INVESTIGATION OF DUCTILE IRON 'SANDWICH' TREATMENT PROCESS PARAMETER

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Thesis submitted in fulfillment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering with Manufacturing Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

NOVEMBER 2009

UNIVERSITI MALAYSIA PAHANG

FACULTY OF MECHANICAL ENGINEERING

We certify that the project entitled "Investigation of ductile iron 'Sandwich' treatment process parameter "is written by Md Fakhrurazi bin Abdul Halil. We have examined the final copy of this project and in our opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering. We herewith recommend that it be accepted in partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering *with Manufacturing Engineering.

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STUDENT DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

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To my Beloved Mother and Father

BESAH BINTI KAPI
ABDUL HALIL BIN ABD MAJID

ACKNOWLEDGEMENTS

I would like to acknowledge and extend our heartfelt gratitude to my supervisor Mr. Mohd Rashidi Bin Maarof. Lecturer of Faculty Mechanical Engineering for his continues support, helpful advice and valuable guidance throughout my thesis. This thesis could not have been done without Mr. Mohd Rashidi Bin Maarof who not only served as my supervisor but also encouraged and guide me through the writing up thesis process by giving his best effort. I also wish to express my sincere appreciate to the lecturers, technical staffs of Faculty Mechanical Engineering, University Malaysia Pahang for their teaching and help during the period of the project.

I also wish to express sincere appreciation to all my friends for their advice to do the study. I benefited greatly from the comments and wisdom these reviewers generously shared with me.

Most importantly, I would like to thank to my family especially my parents, Mrs. Besah Binti Kapi and Mr. Abdul Halil Bin Abd Majid, have guided me throughout my life. They have always sacrifices their time and continuous support me to achieve my dreams and goals. I would like to thank them for all support and encouragement they done for me. Besides that I also want to express my appreciation to my family. I truly could not have done my thesis without them.

ABSTRACT

This thesis deals with ductile iron parameter. There are two main objectives of this research, firstly, to investigate the processing parameter of ductile iron by using Sandwich method and to investigate the process design parameter for ductile iron.The cast iron has graphite in a matrix called pearlitic. The graphite shape is flake which is has lower strength. The study of graphite changes from flake form to nodular form by adding magnesium ferrosilicon as inoculation agent is under consideration. The ductile iron form is enhanced in strength and other mechanical properties. However, the size related to the composition of the magnesium adding. Green sand casting is one of the method for converting cast iron to ductile iron. The thesis describes the method of green sand casting by using Sandwich technique to get the ductile iron sample. From the sample, the hardness test and composition of element is checked to determine the effect and mechanical properties of different sizes ductile iron.

ABSTRAK

Tesis ini membentangkan tentang parameter besi mulur.Terdapat dua tujuan utama dalam kajian ini,pertama,untuk menyiasat aturan parameter besi mulur menggunakan kaedah Terapit dan untuk menyiasat aturan corak parameter untuk dinding besi mulur.Besi tuang mempunyai grafit di dalam matrik yang di panggil pearlitik.Bentuk grafit adalah emping yang mempunyai kekuatan yang rendah.Kajian tentang perubahan grafit dari bentuk emping ke bentuk bintil dengan menambahkan magnesium ferosilikon sebagai ejen inokulasi adalah dalam perkiraan.Bentuk besi mulur diperkayakan kekuatan dan sifat-sifat mekanikal lain.Walaubagaimanapun, siaz setiap besi mulur berkait dengan komposisi magnesium yang ditambah.Teracuan pasir hijau adalah salah satu kaedah untuk menukarkan besi tuang ke besi mulur.Tesis ini turut membincangkan kaedah teracuan pasir hijau dengan menggunakan kaedah Terapit untuk mendapatkan sampel dinding nipis besi mulur.Daripada sampel,ujian kekerasan dan pemeriksaan komposisi bahan untuk menentukan kesan dan sifat-sifat mekanikal dijalankan ke atas besi mulur yang mempunyai saiz yang berbeza.

