around Agadez in Niger Republic were mining local copper for the production of copper technology. As other parts of West Africa including Ghana do not have copper in industrial quantities, they were unable to develop local copper technology until copper could be imported from external sources through the trans-Saharan and European trade.

It is clear that long after Ghana's adaptation of the more complicated technology of iron working, it became possible for craftsmen in Ghana to commerce copper technology, thanks to the facility of importation of brass basins and copper bars through European Commerce. Of great significance, however, is the fact that from AD 1300 and for several centuries thereafter local craftsmen in Ghana acquired the know-how of a wide range of metal casting techniques. These include solid casting, open-work casting, direct casting, casting over an iron core and cuttle fish bone mould casting. Suffice it to say here that during the period AD 1300-1800 craftsmen in Ghana utilised these processes to produce masks, beads, rings, necklaces, spoons, abosodeɛ or ornaments for decorating Asante state swords, state stools and drums and also to produce a great variety of brass weights in different artistic forms for use by merchants in the gold trade for weighing gold. Aquandah (1996) – Ghana National Commission on Culture.

2.3 SOME FORMS OF CASTING

2.3.1 Sand Casting

Sand casting is a process for casting metal in sand moulds. (Fig 2.1). The mould is made by packing the sand around a pattern and is used only once. The sand is recycled after each use (with only small loss) so the process is efficient. There are several different types of casting:

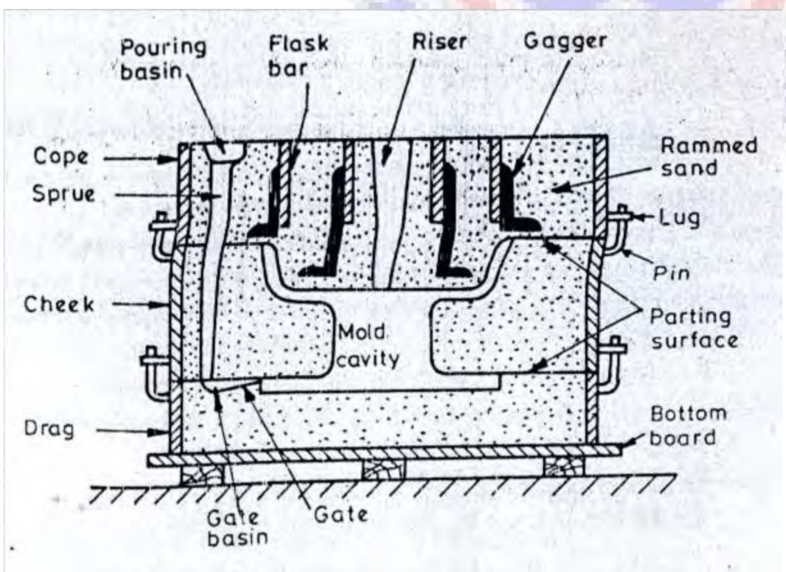

Fig. 2.1 A typical sand casting mould
(Source: Khanna O. P. 1972, pg 179).

Process:

i. Placing a pattern in sand to make an imprint.

ii. Incorporating a gating system.

iii. Filling the cavity with molten metal.

iv. Allowing the metal to cool until it solidifies.

v. Breaking away the sand mould.

vi. Removing the casting part.

Sand casting process can vary greatly in scale from casting multi ton parts for industrial machines to casting as small as a ring. Most sand casting use silica sand (SiO_2)

2.3.2 Die Casting

Die casting is a metal casting process that is characterised by forcing molten metal under high pressure into a mould cavity, (See Fig 2.2). The mould cavity is created using two hardened tool steel dies which have been machined into shape and work similarly to an injection mould during the process. Most die castings are made from non-ferrous metals, specifically zinc, copper, aluminium, magnesium, lead and tin based alloys. Depending on the type of metal being cast, a hot or cold chamber machine is used. Die casting can be gravity die casting in which the molten metal is poured into the mould under gravity only. No external pressure is applied to force the molten metal into the mould cavity or pressure die casting where the molten metal is forced into permanent mould (die) cavity under pressure.

The pressure is generally obtained by compressed air or hydraulically. Two variants of die casting are pore free die casting, which is used to eliminate gas porosity defects; and direct injection die casting, which is used with zinc castings to reduce scrap and increase yield.

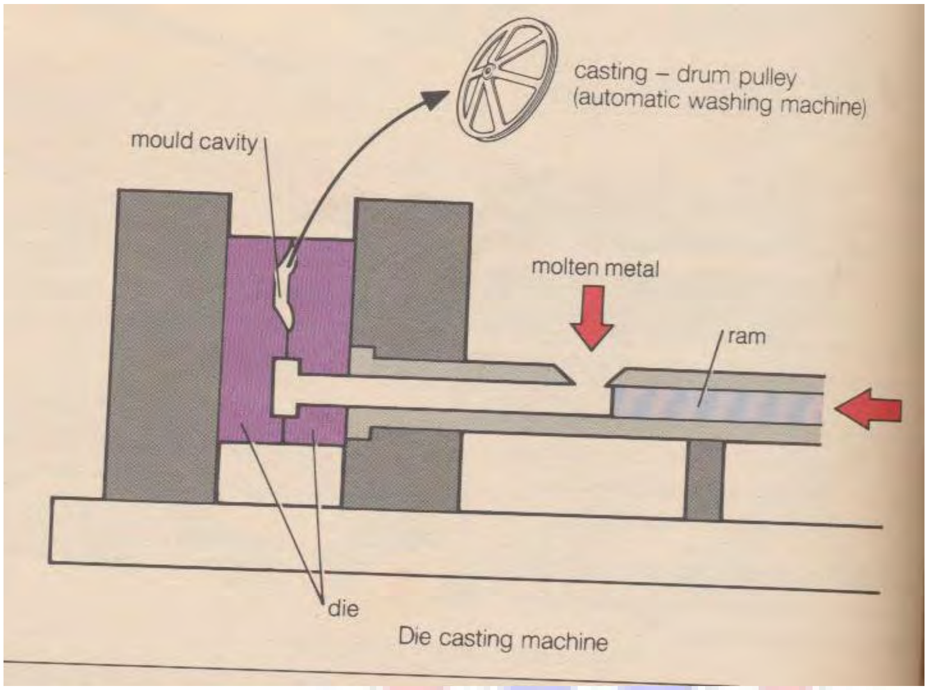

Fig 2.2 Die Casting mould

(Source: James Garratt – 1996)

2.3.3 Shell Casting

Shell moulding, also known as shell mould casting is an expendable mould casting process that uses a resin covered sand to form the mould. Shell mould casting is a metal casting process similar to sand casting in that molten metal is poured into an expendable mould. However, in shell mould casting, the mould is a thin walled shell created from applying a sand-resin mixture around a pattern. The pattern, a metal piece in the shape of the desired part, is reused to form multiple shell moulds. A reusable pattern allows for higher production rates, while the disposable moulds enables complex geometries to be cast. Shell mould casting requires the use of a metal pattern, oven, sand-resin mixture, dump box, and molten metal.

Shell mould casting (fig 2.3) allows the use of both ferrous and non-ferrous metals, most commonly using cast iron, carbon steel, alloy steel, stainless steel, aluminium alloys, and copper alloys. Typical parts are small-to-medium in size and require high accuracy such as gear housings, cylinder heads, connecting rods, and lever arms.

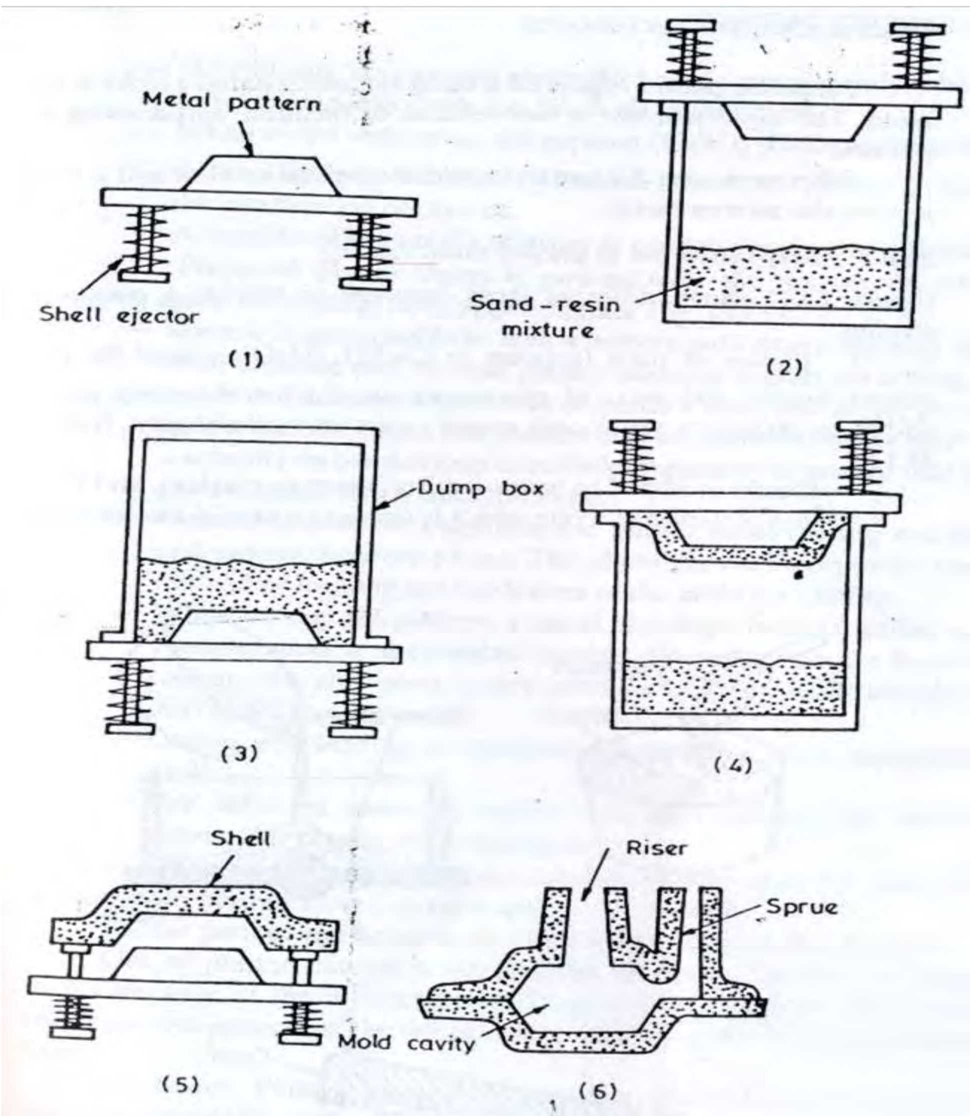

Fig 2.3 Shell Casting mould
Source: Khanna O. P. (1972) pg 500

Fig 2.3 steps

1. Metal pattern;
2. Pattern clamped over dump box;
3. Dump inverted over hot metal;
4. Dump box turned to original position;
5. Shell stripped from the pattern;
6. Shell assembly.

