A Project Report On

"EFFECT OF VARYING CHEMICAL COMPOSITION ON MECHANICAL BEHAVIOUR OF FERROUS CAST PRODUCT"

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DECLARATION

Date: --------------------

I declare that report entitled "***Effect of varying chemical composition on mechanical behaviour of ferrous cast product***" submitted by me, is the requirement of partial fulfillment for the award of ***degree of Master of Technology (M. Tech) in Production Engineering*** at ***Delhi Technological University***. This is my original work, and not copied from any other source. The work embodied in this project has not been presented /submitted for award of any degree in any other university/institute to the best of my knowledge.

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ii.

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Abstract

This project is focused on effect of varying chemical composition on mechanical behavior of ferrous cast product. Ferrous materials occupy a significant position among engineering materials because of their chemical, physical and mechanical properties. In engineering applications, a suitable combination of these properties is required [8]. Mechanical properties have major role among the combination of chemical, physical and mechanical properties. Steel drives its mechanical properties from a combination of chemical composition, heat treatment and manufacturing processes. Although the major constituent of steel is iron yet the addition of very small quantities of alloy elements can have a marked effect upon the properties of steel. The strength of steel can be increased by the addition of alloy elements. However these alloy elements addition can also adversely affect other properties such as ductility and weld ability. Hence, the chemical composition for each steel balanced carefully and tested to ensure that the appropriate properties are achieved [9].

In this project, five important alloy elements such as manganese, chromium, nickel, carbon and molybdenum are selected to find the effect of these elements on mechanical behavior of alloy steel. To find the effect of any one element on mechanical properties of alloy steel, we cast a test piece with selected chemical composition and test the mechanical properties on this test piece. A reading “chemical composition v/s mechanical properties” is found. To find the second reading, a second test piece is casted with chemical composition slightly changing the alloy element their effects have been found. Again mechanical properties are tested and a second reading “chemical composition v/s mechanical properties” is found. In same manner five readings have been taken carefully and responses have been analyzed. This procedure is adopted for each five alloy elements to find the effects of these elements on mechanical properties of alloy steel. It has been observed that the mechanical properties have been found improved with alloying the test piece.

Keywords: Alloy element, Chemical composition, Mechanical properties, ferrous material.

iv.

Contents

TOPIC	Page No
Declaration	i
Certificate	ii
Acknowledgement	iii
Abstract	iv
Contents	v-vii
List of Figures	viii-ix
List of Tables	x
Nomenclature	xi
Chapter: 1 Introduction	13-24
1.1 Material Classification	14
1.2 Metals	14
1.3 Ceramic Materials	14
1.4 Organic Materials	15
1.5 Polymers	16
1.6 Composites	16
1.7 Semiconductors	16
1.8 Engineering Requirement of Materials	16
1.9 Ferrous materials	17
1.9.1 Pig Iron	18
1.9.2 Wrought Iron	18
1.9.3 Grey Cast Iron	18
1.9.4 Malleable Cast Iron	19
1.9.5 Nodular Cast Iron	19
1.9.6 Steel	19
1.9.7 Plain carbon steel	19
1.9.8 Low Carbon Steel	19

1.9.9 Dead Mild Steel 19
1.9.10 Mild Steel 20
1.9.11 Medium Carbon Steel 20
1.9.12 High Carbon Steel 20
1.9.13 Alloy Steels 21
1.9.14 Effects of alloy contents 22