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LIST OF ABBREVIATIONS

Al	Aluminum
Ba	Barium
BCIRA	British Cast Iron Research Association
BHN	Brinell Hardness Number
BID	Brinell Indentation Diameter
C	Carbon
Ca	Calsium
EDX	Energy Dispersive X-ray
Fe	Ferum
FeTi	Ferrotitanium
Si	Silicon
LCD	Liquid Crystal Display
Mg	Magnesium
MgFeSi	Magnesium Ferrosilicon
MgS	Magnesium Sulphide
S	Sulphur
SEM	Scanning Electron Microscope
Sr	Strontium
Ti	Titanium
TiFeSi	Titanium Ferrosilicon
Zr	Zirconium

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Iron is a chemical element with the symbol Fe (ferrum) and atomic number 26. Iron and iron alloys (steels) are by far the most common metals and the most common ferromagnetic materials in everyday use. Fresh iron surfaces are lustrous and silvery-grey in color, but oxidize in air to form a red or brown coating of ferrous oxide or rust. Compared with steel which has a hardness of about 140 Brinell, pure iron is soft, about 80 Brinell. Iron is the most abundant element in the core of red giants, and is the most abundant metal in iron meteorites and in the dense metal cores of planets such as Earth.

1.2 TYPE OF IRON

There are many kind of iron in the world and every iron has differences properties and microstructure. For example pig iron, Pig iron is the intermediate product of smelting iron ore with coke, usually with limestone as a flux. Pig iron has very high carbon content, typically 3.5–4.5%, which makes it very brittle and not useful directly as a material except for limited applications. The Chinese were making pig iron by the later Zhou Dynasty (1122–256 BC). In Europe, the process did not become common until the 14th century. Pig iron can also be used to produce cast iron. This is achieved by re-melting pig iron, often along with substantial quantities of scrap iron, and removing undesirable contaminants, adding alloys, and adjusting the carbon content. Another common example is cast iron.

Cast iron usually refers to grey cast iron, but also identifies a large group of ferrous alloys, which solidify with a eutectic. The color of a fractured surface can be used to identify an alloy. There are varieties of cast iron and for example White cast iron which is named after its white surface when fractured due to its carbide impurities which allow cracks to pass straight through and same goes to Grey cast iron which is named after its grey fractured surface, which occurs because the graphitic flakes deflect a passing crack and initiate countless new cracks as the material breaks. Iron (Fe) accounts for more than 95 %wt of the alloy material, while the main alloying elements are carbon (C) and silicon (Si). The amount of carbon in cast irons is 2.1-4 %wt. Cast irons contain appreciable amounts of silicon, normally 1-3 %wt, and consequently these alloys should be considered ternary Fe-C-Si alloys. Since cast iron has nearly this composition, its melting temperature of 1150 to 1200 °C is about 300 °C lower than the melting point of pure iron. Cast iron tends to be brittle, except for malleable cast irons. With its low melting point, good fluidity, castability , excellent machinability, resistance to deformation, and wear resistance, cast irons have become an engineering material with a wide range of applications, including pipes, machine and car parts, such as cylinder heads, blocks, and gearbox cases. It is resistant to destruction and weakening by oxidization (rust).

Figure 1.1: microstructure of cast iron (flake shape)

Source: Smith, W.F and Hashemi,J. 2006

As mention before, malleable iron starts as a white iron casting, that is then heat treated at about 900 °C. Graphite separates out much more slowly in this case, so that surface tension has time to form it into spheroidal particles rather than flakes. Due to their lower aspect ratio, spheroids are relatively short and far from one another, and have a lower cross section vis-a-vis a propagating crack or phonon. They also have blunt boundaries, as opposed to flakes, which alleviates the stress concentration problems faced by grey cast iron. In general, the properties of malleable cast iron are more like mild steel. There is a limit to how large a part can be cast in malleable iron, since it is made from white cast iron.