2.3.4 Plaster Mould Casting

Plaster mould casting (fig 2.4) is a metalworking casting process similar to sand casting except the moulding material is Plaster of Paris (POP) instead of sand. Like sand casting, plaster mould casting is an expendable mould process, however it can only be used with non-ferrous materials. The plaster is not pure plaster, but rather has additives to improve green strength, dry strength, and permeability and cast ability. For instance, talc or magnesium oxide are added to prevent cracking and reduce setting time, lime and cement limit expansion during baking, glass fibres increase strength, sand can be used as a filler.

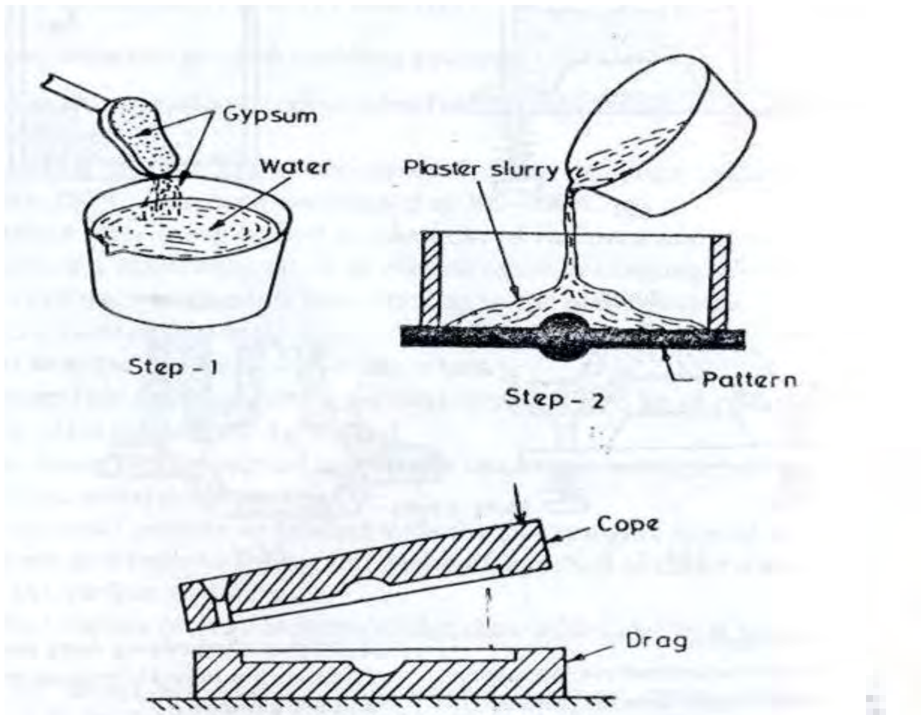

Fig 2.4 Plaster Mould Casting

Source: Khanna O. P. (1972, pg 503.)

Fig 2.4 steps

1. Plastic is added to water (rather water to plastic), and the mixture is stirred at a rate which is neither too rapid nor too slow;
2. Prepared plastic slurry is poured over the pattern on which parting agent has already been applied;
3. After the slurry has been poured over the pattern, it develops an initial set in a few minutes and the pattern can be withdrawn from the mould;
4. The other half is prepared as indicated above;
5. Mould halves are placed together in an oven and heated and when in a hot stage they are assembled and poured with molten metal.

2.3.5 Investment Casting

Investment casting (fig 2.5) is an industrial process based on counter gravity pouring or vacuum pressure pouring and also called lost wax casting, one of the oldest known metal-forming techniques. For 5,000 years ago, when beeswax formed the pattern, to today's high technology waxes, refractory materials and specialist alloys, the castings allow the production of components with accuracy, repeatability, versatility and integrity in a variety of metals and high performance alloys. The process is generally used for small castings, but has been used to produce complete aircraft doors, steel castings of up to 300kg and aluminium castings up to 30kg. It is generally more expensive per unit than die casting and sand casting, but has lower equipment costs. It can produce complicated shapes that would be difficult or impossible with die casting, yet like that process, it requires little surface finishing and only minor machining.

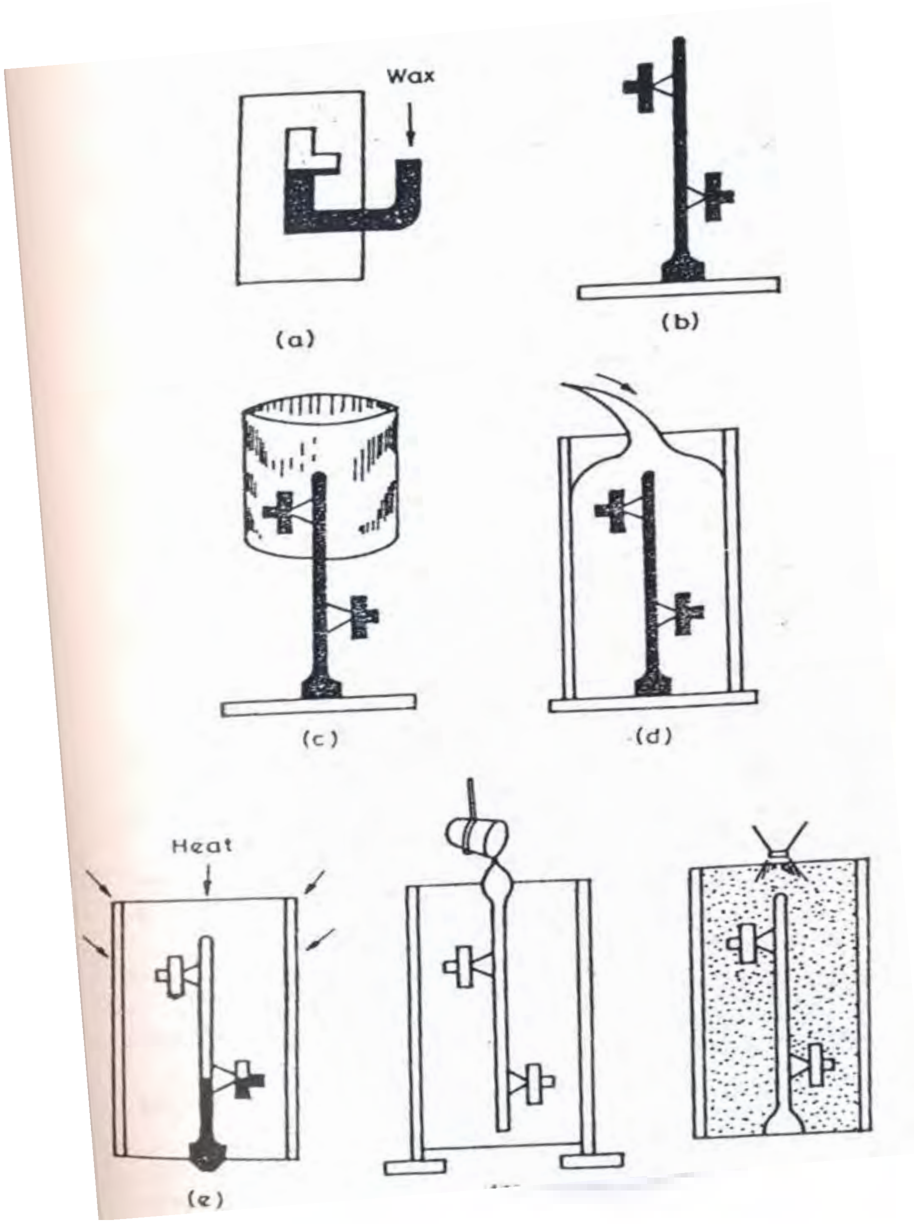

Fig 2.5 Investment Casting

Source: Khama O. P. (1972. Pg 496)

Fig 2.5 steps

(a) wax injected into die to make pattern;
(b) Patterns have been gated to central sprue;
(c) Placing metal flasks around the pattern assembly;
(d) Investing the wax pattern assembly;
(e) Removing wax pattern from investment mould;
(f) Pouring molten metal into the mould;
(g) Removing casting from the mould by breaking casting material.

2.3.6 Permanent Mould Casting

Permanent mould casting (fig 2.6) is metal casting process that employs reusable moulds ("Permanent mould") usually made from metal. The most common process uses gravity to fill the mould, however gas pressure or a vacuum are also used. A variation on the typical gravity casting process called slush casting, produces hollow castings. Common casting metals are aluminium, magnesium, and copper alloys. Other materials include tin, zinc, and lead alloys and iron and steel are also cast in graphite moulds.