Chapter: 2 Literature Review 25-26

Chapter: 3 Testing and Characterization 27-36

3.1 Brinell Hardness Test 27

3.2 Rockwell Hardness Test 28

3.3 Tensile Test 29

3.4 Impact Test 31

3.5 Fatigue Test 32

3.6 Magnetic Particle Inspection 33

3.7 Liquid Penetration Test 34

3.8 Eddy Current Inspection 34

3.9 Radiographic Inspection 35

3.10 Ultrasonic Inspection 36

Chapter: 4 Problem Descriptions and Experimental Work 37-47

4.1 Problem Description 37

4.2 Material Selection 39

4.3 NC: TC (Process plan) 39

4.4 Pattern Making 39

4.5 Moulding 39

4.6 Melting 40

4.6.1 Electric Arc Open Hearth Furnace 43

4.6.2 Induction Open Hearth Furnace 43

4.7 Pouring 43

4.8 Solidification 43

4.8.1 Cooling at Room temperature 44

4.9 Trimming / Grinding 45

4.10 Dimensional Testing 45

4.11 Heat Treatment 46

4.12 Radiographic Testing 46

4.13 Mechanical Testing 47

4.14 Micro structure Test 47

Chapter: 5 Results and Discussions 48-59

5.1 Effect of Manganese in alloy steel 48

5.2 Effect of Chromium in alloy steel 50

5.3 Effect of Nickel in alloy steel 53

5.4 Effect of Carbon in alloy steel 56

5.5 Effect of Molybdenum in alloy steel 59

Chapter: 6 Conclusions and scope of further Work 61-62

Chapter: 7 References 63-64

List of Figures

S.No.	Title	Page No
3.1	Brinell Hardness Test Machine	28
3.2	Rockwell Hardness Test Machine	29
3.3	Tensile Test Machine	30
3.4.2.	Impact Test Machine	31
3.5	Fatigue Test Machine	32
3.6	Magnetic Particle Inspection	33
3.7	Liquid Penetration Inspection	34
3.9	Radiographic Test	35
3.10	Ultrasonic Inspection	36
4.1	Flow Chart of Ferrous Casting	38
4.2	Mould Making Process	40
4.3	Electric Arc Furness	41
4.4	Induction Furness	42
4.5	Pouring	43
4.6	Water Quenching	44
4.7	Trimming/Grinding	45
4.8	Dimensional Testing	45
4.9	Micro Structure Test	47
5.1	Manganese vs Yield Strength	48
5.2	Manganese vs Yield Strength	49
5.3	Chromium vs UTS	51
5.4	Chromium vs UTS	51
5.5	Nickel vs UTS	53

5.6	Nickel vs UTS	54
5.7	Carbon vs UTS	57
5.8	Carbon vs UTS	57
5.9	Molybdenum vs UTS	60
5.10	Molybdenum vs UTS	60

List of Tables

S.NO	Title	Page No
5.1	Manganese v/s Yield Strength	48
5.2	Chromium v/s UTS	51
5.3	Nickel v/s UTS	53
5.4	Carbon v/s UTS	56
5.5	Molybdenum v/s Tensile Strength	59

NOMENCLATURE

NC: TC	Notification Criteria for Test Certificate
Vol.	Volume
UTS	Ultimate Tensile Strength
P	Applied Load
◦C	Degree Celsius
i.e	That is
%	Percent
e.g	For Example
Wt	Weight
BHN	Brinell hardness number
D	Diameter
VHN	Vickers hardness number
Kgf	Kilogram force
µm	Micrometer
KHN	Knop hardness number
mm	Millimeter
UTM	Universal Testing Machine
N/m^2	Newton /$Meter^2$
N	Newton
CRH	Constant rate of heating
PSI	Pound per Square Inch
Å	Angstrom
λ	Wave length
MPa	Mega Pascal

INTRODUCTION

CHAPTER 1

Historically development and advancement of society have been intimately tied to the member ability to produce and manipulate materials to meet their needs. In fact, early civilizations have been designated by the level of their material development (Stone Age, Bronze Age, and Iron Age).

Furthermore, it was discovered that properties of a material can be altered by heat treatment and by the alloying of other substances. It is useful to sub divide the discipline of material science and engineering into material science and material engineering sub disciplines. Material science involves investigating the relationship that exists between structures and properties of material although material engineering is on the basis of these structure –property co-relations [10].

All important properties of solid material may be grouped into following six different categories-

i. Mechanical
ii. Electrical
iii. Thermal
iv. Magnetic
v. Optical
vi. Deteriorative

Many times a material problem is one of selecting the right material from the many thousands that are available. There are several factors on which the final decision is normally based first of which is to characterized service condition than we find the properties which required for material. A second selection consideration is any deterioration of material properties that may occur during service operation. Finally, probably the important consideration is that of economics that what will the product cost.