Wrought iron is commercially pure iron. In contrast to steel, it has very low carbon content. It is a fibrous material due to the slag inclusions (a normal constituent). This is also what gives it a "grain" resembling wood, which is visible when it is etched or bent to the point of failure. Wrought iron is tough, malleable, ductile and easily welded. Items traditionally produced from wrought iron include rivets, nails chains, railway couplings, water and steam pipes, nuts, bolts, horseshoes, handrails, straps for timber roof trusses, and ornamental ironwork. By the way, Wrought iron is no longer produced on a commercial scale. Many products described as wrought iron, such as guard rails, are made of mild steel. They retain that description because they were formerly made of wrought iron or have the appearance of wrought iron. True wrought iron is occasionally required for the authentic conservation of historic structures.

1.3 GENERAL ABOUT DUCTILE IRON

Ductile iron was a recent development material. Ductile iron, also called ductile cast iron, spheroidal graphite iron, or nodular cast iron, is a type of cast iron invented in 1943 by Keith Millis. While most varieties of cast iron are brittle, ductile iron is much more advantages which are flexible and elastic, due to its nodular graphite inclusions. In 1949, Keith Millis, Lee Aunkst, Albert Gagnebin and Norman Pilling received a US patent on ductile iron production via magnesium treatment. When molten cast iron solidifies, some of the carbon precipitates as graphite, forming tiny, irregular flakes within the crystal structure of the metal. While the graphite enhances the desirable properties of cast iron (improved casting & machining properties and better thermal conductivity), the flakes disrupt the crystal structure and provide a nucleation point for cracks, leading to cast iron's characteristic brittleness. In ductile iron the graphite is in the form of spherical nodules rather than flakes, thus inhibiting the creation of cracks and providing the enhanced ductility that gives the alloy its name. The formation of nodules is achieved by addition of "nodulizers" (for example, magnesium or cerium) into the melt. Yttrium has also been studied as a possible nodulizer. The compositions of material in percentage of ductile iron are iron, Carbon 3.3 to 3.4%, Silicon 2.2 to 2.8%, Manganese 0.1 to 0.5%, Magnesium 0.03 to 0.05%, Phosphorus 0.005 to 0.04% and Sulfur 0.005 to 0.02%.Other elements such as copper or tin may be added to increase tensile and yield strength while simultaneously reducing elongation. Improved corrosion resistance can be achieved by replacing 15% to 30% of the iron in the alloy with varying amounts of nickel, copper, or chromium.

Figure 1.2: microstructure of ductile iron (spheroidal shape)

Source: Smith, W.F and Hashemi,J. 2006

1.4 TYPE OF TREATMENT TO CONVERT CAST IRON TO DUCTILE IRON

There are many type of process to convert cast iron to ductile iron. The most successful process using pure magnesium is George Fischer converter which was invented by him. The sequence of process or method start with the design of vessel and the metal is added when it is in the horizontal position. After charging the metal, the magnesium is added to the treatment chamber through the hole formed in the side of ladle. This hole is then sealed and the converter is moved to the vertical position when metal flow to reaction chamber .The advantages of this process are high magnesium recovery and the disadvantages for this process are capital cost of equipment and the need to treat a minimum of about 6 tons metal per hour.

Other process is treatment in the mould. The technique of adding magnesium in the mould cavity, now well known as the inmould process is being used in a number of countries1. The runner system for each casting contains a suitably designed chamber in which is placed a weighed amount of magnesium alloy, usually magnesium ferro-silicon. The metal flowing at known flow rate over the magnesium produces a continuous reaction and result in a consistent pick-up of magnesium throughout the pouring period. This is proved by the fact that multi impression mould can be satisfactorily cast using this technique. The advantages are its ability to provide metal for pouring at many rate desired also in ladles of various capacity and also no fume is produce but the possible disadvantage are its relative inflexibility, as all pattern must be provide with the specially design treatment chambers and extensive slag traps to remove 6the reaction product from the metal in the runner system, and the general need to test each casting produced.