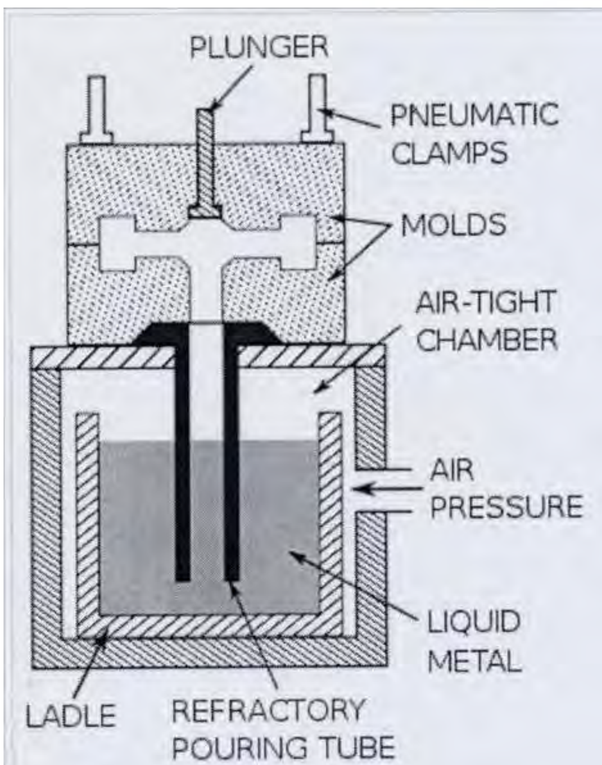

Fig 2.6 Permanent Mould Casting

(source: File:///G:/permanent mould casting.htm)

Retrieved: 25-09-2012

2.4 SOME METALS USED IN CASTING

According to (Khanna 1972) selecting a metal or metal alloys for a specific casting application depends on many factors other than cost of metal and its availability. The method of casting, for example, may limit metal selection options because it has a profound effect on the casting quality, production volume and delivery commitments.

Metal castability for a given casting design and casting method affects metal selection as well as mechanical and physical properties. Foundry alloys and metals can be classified as ferrous (iron base) or non-ferrous.

2.4.1 Cast Steels

The most common types of steels used in casting are carbon steels, which by design contain only carbon as the principal alloying element. Other elements are present in small quantities including those added for deoxidation. Silicon and manganese in cast carbon steels typically range from 0.25 to about 0.80% Si and 0.50 to about 1.00% Mn. Carbon steels are classified by their carbon content in three distinct groups: (1) Low carbon steel – $C \leq 0.20\%$, (2) Medium carbon steel – $C = 0.20 – 0.50\%$ and (3) High carbon $C \geq 0.50\%$.

2.4.2 Cast Iron

Cast iron is a ferrous metal, and an alloy of iron and carbon. It is used for casting machines, bodies of horticultural and agricultural implements and the likes Sackey and Amoakohene, (1996). The term cast iron, like the term steel, encompasses a family of ferrous alloys: grey iron, alloy iron, white iron, malleable iron, ductile iron and compacted graphite iron. Wide variations in properties can be achieved by varying the balance between carbon and silicon, by alloying, and by applying various types of heat treatment.

2.4.3 Aluminium Alloys

Aluminium is produced by an electrolytic process. It is refined by digesting crushed bauxite with a hot caustic soda solution. Aluminium has a melting temperature of about 660^0C. It has a white silvery colour.

Pure aluminium is soft ductile and mechanically weak, but when alloyed with small amounts of other elements, its hardness and strength are increased. Teye and Amekuedi (1987)

According to (Khanna 1972) aluminium continues to grow in acceptance, particularly in the automotive industry because of dramatic weight reduction, design efforts designed to meet government-mandated gasoline consumption limitations. Aluminium can be cast by virtually all of the common casting processes particularly die casting, sand casting, evaporative pattern casting etc. According to Teye and Amekuedi (1987), aluminium makes up approximately 12% by weight of the metals produced in the casting industry making it the most popular iron-ferrous metal, the reason for the interest in aluminium lies in its relatively low melting point, excellent corrosion resistance, high strength and low specific gravity.

2.4.4 Copper alloy

The technology of copper alloy founding has advanced considerably in recent years and casting are produced to a high degree of integrity to fulfil many critical applications where inspection requirements are particularly onerous.

The most flexible casting uses sand moulds. It is applicable equally to one-offs or to long runs of castings and is suitable for castings from a few grains in weight to several tonnes. Both sand and die casting allow low cost production of complex near net shape components, minimising machining costs and avoiding difficult fabrications. Rings and discs for the manufacture of products such as gears or valve settings and tubes or flanged pipes as well as other symmetrical shapes are available as centrifugal castings.

The casting process is far more versatile than fabrication in that it imposes few limitations on shape. No protective treatments against corrosion are necessary with copper alloys. Slow tarnishing occurs in moist air but this is superficial. Most alloys are resistant to attack in fresh waters and general corrosion rates are typically less than 0.05mm/year in sea water. There are several families of alloys used for copper alloy castings. Each has properties uniquely appropriate to particular fields of use, although many have also general applications.

2.4.5 Zinc alloys

There are two basic families of zinc casting alloys. ZAMAK alloys and ZA alloys. The ZAMAK alloys were developed for pressure die casting during the 1920's and have seen widespread usage since then. It is for this reason that specifiers often relate zinc as synonymous with die casting.

However, the development of ZA (Zinc Aluminium) alloys during the 1970's has radically changed zinc product design and manufacturing properties. Zinc alloys were initially developed for gravity casting. Their mechanical properties compete directly with bronze, cast iron and aluminium using sand, permanent mould and plaster mould casting methods.

Distinguishing features of the ZA alloys are their high aluminium content and excellent bearing properties. During the 1980's, ZA alloys evolved as valuable die casting material. Zinc casting alloys are versatile engineering materials. No other alloy provides the combination of strength, toughness, rigidity, bearing performance and economical castability. (Source: www.nshore mfg. com/zinc28/08/2012)

2.5 Critical Factors That Must Be Followed To Ensure High Quality of Sand Cast Products

To most consumers, quality of a product is usually the main driving force to acquiring that product. Quality control is one of the crucial element of successfully sourcing a product globally (ESP International – 2009). Casting quality is one of the keys to survival in the foundry industry today.

High quality castings depend on the ability of a casting producer to test and inspect raw materials – sand, metals, alloy and additions. Some common requirements of a casting may include evaluation of:

1. Mechanical properties
2. Chemical properties
3. Dimensional tolerance
4. Surface roughness and integrity
5. Internal soundness

2.5.1 Mechanical Properties

Most of the materials in engineering are metallic in nature. The prime reason simply is the versatile nature of their properties. These spread over a very broad range compared with other kinds of materials. Many engineering materials are subjected to forces both during processing fabrication and in service. Ahmad Faisal Bin Mohammad (2009).

According to Hurst (2006) when a force is applied to a solid material it may result in translation, rotation, or deformation of that material. The deformation may be permanent or temporary. The ability of a material to withstand the applied force without deformation is expressed in two ways, that is, strength and hardness. Forces applied act on a surface of a material, and thus the force intensity, force per unit area is used in analysis.

2.5.2 Chemical Composition

Steel castings are commonly ordered mechanical property specifications. Additional requirements may include heat or corrosion resistance. The chemical composition of the material is specified in order to produce a material that fits the application it will be used in. If the application of a material is non-structural and not of a critical nature, the composition of the material may not be controlled as tightly as if it were an application that had low factor of safety and a very tightly controlled mechanical property specification.

Steel which is used to cast milling plates comprises iron and other elements such as carbon, manganese, phosphorous, sulphur, nickel, chromium and more. Iron is the basic component of steel. When carbon, a non metal, is added to iron in amounts up to 2.1% the result is an alloy known as steel.

2.5.3 Dimensional Tolerance

A casting dimensional tolerance is developed from various factors. The tolerance of a raw casting is largely defined by the type of process used. An investment cast part will yield significantly better dimensional capability from a sand cast part. A sand cast part that has a sand mould compacted by an automated machine will yield a better dimensional capability than a sand mould created by hand. Hurst (2006).

There is some tolerance used up in the creation of the pattern as well. The pattern is built expecting that a certain amount of contraction from the pattern to the final part. The correct amount of adjustment, that is, made to the pattern for the alloy being poured can be uncertain due to the part geometry and this can drive to a larger tolerance on the final part. If certain dimensions are critical, a small amount of capability casting, using the production process, can be poured before regular production begins. The size and the weight of the part will determine the tolerance required on specific dimensions.

2.5.4 Surface Roughness and integrity

The finish of a casting will vary greatly depending on the process being used. An investment cast part will yield about a 125μ inch RMS surface, a die cast part about a 64μ inch RMS surface while a sand casting will be around 500μ inch RMS.

Table 2.1: The surface finish of products from various casting processes.

Die casting	20 – 120 RMS
Ceramic investment cast	60 – 200 RMS
Silica investment cast	300 – 560 RMS
Shell mould	120 – 300 RMS
Sand casting	560 – 900 RMS

Source: (Casting Design Guide 1972)

The surface finish in all casting processes can be modified throughout the part by shot or bead blasting if needed. The surface finish will be modified in areas where a gate or riser has been removed. This can be a broken area where the gate was snapped off or ground/cut surface where the gate was removed.

2.5.5 Internal Soundness

The internal soundness of a casting can be important in some applications. But it is very difficult to cast a defect free casting. Determination of the acceptable defect level in a casting is important and over specification of the defect level will lead to high scrap rates and higher casting costs. Jain (2003).