1.1 MATERIAL CLASSIFICATION

Most Engineering materials may classed into one the following types

i. Metals – Ferrous and Non – Ferrous
ii. Ceramics
iii. Organics
iv. Composites
v. Semi-Conductors
vi. Advanced Material

1.2 METALS

In this group materials are composed of one or more metallic elements such as Iron, Aluminum, Copper, Titanium, Gold and Nickel and also nonmetallic elements for example Carbon, Nitrogen and Oxygen. Metals play a major role in the industrial and everyday life of human. We see hundreds of metals objects and parts which find engineering applications. Metals are composed of elements which readily give up electrons to provide a metallic bond and electrical conductivity. [11]

Metals generally possess the following characteristics such as luster, hardness, low specific heat, plasticity, formability, good thermal and electrical conductivity, relative high melting point, Strength, Ductility, Malleability, Opaqueness, Stiffness, Rigidity and Formability, Machinability, Weldability, Castability, Dimensional stability. Commonly employed metals are Iron, Aluminum, Copper, Zinc, Magnesium etc.

1.3 CERAMIC MATERIALS:

These usually consist of oxides, nitrides, carbides, silicates or borides of various metals. These are many inorganic, non-metallic solids processed. These materials are rock or clay minerals materials. These Materials contain compounds of metallic and non-metallic elements such as MgO, SiO_2, SiC, $BaTiO_3$, glasses etc. such compounds contain both ionic and covalent bonds. These materials are generally used at high temperatures.

Important Characteristics of ceramic materials are:

- High temperature strength
- Hardness
- Rock – like appearance
- Corrosion resistance
- Resistance to high temperatures
- Insulation (not to flow of electric current)
- Opaqueness
- Brittleness

Examples of ceramic materials

Sand, Glass, Brick, Cement, Concrete, Insulators, Silicon Carbide, Tungsten Carbide, Boron Nitride, Refractories, Abrasives and Plaster.

1.4 ORGANIC MATERIALS

Organic materials are polymeric material composed of carbon compounds. Polymers are solids composed of long molecular chains. Countless organic materials are natural and synthetic or manufactured and based chemically on carbon.

Important characteristics of organic materials (e.g. wood, rubber and plastic) are

- Poor resistance to temperature
- Not dimensionally stable
- Poor conductors of heat and electricity
- Ductile
- Light weight
- Combustible

Examples of organic materials:-

Adhesives, Plastics, Paper, Explosives, Fuels, Woods, Lubricants, Textiles, Rubber and Paints.

1.5 POLYMERS

These include plastic and rubber materials. Many of them are organic compounds that are chemically based on hydrogen, carbon, and other non-metallic elements: furthermore, they have very large molecular structures. Polymers materials typically have low densities and may be extremely flexible.

1.6 COMPOSITES

These materials consist of more than one material type. Fiber – glass is a familiar example, in which glass fibers are embedded within a polymeric material. A composite is designed to display a combination of the best characteristics of each of the components materials. Fiberglass acquires strength from the glass and flexibility from the polymer.

1.7 SEMI CONDUCTORS

These have electrical properties that are intermediate between the electrical conductors and insulators. Furthermore, the electrical characteristics of these materials are extremely sensitive to the presence of minute concentrations of impurity atoms, whose concentrations may be controlled over very small special regions. These have made possible the advent of integrated circuitry that has totally revolutionized the electronics and computer industries.

1.8 ENGINEERING REQUIREMENT OF MATERIALS

Engineering requirement of a material mean as what is expected from the material so that the same can be successfully used for making engineering components such crankshaft, spanner etc.

When an engineer thinks of deciding and fabricating an engineering part, he goes on to search of that material which possesses such properties as will permit the components part to perform its functions successfully while in use. For example, one may select high speed steel for making a milling cutter or a power hack saw blade.

Main engineering requirements of a material, has three categories

i. Service requirements
ii. Fabrication requirements
iii. Economic Requirements.

1.9 FERROUS MATERIALS

Due to their extensive use, ferrous materials are very important in the society. Widespread the broad use of alloy is accounted by the factors that Iron containing compounds exists in major quantity in the earth's crust. By using relatively economical extraction refining, alloying and fabrication techniques metallic irons and alloy may be produced. Ferrous materials have a wide range of mechanical and physical properties. Susceptibility to the corrosion is main disadvantage of ferrous materials.