1.5 SANDWICH TREATMENT

For this project, a convention of cast iron to ductile iron using sandwich process. The aim of this technique is to produce a high magnesium recovery by holding down the magnesium alloy for period of time and also producing a localized low temperature area. The technique is shown in figure 3 and consist a building pocket into the bottom of the ladle, into which is placed the magnesium alloy and a cover a steel scrap (2-3 per cent of metal weight) or a steel or ductile iron plate. The metal stream from the furnace must be directed away from the pocket.

Magnesium recovery is increase for example, when using 5 per cent magnesium alloy the value is increase from about 25-30 per cent (simple pour-on technique) to above 40-45 per cent. To obtain the maximum benefit the pocket should be deep enough to contain all of the alloy and steel scrap, and the latter should be of a small size in order to produce a high packing density. The main disadvantage of the technique is the reduction in metal temperature resulting from the addition of the 2-3 per cent of cold steel scrap. Alternative designs of the pocket or recess are shown in. The deep pocket, which maybe position at the centre of the bottom of the ladle, has a lower surface area than that shown for normal recess and this, together with the greater depth, gives a longer incubation time before commencement of reaction and also a longer, less reactive reaction. This type of pocket and normal process reduce the effective capacity of the ladle, but this can be overcome by using the bridge recess which is form by placing a refractory bridge across the centre of the ladle base.

The depth and surface area of the form cavity must be sufficient to contain magnesium alloy and steel scrap. The metal stream is direct the empty half which then produces a smooth flow of metal across the steel scrap, thereby preventing premature reaction. The sandwich process often employed with a deep. Reaction ladle where the height-to-diameter ratio is 1.5 to 2:1. The extra metal depth increases recovery: for example values slightly in excess of 50 per cent can be obtained when using 5 per cent magnesium ferrosilicon alloy, even at temperature as high as 1500 celcius. It is essential that the recess or pocket is maintained in good condition if the best results are to be achieved from the sandwich technique.

1.6 OBJECTIVE

There are three main objectives of this research:

i. To investigate the processing parameter of ductile iron.

ii. The study the ductile iron casting process by Sandwich method.

iii. To investigate the process design parameter for ductile iron.

1.7 SCOPE

There are many scopes that we can investigate size of the pattern, the percentage of ferrosilicon magnesium and type of pocket. So based on my objective to investigate the mechanical properties of ductile iron and the properties including hardness the decided parameters were like below:

i. Variable of pattern size range from 0.5kg-1.5kg
ii. Variable of percentage ferrosilicon magnesium range from 0.2%-0.6%
iii. Fixed type of pocket, which is normal pocket.

1.8 PROBLEM STATEMENT

The cast iron has graphite in a matrix called pearlitic. The graphite shape is flake which is has lower strength. The study of graphite changes from flake form to nodular form by adding magnesium as nodularising agent and ferrosilicon as inoculation agent is under consideration.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

For this literature review, the subtopic is divided into four subtopics which are 4M. It will be review about manpower, machine, material and method. All this element will be discuss base on this project. It is importance to understand of this element before conducting the experiment of this project so at the end the expecting result will be achieve.

2.2 MANPOWER

In this project, an investigation and performing the experiment are required to convert cast iron to ductile iron. For information, sandwich process is very suitable for small type convertion. Its will not require any expensive tool or complicated machine to run the experiment. Just single or double person is enough to make the experiment. The manpower only needed when fabricating the mould and ladle. Other then that were after melt the iron and pour the molten metal into mould. The other process need man power such as prepare the sample for testing. By testing, the sample should be cut into smaller pieces the easily the handling of testing. Before that, the sample must undergo polishing process to get flat surface.

2.3 MACHINE

2.3.1 Casting Process

An induction furnace is an electrical furnace in which the heat is applied by induction heating of a conductive medium (usually a metal) in a crucible placed in a water-cooled alternating current solenoid coil. The advantage of the induction furnace is a clean, energy-efficient and well-controllable melting process compared to most other means of metal melting. Most modern foundries use this type of furnace and now also more iron foundries are replacing cupolas with induction furnaces to melt cast iron, as the former emit lots of dust and other pollutants. Induction furnace capacities range from less than one kilogram to one hundred tonnes capacity, and are used to melt iron and steel, copper, aluminum, and precious metals. One major drawback to induction furnace usage in a foundry is the lack of refining capacity; charge materials must be clean of oxidation products and of a known composition, and some alloying elements may be lost due to oxidation (and must be re-added to the melt).