2.5.6 Additional Considerations

In addition to the already outlined factors the following significantly contribute to the quality of products:

(a) The skill and experiences of the castor.

(b) The furnace used to melt the metal.

(c) The type of mould used.

(d) The temperature of the pouring molten metal.

(e) The quality control measurements adopted by the producer.

(f) The kind of testing machines used to verify qualities. (Example, surface finish).

2.6 SOME ADVANTAGES AND DISADVANTAGES OF SAND CASTING

The advantages of sand casting include the following:

i. It is simple, that is, the production process of green sand casting is very simple. Comparatively so easily handled. The materials are simple, and easily available.

ii. Lower production cost because the materials used are simple and its prices are lower comparatively, the production costs of green sand castings are lower. Therefore, the green sand castings are lower. Therefore the green sand castings are cheaper than resin sand casting and shell mould casting.

iii. The production process does not require very high skilled labour force.

iv. It is suitable for few small production rates.

v. The equipment used are cheap and easy to deal with.

vi. Can be used to produce large (very large) casting (that is pit casting in a very large hole in the ground)

vii. The mould material is also reclaimable because between 90 -95% of the sand being used is recycled although new sand and additions are required to make up for the discarded.

viii. Higher production rate. The green sand casting can achieve high production rate. The floor mould can produce castings of 100 – 200 sand boxes each day.

Disadvantages of green sand casting

(i) Green sand mould is a kind of soft mould so it is not hard enough as the resin sand mould and shell mouldings.

(ii) Rough surface finish – The casting surfaces by green sand casting process are very rough and coarse. If the iron foundries use the very fine green sand, the rough surface will be better.

(iii) Bad casting dimensions – Since the green sand will have larger shrinkage, the casting dimensions will have larger changes during moulding and cooling periods. Therefore, the green sand casting process will cause larger dimensional tolerance.

(iv) Unstable casting quality – The temperature has some influence to the casting quality made by the green sand casting process. Therefore, the iron foundries should keep good temperature during moulding and casting.

2.7 SOME CASTING DEFECTS

Defects in casting are undesirable features or imperfections which contribute to a normal quality variation and imperfections are taken as flaws or defects only when they affect the appearance or the satisfactory functioning of the castings and the casting in turn do not come up to the quality and inspection standards being applied. Khanna (1972). Defective castings offer an ever-present problem to the foundry industry. Defective castings account for the normally higher losses incurred by the foundry industry.

Casting defects are usually not accidents, they occur because some steps in the manufacturing cycle do not get properly controlled and somewhere goes wrong. A defect may be the result of a single clearly defined cause or of a combination of factors in which case necessary preventive measures are more observed. Defects found in castings may be divided into three classes:

(a) Defects which can be noticed on visual examination or measurement of the casting

(b) Defect which exist under the surface and are revealed by machining, sectioning or radiography.

(c) Material defects discovered by mechanical testing (tensile, bending, impact, etc) of the casting.

Under-listed are some common defects with green sand casting:

i. Shrinkage – This is a depression or vacancy typically internal to the casting that is caused by a molten island of material that does not get enough feed to supply it. Liquids contract on freezing because of re-arrangement of atoms from open "randomly-packed" structure to a regular "densely packed structure. (Rashid A K M B – 2010)

ii. Shrinkage cavities are characterised by a rough, dendritic, interior surface. The possible causes of shrinkage are: volume contraction of the metal, either from liquid contraction of the melt or from contraction from phase change from liquid to solid. Insufficient feed metal in defects areas. Gating feeding system and part design creates locally hot areas with the casting that are not fed well.

iii. Porosity is a void in the casting that is characterised by smooth interior walls that are shiny or in the case of iron, are covered with a thin layer of graphite. These voids can appear in one cavity or several small cavities dispersed throughout the casting.

The possible causes may include:

- A large amount of mould or core gas with insufficient evacuation from the mould cavity.

- Entrainment of air due to turbulence in the gating system.
- Excessive gas content in melt.

In the case of steel and irons, formation of carbon monoxide by the reaction of carbon with oxygen present in the melt.

(i) Inclusions are a piece of foreign material in the cast part. An inclusion can be a metallic inter-metallic or non metallic piece of material in the metal matrix. The possible causes include: charge materials which have not been completely dissolved in the melt. Exposed core wires or rods. Loose sand in the mould.

(ii) Tears and cracks are linear separations or cuts in a casting due to stresses set up in the mould during solidification and cooling.
Sackey & Amoakohene (1996).

(iii) Voids are depressions formed in a casting because of trapped air in the molten metal.

(iv) Pouring metal defects include misruns, cold shots and inclusions. A misrun occurs when the liquid metal does not completely fill the mould cavity, leaving an unfilled portion. Cold shot occur when two fronts of liquid metal do not fuse properly in the mould cavity leaving a weak spot. Both are caused by either a lack of fluidity in the molten metal or cross sections that are too narrow. Misruns and cold shots are closely related and both involve the material freezing before it completely fills the mould cavity.

(v) Metallurgical defects include hot tears and hot spots. Hot tears, also known as hot cracking are failures in the casting that occurs as the casting cools. This happens because the metal is weak when it is hot and the residual stresses in the material can cause the casting to fail as it cools.

Hot spots areas on the surface of casting that become very hard because they cooled more quickly than the surrounding material. This type of defect can be avoided by proper cooling practices or by changing the composition of the metal.

According to Aquandah (www.ghanaculture.gov.gh retrieved 27/7/2012) a society that lacks technological infrastructure or the resources for creating one and depends on imported technology runs a great risk of sudden decline and collapse if the external sources for providing technology are cut off. Technological production is based not only on inherited know-how ingenuity and craftsmanship but also on types of raw material available from the local environment or external sources, raw materials such as different types of stone, clay, sand, wood, glass, metal, plant parts and animal parts.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Introduction

The purpose of this chapter was to present the technological and scientific assumptions underpinning this research as well as to introduce the research strategy and the empirical techniques applied. A limitation of the research design situates the research amongst existing research traditions in information systems. The chapter also looked at the target population, sampling and sampling techniques, methods of selection, the sample test process the study and how the results were analysed and the interpretation of the data.

3.1 Research Design

The study primarily looked at the quality of locally manufactured milling plates for corn mills produced by artisans in Suame – Magazine in Kumasi and its environs. A comparative study between locally produced milling plates and that of foreign ones (from India) have been carried out through testing to determine their hardness, microstructure and chemical composition.

As stated earlier on, under the statement of the problem, the purpose of the study is to create better understanding of the interplay between the process and procedures which culminate in the development of high quality locally manufactured milling plates for corn mills.

3.2 Population

The term population refers to the complete set of individuals (subjects) or events having common observable characteristics in which the researcher is interested. According to Yaw Adu-Gyamfi et al (2010) who wrote about Suame Magazine Industrial Development Organisation (SMIDO) said Suame Magazine is located in Kumasi, Ghana's second largest city, Suame Magazine is an industrial cluster focusing on vehicle repairs and metal working.

The location of Suame Magazine is shown on the map in fig. 3.5

The formation of the cluster started in 1930s and 1940s around the former armouries but moved to its present location in the 1950s and 1960s.

The Intermediate Technology Transfer Unit (ITTU) developed by Kwame Nkrumah University of Science and Technology introduced new technology and machine tools, encouraged a move from repairs to manufacturing, and iron foundry, etc.

Suame Magazine covers an area approximately 1.8km long and 0.3km wide and has approximately 200,000 people working at 12,000 small informal enterprises.(Yaw Adu-Gyamfi 2010).

The make-up of the Suame Magazine cluster include vehicle repairers, metal processors, spare parts vendors, fabricators, vehicle assemblers, foundry workers and blacksmiths.

Fig 3.1(a) A typical foundry at Suame Magazine

Fig 3.1(b) Metal processing and a retail shop for the sale of machine lubricants.

Source (Suame Magazine Industrial Development Organisation (SMIDO) by Messrs Adu Gyamfi et al)

3.3 Materials

Three local and two foreign-produced corn mill plates were procured from a foundry shop at Suame magazine, in the Kumasi metropolis for quality assessment. The foreign corn mill plates were produced in India. The samples were labelled L1, L2, L3, and F1, F2 for the local and the foreign corn mill plates, respectively.

3.4 Sample Preparation

Specimens of dimension 12 mm x 17 mm x 8.5 mm were cut from the bulk material for testing using diamond cutter. Cutting was done under coolant to minimise heat generation which could affect the microstructure of the mill plates and hence the hardness values. For each testing method (that is chemical, microstructure and hardness), three specimens were prepared making a total of nine specimens. Specimens were ground, and machined to the required dimensions before polishing.

3.4.1 Grinding

The samples were ground using SiC emery cloth of different grit sizes on "Labpol Duo 8 twin disc" mechanical grinding/polishing machine at the Materials Testing Laboratory in the Physics Department of Kwame Nkrumah University of Science and Technology (KNUST), Kumasi. This operation was aimed at producing a surface that is flat, smooth, and free from surface contaminations. The specimens were ground on a series of silicon carbide papers of increasing fineness from 150, 240, 300, 400, 600 800, 1000 to 1200 grits, respectively. This grading enabled the specimen to be ground using coarser paper first, which allowed for a more effective removal of the surface contaminants and as the specimen moved from one grade of cloth to the other, it is rotated through 90 degrees to allow for the removal of scratch lines done on the surface by the first grade of grinding cloth. This process was well flushed with running water to wash away the debris/metal particles which was capable of being embedded at the surface of the specimen. Each sample was thoroughly cleaned after each grinding step to avoid any leftover of abrasive particles carried over to the next fine abrasive grinding step. This procedure was continued until a fine, flat and smooth surface was obtained.