Classification:

Metal / Alloys:

- Ferrous.
- Non – Ferrous.

Ferrous

- Steels.
- Cast Irons.

Steels

- Low Alloys.
- High Alloy.

Low Alloy

- Low Carbon.
- Medium Carbon.
- High Carbon.

Low Carbon

- Plain.
- High Strength Low Alloy.

Medium Carbon

- Plain
- Heat treatable

High Carbon

- Plain
- Tool

Cast Irons

- Grey cast Iron
- Ductile (Nodular cast Iron)
- White cast Iron
- Malleable cast Iron

1.9.1 PIG IRON

Pig iron is originated in the early days by iron ore reduction. The method of pig casting in sand beds has been largely superseded by the pig casting machines. In cupola Furnace pig iron is refined then various grades of cast iron are produced. From pig iron various steel making process are used such as Bessemer, open–hearth etc.

1.9.2 WROUGHT IRON

Mechanical Mixture of very pure iron and silicate slag is called wrought iron. It is a ferrous material. Uses of wrought iron are in building construction, public works, industrial, road and marine and others such as gas collection hoods, handling equipment, cooling tower and spray pond piping. Manufacturing of wrought iron is done by pudding process and ton's process.

1.9.3 GREY CAST IRON

Basically it is an alloy of carbon and silicon with iron. It is readily casted into a desired shape in sand mold. It contains 2.5-3.8% C, 1.1-2.8% Si, 0.4-1% Mn, 0.15% P and 0.10% S. It has high fluidity hence, it can be casted into a complex shapes and thin sections.

Applications

Household appliances, Piston rings, Ingot molds, Tunnel Segments, Manhole covers, Frames for electric motors, Machine tool structures (bed, frame etc).

1.9.4 MALLEABLE CAST IRON

It can be hammered and rolled to obtain different shapes. Malleable cast iron has 2-3% C, 0.3-1.3% Si, 0.2-0.6% Mn, approx. 0.15% P and 0.10 % S.

Applications

Automotive crank shaft, sprocket, rear axle housing, Gear case, Automotive industry rail road, Agricultural implements, Electrical line hardware, Conveyor chain links and truck axle assembly parts.

1.9.5 NODULAR CAST IRON

Nodular cast iron possesses damping capacity intermediate between cast iron and steel. It possesses excellent cast ability and wear resistance. Ductile cast iron or nodular cast iron contains 3.2%-4.2% C, 1.1-3.5% Si, 0.3-0.8% Mn, approx. 0.08% P and 0.02% S.

Applications

Pipes, pumps and compressors, valves and fittings, pumps and compressors, construction machinery, parts of tractors, power transmission equipment, internal combustion engines parts, Paper industries machinery.

1.9.6 STEELS

An alloy of iron and carbon is called steel.

1.9.7 Plain carbon Steel

An alloy of iron and carbon is plain carbon steel. It is different from cast iron as regards the percentage of carbon. Carbon steel contains from 0.10% - 1.50 % carbon whereas cast iron contains from 1.82 %– 4.82 %, carbon classification of carbon steel may be as low carbon steel , medium carbon steel and high carbon steel .

1.9.8 Low carbon steel

Low carbon steel or Mild steel may be classified as

1. Dead mild steel
2. Mild steel

1.9.9 Dead Mild Steel

It has carbon percentage from 0.05 - 0.15 %. It has tensile strength approx. 390 N/mm^2 and hardness approx.115 BHN.

1.9.10 Mild Steel

Mild steel containing 0.15 % -0.20% carbon, has tensile strength about 420N/mm^2 and hardness about 125 BHN. Mild steel containing 0.20 % - 0.30% carbon, has tensile strength about 555 MPa and hardness about 140 BHN.

Applications

Gears, valves, crank shafts, connecting rods, railway axles, fish plates, small forgings, hand blades, welded tubing, etc.