An induction furnace, with fume hood closed, tapping a melt operating frequencies range from utility frequency (50 or 60 Hz) to 400 kHz or higher, usually depending on the material being melted, the capacity (volume) of the furnace and the melting speed required. Generally the smaller the volume of the melts the higher the frequency of the furnace used; this is due to the skin depth which is a measure of the distance an alternating current can penetrate beneath the surface of a conductor. For the same conductivity the higher frequencies have a shallow skin depth - that is less penetration into the melt. Lower frequencies can generate stirring or turbulence in the metal.

The main machine that will be use is electrocherm induction melting furnace. This machine was assembling in India and sends to University Malaysia Pahang and this machine is available in FKM lab. This machine is use to melt the cast iron into temperature 1400 approximately. The melting process may take several times around 1 hour the melt the cast iron. The capacity of this furnace is about 50 kg. Other than that, Rockwell hardness tester will be use determines the hardness of every sample and compare with the amount of ferrosilicon magnesium and size of sample. Using spectrometer machine, the composition of element in every sample will be determined. The value will help to calculate the magnesium recovery.

2.3.2 Analysis Process

2.3.2.1 Spectrometer

A spectrometer is an instrument used to measure properties of light over a specific portion of the electromagnetic spectrum, typically used in spectroscopic analysis to identify materials. The variable measured is most often the light's intensity but could also, for instance, be the polarization state. The independent variable is usually the wavelength of the light or a unit directly proportional to the photon energy, such as wave number or electron volts, which has a reciprocal relationship to wavelength. A spectrometer is used in spectroscopy for producing spectral lines and measuring their wavelengths and intensities. Spectrometer is a term that is applied to instruments that operate over a very wide range of wavelengths, from gamma rays and X-rays into the far infrared. If the region of interest is restricted to near the visible spectrum, the study is called spectrophotometry.

In general, any particular instrument will operate over a small portion of this total range because of the different techniques used to measure different portions of the spectrum. Below optical frequencies (that is, at microwave and radio frequencies), the spectrum analyzer is a closely related electronic device.

2.3.2.2 Rockwell hardness tester

The Rockwell scale is a hardness scale based on the indentation hardness of a material. The Rockwell test determines the hardness by measuring the depth of penetration of an indenter under a large load compared to the penetration made by a preload.[1] There are different scales, which are denoted by a single letter, that use different loads or indenters. The result, which is a dimensionless number, is noted by HRX where X is the scale letter.

During hardness testing process, indentation hardness correlates linearly with tensile strength. This important relation permits economically important nondestructive testing of bulk metal deliveries with lightweight, even portable equipment, such as hand-held Rockwell hardness testers

2.4 MATERIAL

2.4.1 Magnesium Ferrosilicon

Research work has shown that on laboratory scale additions of number of elements are capable of producing ductile graphite structures in cast irons. These elements include magnesium, cerium, calcium and yttrium. Like many other potential nodularising element, magnesium also a powerful desulphurizing element and so react with all of the sulphur present in the base metal before it become effective in changing graphite form from the flake to nodular, the removal of sulphur, by magnesium or by treatment prior to the nodularizing process proper, is an important consideration in selecting the method of addition of the magnesium.

There are number of inherent problem with the addition of magnesium and much of the investigative work relating to the production of ductile iron has been associated with ways and means of overcoming these problems.

i. **low boiling point** magnesium has low boiling point of about 1107 celcius which is far lower than the temperature of molten cast iron and hence the addition of magnesium cause a violent reaction.
ii. **Low solubility** magnesium is only sparingly soluble in molten cast iron.
iii. **Low specific gravity** the specific gravity of magnesium is only 1.74 in comparison with a value above 7 for cast iron. When added to cast iron, magnesium or its low density alloy tend to float giving rise to excessive losses cause by local boiling.