3.4.2 Polishing

Fine scratches were removed from the surface of the specimen with the aid of a "Labpol Duo 8 twin disc" mechanical polishing machine at the Materials Testing Laboratory in the Physics Department of KNUST, Kumasi. The surface of the specimen was held lightly on a horizontally rotating polishing disc covered with "Selvyt" polishing cloth.A 1 μm alumina slurry as polishing agents. The polishing agent was applied to the selvyt cloth while the specimens were being polished. By careful adjustment of hand pressure a highly polished surface (i.e. mirror like shining surfaces) free from scratches were produced.

3.4.3 Etching

After polishing, the specimen was washed with water and the samples were etched using 2% nital(2% concentrated Nitric acid in methanol solution). This was done to reveal the microstructure of the mill plates.

Fig. 3.2 Labpol Duo and Twin disc machine for polishing samples for testing (enlarged). 20th September 2012. Source: Physics Department – KNUST, Kumasi.

3.5 Microscopy

The microstructure of the specimens were observed using optical microscope (Lecia DM 1000) attached to a computer and camera at the Materials Testing Laboratory in the Physics Department of KNUST, Kumasi. The test was carried out on the 20th of September 2012.

Fig. 3.3 Lecia DM 1000 Machine for checking microstructure of samples (enlarged).
Source: Physics Department – KNUST, Kumasi.

3.6 Chemical Analysis

The chemical compositions of the corn mill plates were determined using an Emission Mass Spectrometer (Angstrom V 960) at Quality Control Laboratory at the Tema Steel Company Limited which displays the percentages of all elements in the sample.

3.7 Hardness Testing

The hardness tests were done using the Leeb Hardness Tester MH180 which is capable of automatically converting values from one scale to the other. The test was carried out at the Materials Engineering Department of KNUST supervised by Mr. Felix Ati of Materials Engineering Department of KNUST. The test was carried out on the 16th of October, 2012.

Fig. 3.4 Map of Ghana

Source – Suame Magazine Industrial Development Organisation (SMIDO) by Mrs. Adu Gyamfi et al.

Fig. 3.5 Map of Kumasi Metropolitan Area.

Source – Suame Magazine Industrial Development Organisation (SMIDO) by Mrs. Adu Gyamfi et al.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Introduction

The chapter evaluates the results obtained by comparing the qualities such as microstructure, chemical analysis and hardness of three locally produced milling plates and two foreign milling plates.

4.1 Chemical Compositions

Two foreign and three locally produced milling plates were investigated. The chemical composition of the investigated mill plates are shown in Table 4.1. The chemical analyses indicate that both the local and foreign mill plates investigated can be considered as unalloyed cast iron. The main elements in unalloyed cast iron are carbon, manganese, phosphorus, sulphur, and silicon. The other elements such as chromium, copper and nickel are considered as impurities in unalloyed cast iron. Callister, (2000). It is observed that with exception of silicon, the locally produced mill plates generally had higher contents of the major elements than their foreign counterparts. To effectively analyse the effect of the chemical composition on the casting process, microstructure and properties of the cast iron mill plates, there is the need to calculate the carbon equivalents for the different materials investigated. This is because the type and properties of cast iron depends on the amount of carbon in the iron (Leslie and Hornbogen, 1996). The carbon can exist either in the free form as graphite or in combined form as cementite, Fe_3C. Cementite is the harder phase compared to graphite and thus improves the wear resistance property of the material. The carbon equivalents (CE%) can be calculated using the following equation (Glicksman, 2011);

$$CE(\%) = C\% + 0.33Si\% + 0.33P\%$$

The CEs for samples F1, F2, L1, L2, and L3 are 3.62, 3.61, 3.60, 3.70, and 3.73, respectively. It has been reported that when casting unalloyed cast iron, a low value of CE and high cooling rate would result in the formation of white cast iron whereas a low cooling rate and high CE promotes grey cast iron formation. Additionally, as the CE increases, less shrinkage is observed. When white cast iron is produced, the material becomes harder than grey cast iron due to the presence of cementite (Fe_3C) in the former. The later contains primarily carbon in the form of graphite which is soft and therefore makes the material less hard (Callister, 2000).

The cooling rates used for the investigated mill plates are not known. However, under the same conditions, the tendencies to form white cast iron for the investigated materials are L1, F2, F1, L2 and L3, respectively. Thus the locally produced mill plates would have high probability to form grey cast iron compared to their foreign counterparts due to the relatively higher CE values.

Table 4.1: Chemical composition of foreign (F) and locally (L) produced mill plates

Sample	C	Mn	P	S	Si	Cu	Ni	Cr	V	Fe
F1	3.37	0.26	0.18	0.21	0.59	0.03	0.01	0.02	0.01	Bal
F2	3.33	0.18	0.18	0.11	0.67	0.03	0.01	0.02	0.01	Bal
L1	3.35	0.24	0.27	0.20	0.48	0.15	0.06	0.33	0.03	Bal
L2	3.44	0.27	0.23	0.16	0.56	0.13	0.03	0.26	0.02	Bal
L3	3.48	0.25	0.27	0.20	0.50	0.15	0.06	0.33	0.03	Bal

The silicon contents were higher in the foreign than locally produced mill plates. Higher silicon content could promote graphitization of cementite into carbon and iron (Callister, 2000; Glicksman, 2011). The stability of cementite phases in cast iron also depends on the manganese/sulphur ratio in the material. High concentration of manganese promotes formation of cementite phases whilst high concentration of sulphur would stabilize cementite promoting formation of white cast iron Reeley (2001). The dynamic effect of these two elements in cast iron is usually investigated by calculating the Mn:S ratio. According to Reeley (2001) at Mn:S ratio less than 1.7, sulphur would stabilize cementite promoting formation of white cast iron. The Mn:S ratio for samples F1, F2, L1, L2, and L3 are 1.23, 1.64, 1.20, 1.69, and 1.25, respectively. The calculated ratios indicate that sulphur would stabilize cementite to promote formation of white cast iron. However, the formation of the cementite phases, as mentioned earlier, would depend on the value of CE, which indicates that the foreign mill plates have higher tendency to form white cast iron than the locally produced mill plates.

4.2 Microstructure and Hardness Analyses

Figure 4.1 shows the optical images of the investigated materials. Additional images are provided under Appendix A. Three phases can be identified in all the micrographs: cementite (white), pearlite (black), and ferrite (grey) phases. The fractions of cementite phases were slightly higher in locally produced mill plates than their foreign counterparts. This is due to the relatively higher carbon equivalents in the locally produced mill plates promoting the formation of more cementite phases. It could also be observed that the grey phases (ferrite) were high in foreign mill plates. This is due to the higher silicon content which caused graphitization of the cementite into carbon and iron (Hume-Rothery, 1966). Graphite (carbon) phases could be observed in the foreign mill plates at higher magnification (see Appendix A).

Figure 4.2 shows the hardness values of investigated samples. Hardness values were recorded against the Rockwell C scale. It was observed that locally produced mill plates had higher hardness values than their foreign counterparts. The average hardness values of samples F1, F2, L1, L2, and L3 are respectively 37.0, 39.5, 41.5, 40.0, and 42.0 HRC. Sample L2 had lower hardness value than L1 and L3 due to the relatively bigger grain sizes. The smaller the grain sizes of a material, the harder the material (Callister, 2000). The high values measured for the locally produced mill plates are due to the high cementite volume fractions and the absence of ductile graphite phases in the investigated samples (Callister, 2000, Reeley, 2001). Additionally, the relatively high alloying elements like chromium in the locally produced mill plates improved the hardness by forming chromium carbides during casting process (ASM International, 2004).

For wear resistant materials, high hardness value is required (ASM International, 2004). There is also a correlation between hardness and wear rate in that wear rate increases with decreasing hardness of corn mill plates (Kwofie and Chandler, 2006). Thus it can be deduced that the locally produced mill plates investigated in this work would have better wear resistance than the foreign produced mill plates. Earlier work done by Kwofie and Chandler (2006) suggested that mill plates produced locally had poor wear resistance compared to their foreign counterparts. They reported that the locally produced mill plate wears 3 to 10 times faster than the foreign plates. It should be mentioned here that the chemical composition of the mill plates investigated were different. The foreign mill plates (produced from United Kingdom) investigated were white cast iron whereas the local ones were grey cast iron. Additionally, the alloying elements were found to be higher in the foreign than the local ones. In this work, the locally produced mill plates have been found to be white cast iron and the foreign grey cast iron due to the graphitization of the cementite due to the high silicon contents in the foreign mill plates. Thus improvement in the hardness and therefore wear property could be achieved by controlling the chemical composition of the cast iron mill plates.