1.9.11 Medium Carbon Steel

It contains 0.30-0.45% carbon. The steel having 0.30-0.45% carbon has tensile strength of about 750N/mm^2. They are used for making small and medium forgings axels, brake levers, wires and rods, connecting rods, spring clips, gear shafts.

Steel containing 0.50 -0.55% Carbon has tensile strength approx.1000 N/mm^2 and are used for parts subjective to heavy shocks such as crank shafts, crank pins, railway coach axles and shafts.

1.9.12 High Carbon Steel

High carbon steel has Carbon 0.60 - 1.50 %. Steel Containing 0.6 - 0.75% carbon has tensile strength of 1230 N/mm^2 and hardness of 400-450 BHN and are used for making die blocks, clutch discs, plate punch and forging die, cushion rings, valve springs, etc. Containing 0.75 % – 0.8% carbon, tensile strength approx. 1400 N/mm^2 and hardness approx. 450-500 BHN. These steels are used for making automobile clutch disc, shear blades, cold chisel, wrench, jaw, pneumatic drill bits, and wheels for railway services trains.

Containing 0.8 % -0.9% carbon, High Carbon Steel has a tensile strength approx. 660 N/mm^2 and hardness 550 BHN. These steels are used for manufacturing shear blades, pins, spring, punch and keys etc.

Containing 1 % - 1.1% carbon, high carbon steel are applicable for mandrels, railway springs, machine tools.

Containing 1.1 % – 1.2% carbon, high carbon steel are applicable for knives, twist drills and taps. Containing 1.2 % - 1.3% carbon, high carbon steel are applicable for reamers, files, metals cutting tools etc.

Containing 1.3 % - 1.5% carbon, high carbon steel are applicable for metal cutting saws, wire drawing dies, tools for turning chilled iron etc.

1.9.13 Alloy Steel

Steel is considered to be alloy steel when the maximum of the range given for the content of alloying elements exceeds one or more of the following limits:

Mn 1.65%, Si 0.60%, Cu 0.60%

Or in which a definite range or a definite maximum quantity of any of the following elements is specified or required within the recognized filed of constructional alloy steels: Al, B, Cr, up to 3.99%, Co, Mo, Ni, Ti, W, V, or any other alloying elements added to obtain a desired alloying effects.

Disadvantages of Alloy Steel

- Higher cost.
- Special handling during process.
- Brittleness in certain grades.
- Tendency towards austenite retention.

Alloying Purpose

- Greater case hardening property.
- Greater cutting ability.
- Greater wear resistance.
- Greater toughness.
- Greater Ductility.
- Greater Temperature Stability.
- Greater Strength.
- Grain size Control.
- Greater Corrosion Resistance.

1.9.14 Effects of Content

Carbon: It affects

- Melting point.
- Machinability.
- Hardness.
- Tensile strength.

Nickel:

- It increases toughness and resistance to impact.
- It lowers distortion in quenching.
- It lowers the critical temperature of steel and range of heat treatment.
- It improves strength.

Chromium:

- It adds to depth hardenability.
- It improves resistance to abrasion and wear.

Silicon:

- It improves oxidation resistance.
- It improves strength in low alloy steel.
- It acts as a deoxidizer.

Titanium:

- It reduces martensite hardness and hardenability in medium chromium steel.
- In high chromium steel, it prevents formation of austenite.
- In stainless steel during long heating, it prevents localize depletion of chromium.

Molybdenum:

- It forms abrasion resisting particle.
- It enhances corrosion resistance in stainless steel.
- It improves tensile strength at high temperature.
- It improves creep strength at high temperature.
- It counteracts tendency towards temper brittleness.

- It makes tough at various hardness levels.
- Grains are refined.
- It improves hardenability of steel.

Vanadium:

- It improves strength and toughness in heat treated steel.
- It improves hardenability.
- It improves fine grains

Tungsten:

- It improves strength at elevated temperature.
- It increase hardness
- It improves fine grains.

Manganese:

- It lowers ductility and weldeability with high percentage in high carbon steel.
- It counter acts brittleness from sulphur.
- It contributes strength and hardness.

Copper:

- It increases resistance to atmospheric corrosion.
- It acts as a strengthening agent.

Boron:

- It increases hardenability

Aluminum:

- It produces fine austenitic grain size.
- It acts as a deoxidizer.