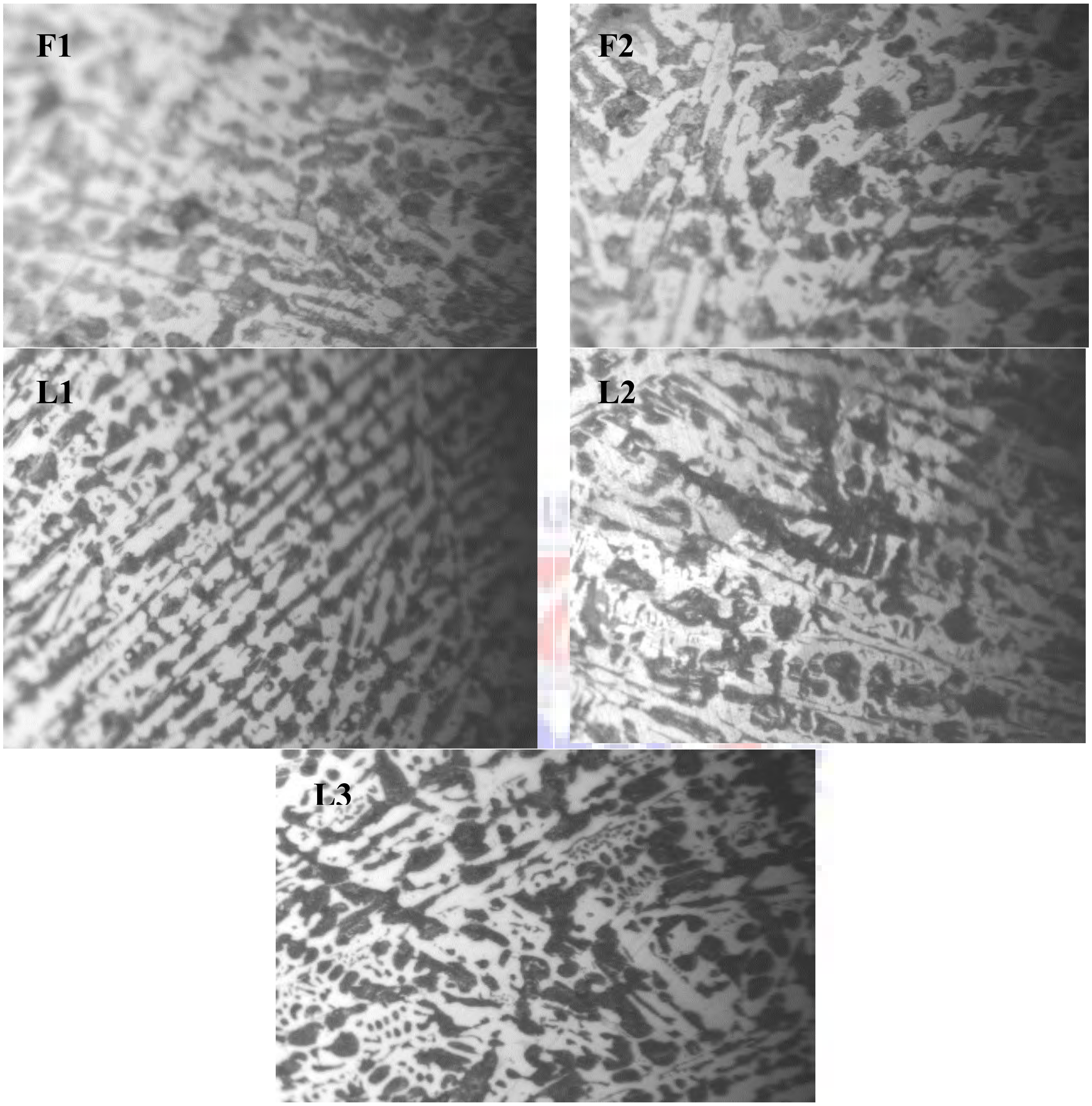

Figure 4.1: Optical images of investigated cast iron mill plates showing cementite (white), pearlite (black) and ferrite (grey) phases (200X magnification, nital etched)

Source: Physics Department – KNUST Kumasi.   .

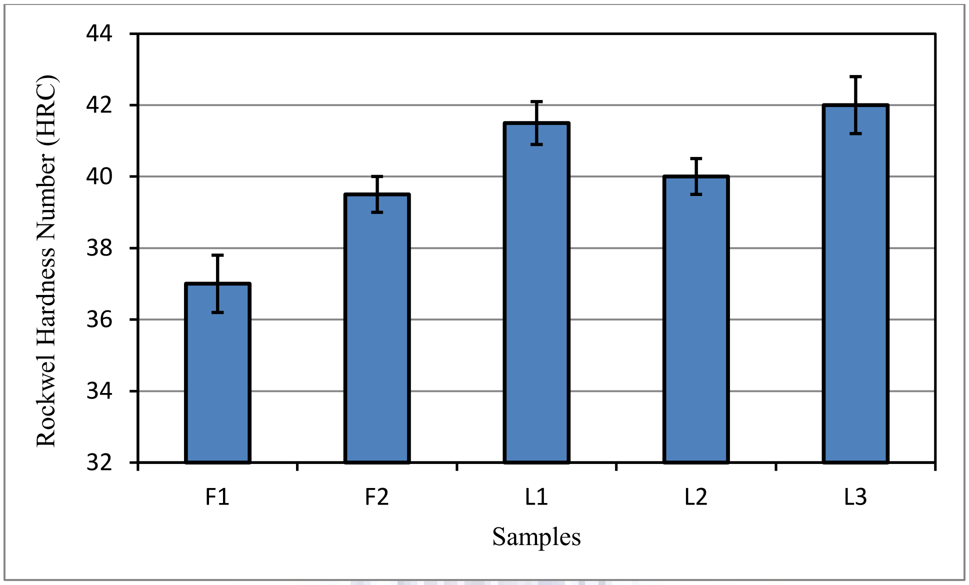

Figure 4.2: Micro hardness values of investigated samples.
Source: Physics Department – KNUST Kumasi.

4.3 Summary

The quality of mill plates is mainly dependant on the chemical composition and casting process. In this work, it has been observed that the quality of the locally produced mill plates, measured in terms of chemical composition and hardness values, is better than their foreign counterparts. This is contrary to what has been found by Kwofie and Chandler (2006). The reason for this disparity could be attributed to the varied quality of both locally- and foreign-produced mill plates on the market. Additionally, the quality of the locally produced corn mill plates varies even for samples selected from the same foundry shop. One reason that could be attributed to this is the uncontrolled charging of raw materials into the furnaces, especially in the local foundry shops. This leads to varied chemical composition in the finished cast product and hence varied quality.

CHAPTER FIVE

SUMMARY AND CONCLUSIONS

5.0 Introduction

This concluding chapter will consider the following: summary of the results obtained from the tested samples, conclusions, recommendations and suggestions for further research work.

5.1 Summary

The overriding purpose of this study was to do a comparative, quality analysis of locally produced corn mill grinding plates by artisans at Suame – Magazine in Kumasi and that of the imported (foreign) ones, specifically from India. To accomplish that goal, it became necessary to reach some prerequisite goals by having to procure some locally produced milling (grinding) plates for corn mills by artisans at Suame – Magazine in Kumasi and some foreign corn mill plates from India sold in Ghana.

During the literature review, an extensive review has been made on the various methods of casting and the technologies that are applied because these have greater influence on the qualities of a final cast product. Related to that effort, a number of tests which included chemical analysis, microstructure and hardness were conducted on both the local plates as well as the foreign ones at the Physics Department, KNUST- Kumasi.

5.2. Conclusions

The tests on the chemical composition of both local and foreign mill plates were considered unalloyed cast iron with all of them containing carbon, manganese, phosphorus, sulphur and silicon. The other elements such as chromium, copper and nickel are considered as impurities (Callister 2000).

It was observed that with the exception of silicon, the locally produced milling plates had higher contents of the major elements than the foreign ones from India.

In order to effectively analyse the effect of the chemical composition on the casting process, micro-structure and properties of the cast iron mill plates, the carbon equivalents (CEs) of the various investigated mill plates have been calculated because the properties of cast iron depends on the amount of carbon in the iron (Leslie and Hombogen, 1996) or in combined form as cementite. Cementite is the harder phase compared to graphite and the cementite tends to improve upon the wear resistance of the material.

The rates of cooling used for the investigated materials were not known but under the same conditions, it was observed that the tendency to form white cast iron in order of ascendancy were L_1, F_2, F_1, L_2 and L_3 indicating that the local mill plates had higher probability to form gray cast iron than their foreign counterparts and this was attributed to the higher carbon equivalents (CEs) values.

On the other hand, the silicon contents were observed to be higher in the foreign mill plates than their local counterparts. The manganese – sulphur ratios which were calculated pointed to the fact that the foreign mill plates had the tendency to form white cast iron than the local counterparts.

The microstructure and the hardness analyses of the investigated mill plates showed some micrographs phases which were cementite (white), pearlite (black) and ferrite (grey). The local mill plates had the cementite phases slightly higher due to the higher carbon equivalents (CEs) mentioned earlier.

The foreign mill plates had higher ferrite (grey) phases due to the higher concentration of silicon which promotes graphitisation of the cementite into carbon and iron.

The hardness values obtained using the Rockwell C scale indicated that the local mill plates were harder than the foreign mill plates due to the higher cementite volume fractions. Additionally, the relatively high alloying elements such as chromium improved the hardness by forming chromium carbides during casting process.

According to Kwofie and Chandler (2006), mill plates produced locally had poor wear rates compared to the foreign mill plates but the results obtained from the various analyses that have been made pointed to the contrary. There is a correlation between hardness and wear rates, that is, the higher the hardness, the lower the wear rates and vice versa. Therefore, once the local mill plates were observed to be harder than the foreign mill plates, it was concluded that the local mill plates had a better wear resistance than the foreign ones from India. The work which was done by Kwofie and Chandler (2006) compared foreign mill plates from the United Kingdom and they were white cast iron as against those from India which have been used in this research.

The quality of mill plates is dependent on the chemical composition and the casting process used, therefore, the contrary results to Kwofi and Chandler (2006) could be attributed to the varied qualities of both locally and foreign mill plates even with samples selected from the same foundry shop.

Another reason for the varied qualities of mill plates from the same foundry shop could be due to the uncontrolled charging of raw materials into the furnaces, especially in the local foundry shops.

CHAPTER SIX

RECOMMENDATIONS AND SUGGESTIONS

6.0 Introduction

This chapter gives an account of the recommendations and suggestions that will contribute to the production of high quality corn mill grinding plates by artisans at Suame Magazine in Kumasi.