Cobalt:

- It improves heat resistance.
- It affects tensile strength.
- Improves fatigue strength.
- It affects hardness.

Some Prominent Alloys:

- Molybdenum Steel
- Silicon Manganese Steel
- Silicon Steel
- Nickel Steel
- Chrome Nickel Steel
- Chrome Vanadium Steel
- Cobalt Steel
- Vanadium Steel
- Tungsten Manganese Steel
- Chrome Steel
- Chrome Molybdenum Steel

LITREATURE REVIEW

CHAPTER 2

M.N. Yoozbashi, S. Yazdani [1] had done proper design of chemical composition which may achieve suitable mechanical properties in the steel. In their work the mechanical properties and microstructure of steel was evaluated using tensile and Charpy impact test and XRD, SEM,TEM tests. The paper suggested that it is possible to design a new steel with required mechanical properties and microstructure without trial and error method. Micro structure characteristics mark the mechanical properties of steel. Microstructure characteristics are evolved during isothermal transformation.

Sorokin G.M., Malyshey V.N. [2] have done the ranking of various steel rates on wear resistance without needing of their tests on wear using criteria based on standard mechanical properties of steel and alloys. M.M. Khuruchev had prooved that the dependence of wear on hardness first time. But this dependence always had a question: while different grade of steels which have equal hardness show varying wear resistance? And wear resistance of pure metals, depending on the hardness are characterized by a straight line. But in this paper standard mechanical properties of steel and alloy were used to specify the grade of steel on wear resistance without needing of their tests.

A. Kurc-Lisiecka, M.Kciuk [3] described that austenitic Cr-Ni has many favorable mechanical properties which are beneficial in engineering applications such as manufacturing of tank container, pressure pipes for liquid and gaseous nitrogen. Also for high strength and ductile wires. The aim of the paper was to find the effect of the chemical composition on mechanical properties such as are high strength, ductility, corrosion resistance, weld ability etc.

J.adamczyk, and A.Graccar [4] have found the influence of heat treatment on the structure with light and transmission electron microscopy method. Mechanical properties were determined by means of tensile test. A strain hardening exponents as a function of true strain was evaluated too. The aim of the paper was to design heat treatment conditions of dual phase steel and to determine their influence on the structure and mechanical properties of steel.

A.Ravendra, and B.V.R Ravi Kumar [5] found the enhancement in mechanical properties such as tensile properties and weld metal hardness due to the refinement in fusion zone grain size. Hence, the basic reason for the improvement in mechanical properties is the refinement produced in fusion zone, grain size by pulse current welding. From the result it is evident that the pulsed current has greater influence on mechanical and metallurgical properties.

In order to improve the mechanical integrity of the weldments, it would be desirable to study the micro-hardness of weldments. The present study was performed in order to show difference of micro-hardness and mechanical properties of the weldments made with pulsed and non-pulsed current at different frequencies of GTAW(gas tungusten arc welding). The hardness measurement can provide information about the metallurgical changes caused by the welding.

In this experimental study, the weld micro-hardness and mechanical properties of weldments have been carried out on EN24 alloy steel using GTAW with pulsed non –pulsed current at different frequencies 2Hz, 4Hz and 6Hz.

Ashish Kashyap and Aditya Varma [6] found the influence on the hardness of three sample Grades of Tool steel i.e. EN-31 , EN-8 and D-3 after Heat Treatment Processes such as Annealing , Normalizing and hardening & Tempering .

After selection of the material & heat treatment processes further aims to perform mechanical & chemical analysis i.e. composition testing of the three tool steel EN-31, EN-8 and D-3 before treatment. After chemical testing, the aim is to do heat treatment and then to perform hardness testing on the treated and untreated work samples.

Research Gap

A research may towards finding the effects of varying percentage of individual alloy element on mechanical behavior of cast steel providing practical datas which may help to select the chemical composition for required mechanical properties of cast steel .

TESTING AND CHARACTERIZATION

CHAPTER 3

Material testing is an essential step to characterize the material .There are two streams for mechanical testing.