6.1 Recommendations

The following recommendations are offered for foundry work most especially casting of mill plates:

1. The original intention of setting up ITTU was to give capacity building to artisans and that should be revived and occasionally organize workshops for those in the industry to improve upon the quality of their product.
2. Considering the advancement of technology in the area of , artisans should encouraged to employ modern technologies in casting.
3. There have been plans by successive governments of Ghana to make Suame Magazine, the manufacturing hub of Ghana, hence those who are into casting should be given some financial assistance to upgrade the furnace and equipment used in the industry this is because manufacturing revolves around casting.
4. The managers of the city of Kumasi should designate an area purposely for sitting of foundries to improve upon the working environment instead of the present situation where the foundries are dotted around the Suame Magazine industrial area. .

6.2 Suggestions for Further Studies

1. The research sought to compare the qualities of locally produced corn mill grinding plates by artisans at Suame Magazine in Kumasi and those that are imported from India. Three (3) locally produced corn mill grinding plates and two (2) foreign (from India) were used for the study. In the light of the limited scope of the study, the findings cannot be generalised to be a reflection of all locally produced corn mill grinding plates by artisans at Suame Magazine in Kumasi and those that are imported from India. To implicate this study, a larger population of locally produced corn mill grinding plates as well as the imported ones from India should be used.
2. Studies could be conducted into the surface finish of the locally produced plates which makes them not look attractive by visual inspection as compared to the foreign (imported) ones from India.
3. The surface finish of local mill plates do not look attractive hence the general perception that the local mill plates are not durable. This is due to the rough type of sand which is used to prepare the mould thus making the surface very rough. The surface roughness does not allow the surface serration to be very visible.
4. The charging of raw materials into the furnace should be carefully sorted to ensure that only cast iron is used in casting mill plates. The proper sorting of materials will help in the measure of the correct proportions that can be used to produce a more durable cast plate.
5. It is expected that for some few years to come and with the use of modern technology, the local mill plates will be able to stand toe to toe with their foreign counterparts and this would eventually conserve foreign exchange. This expectation will become real if the

government of Ghana makes a deliberate policy to invest heavily in helping the players in the industry to acquire modern foundry equipment and be trained on how to use them in the production process.

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APPENDIX A

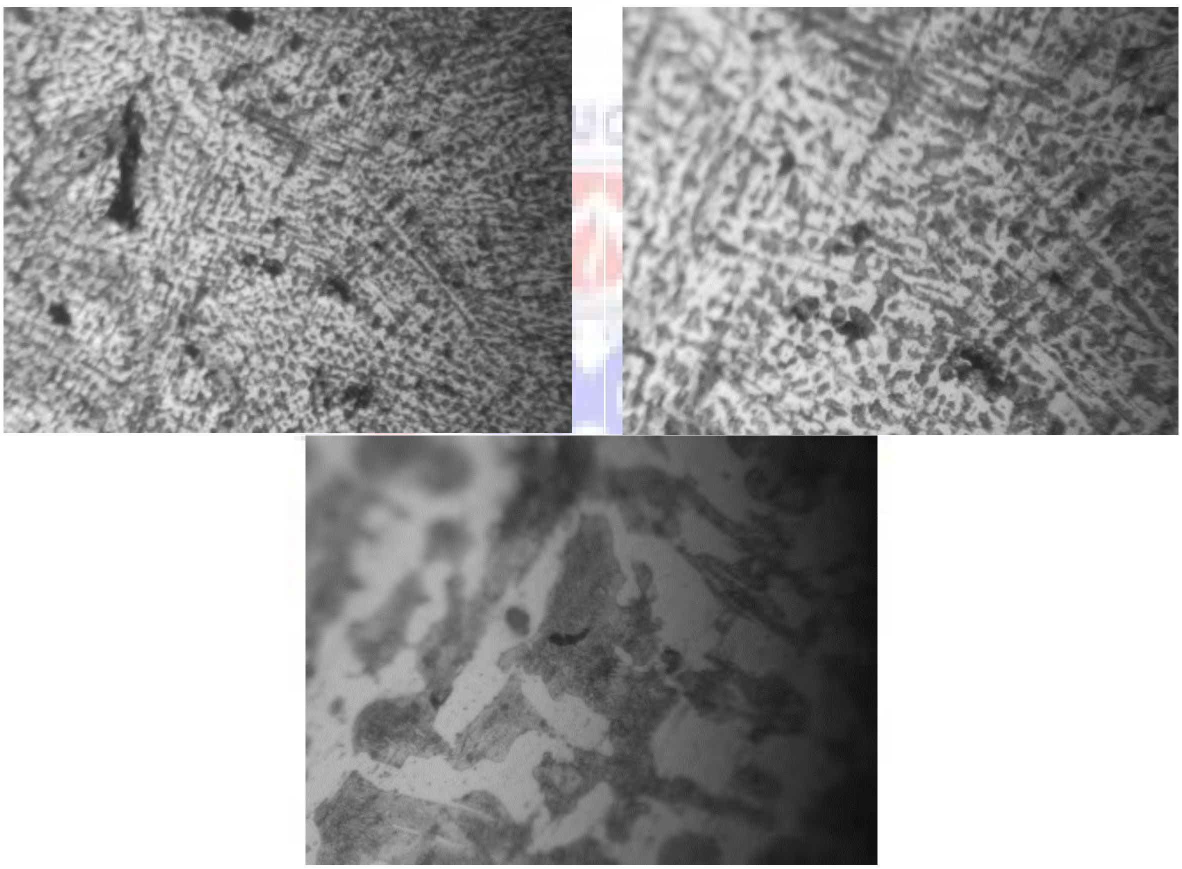

Figure A1: Optical images of sample F1

Source: KNUST – Physics Department (15/10/2012)

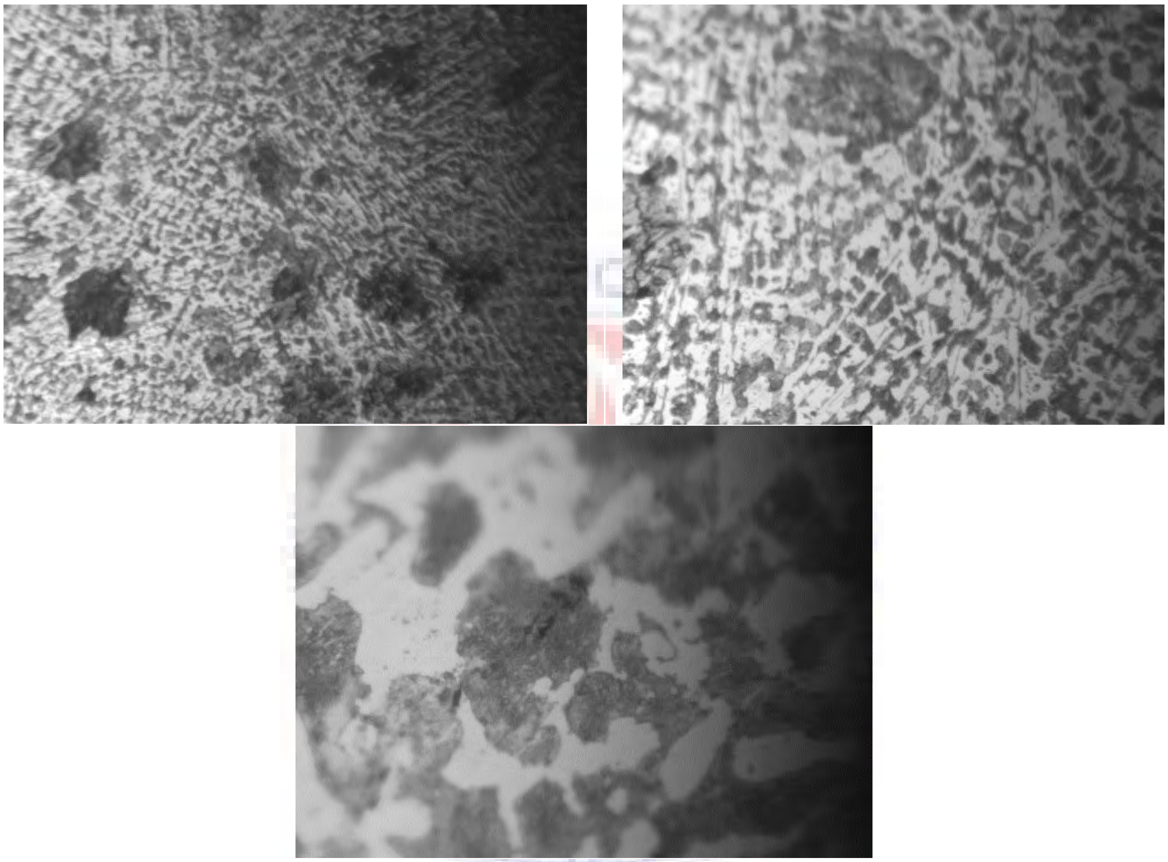

Figure A2: Optical images of sample F2

Source: KNUST – Physics Department (15/10/2012)

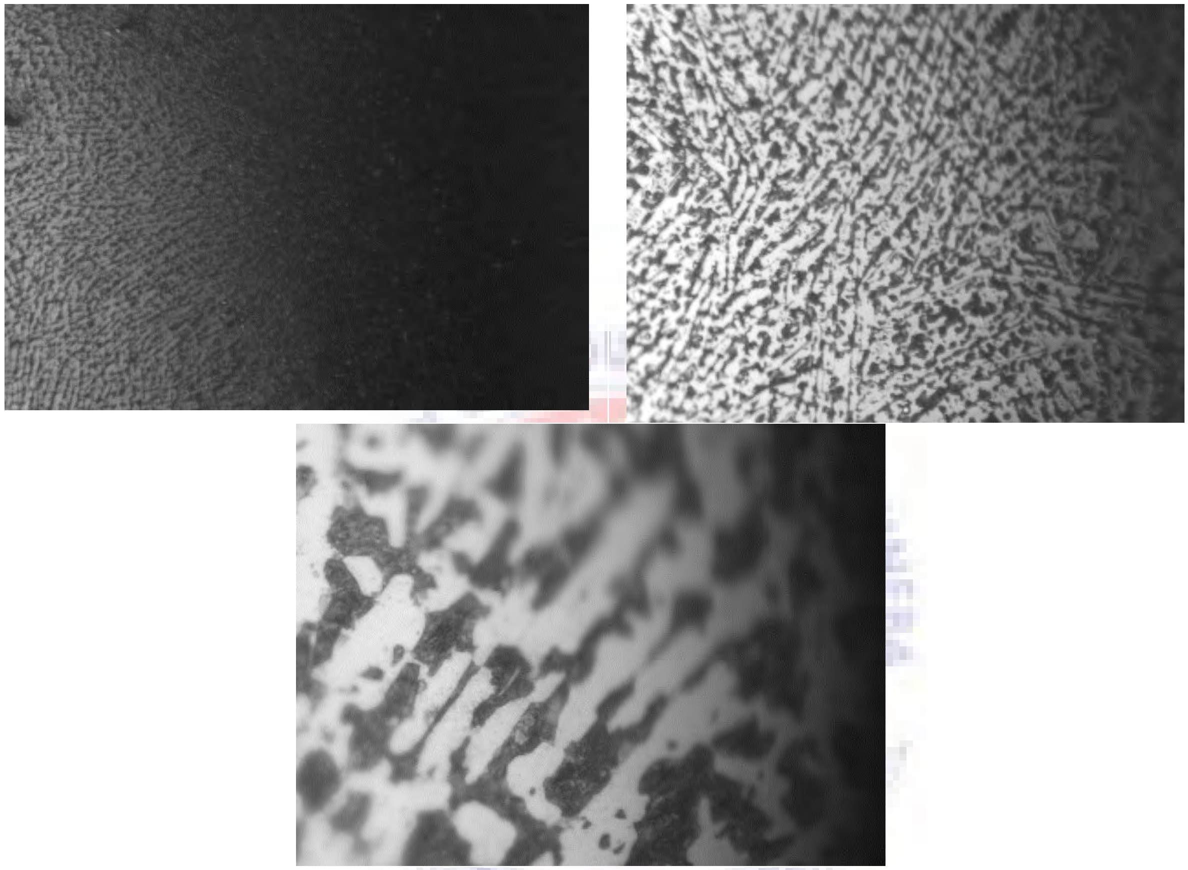

Figure A3: Optical images of sample L1

Source: KNUST – Physics Department (15/10/2012)

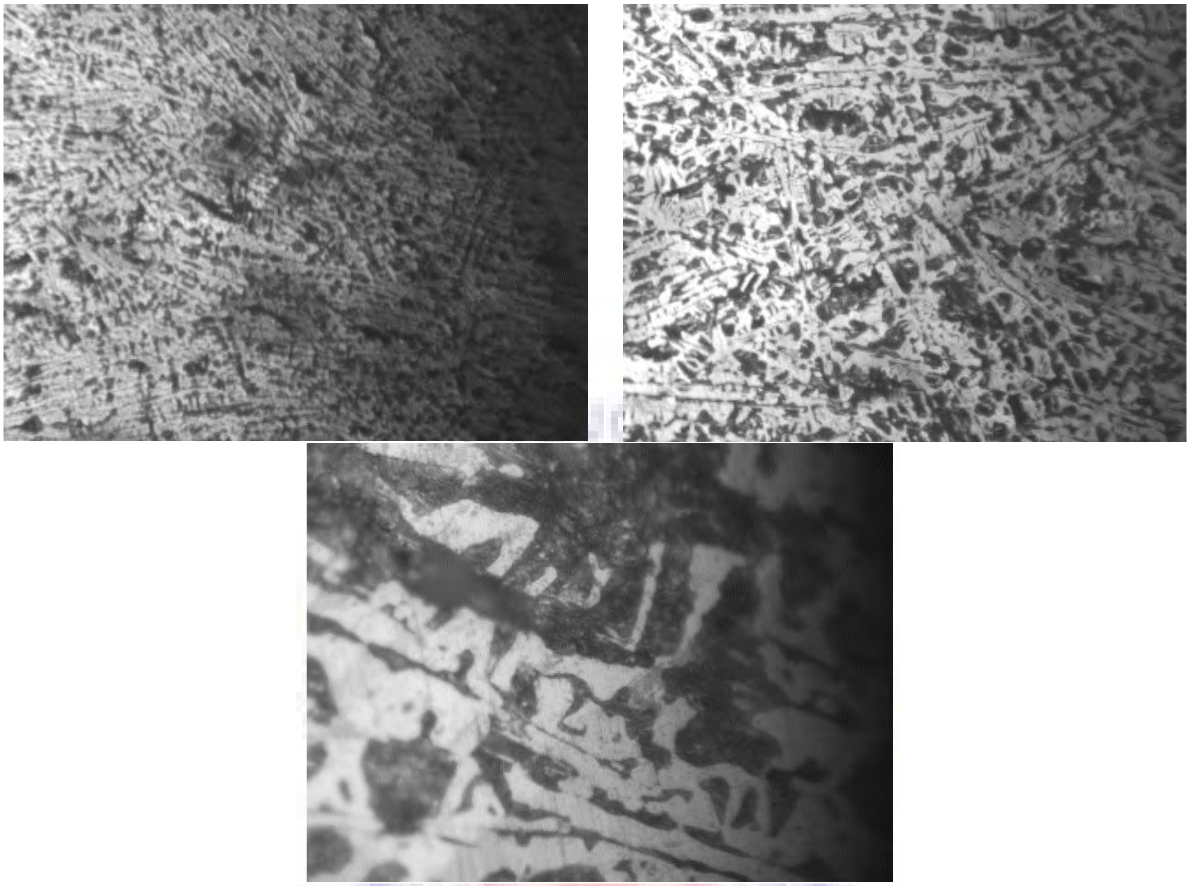

Figure A4: Optical images of sample L2

Source: KNUST – Physics Department (15/10/2012)

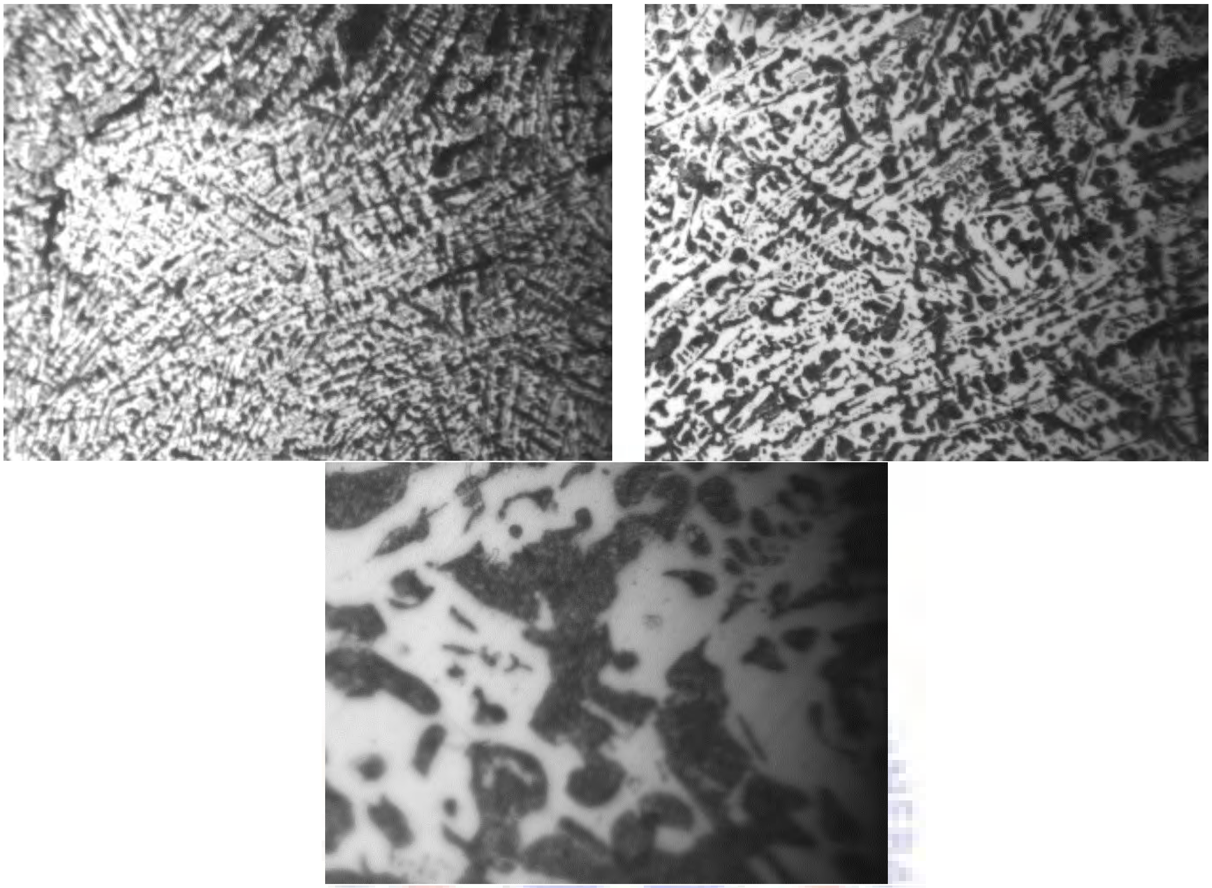

Figure A5: Optical images of sample L3

Source: KNUST – Physics Department (15/10/2012)