A. Destructive Test

1. Hardness Test
2. Tensile Test
3. Impact Test
4. Fatigue Test

B. Non Destructive Test

1. Radiography Inspection.
2. Ultrasonic Inspection.
3. Magnetic Particle Inspection.
4. Liquid Penetration Inspection Test.
5. Eddy Current Inspection.

3.1 Brinell Hardness Test

Hardness Test is used from very old time, most of the materials has this property. Diameter of an indenter becomes about 10 mm at 3000 kg load. Material of ball is hardened steel but for harder material, it is of tungsten carbide. The specific ratio of applied load to square of the diameter of indentation ball is maintained.

$$\text{Specific ratio} = P/D^2$$

Test piece is loaded hydraulically. A mechanism is applied to vary the load. Load is released after about 30 seconds. Diameter of indentation is measured by power microscope.

The calculation of the BHN hardness is done by the formula or BHN value is read from the standard table correlating the diameter of indentation to Brinell hardness number for a given size of indentation ball and applied load.

Fig. 3.1 Brinell Hardness Test Machine [15]

3.2 Rockwell hardness test

In Brinell hardness test and Rockwell hardness test, difference is in the depth of penetration but surface area becomes same. In this test the depth of penetration varies with the hardness of material. If the hardness is higher, then depth will smaller and vice versa. Measuring of depth of penetration is not required. The hardness value can be read on the dial attached to the tester directly. Readings are calibrated for depth of penetration. Hence, calculation is not required. Now a day, this tester is very popular in industry because of two reasons.

1. It has fast process.
2. Indentation is made very small

Fig. 3.2 Rockwell Hardness Test [15]

3.3 TENSILE TEST:

Tensile test is performed widely to characterize the mechanical property of a material. Tensile strength, yield stress, upper and lower yield point, elongation and reduction in area can be determined by this test. In general universal testing machine is used for this test. A standard size specimen is prepared for this test. In this test specimen is subjected to tensile load until fracture occurs. By this test different curves are drawn true stress strain curve, engineering stress – strain curve. For engineering stress strain curve, average longitudinal stress and average linear strain are taken to plot the curve.

The **yield stress** is at which elastic deformation takes place at constant load on the specimen. Stress at which some small amount of permanent deformation (say equal to 0.15%

strain) is called **Proof stress** or we can say it is the stress, which produce a permanent elongation after removing the load.

Ultimate tensile strength is the maximum stress which material can withstand. There is thumb rule for relation between tensile strength and hardness.

Tensile strength = 3.551 x BHN for heat treated low carbon steels

Tensile strength = 3.396 x BHN for heat treated medium carbon Steels

Tensile strength = 3.242 x BHN for heat treated alloy steels

Percentage change in length per unit length of a given specimen is called percentage elongation or change in length per unit length multiplied by 100.

Percentage elongation = 100 x (Final length – original length)/(original length)

Fig. 3.3 Tensile test [15]

3.4 IMPACT TEST

It is the strength of material under dynamic loading. In this test the material is subjected to impact load. It is the capability of the material to absorb energy leading to failure under impact loading. It depends on material of specimen. Two methods are applied.

1. Izod Impact test
2. Charpy Impact test

The specimens for both tests are called Izod specimen and Charpy specimen respectively.

Value of Impact strength is affected by some factors such as temperature. The temperature at which 50% is brittle and 50% ductile is called fracture appearance transition temperature (FATT).

Fig. 3.4 Impact test [15]

3.5 FATIGUE TEST

When component is subjected to repetitive or fluctuating tensile or bending load, failure of material can take place at lower level than direct tensile or bending load, such failure is called fatigue failure. It always results in brittle fracture. Fracture becomes instantaneously without any prior indication, some general components under cyclic loading are power driven machines blades, spring, connecting rods, gears and crank shafts etc.

In fatigue testing, the test piece is mounted on the machine and subjected to rotation. During rotation, upper surface of test piece is under tension and lower surface of test piece is under compression.

Till failure of specimen, rotation becomes continued. Test is done at varying cyclic stress for a given material. A Graph is plotted between varying cyclic stress and no. of cycles. Such graph is called S-N curve. With S-N Curve fatigue strength is calculated.

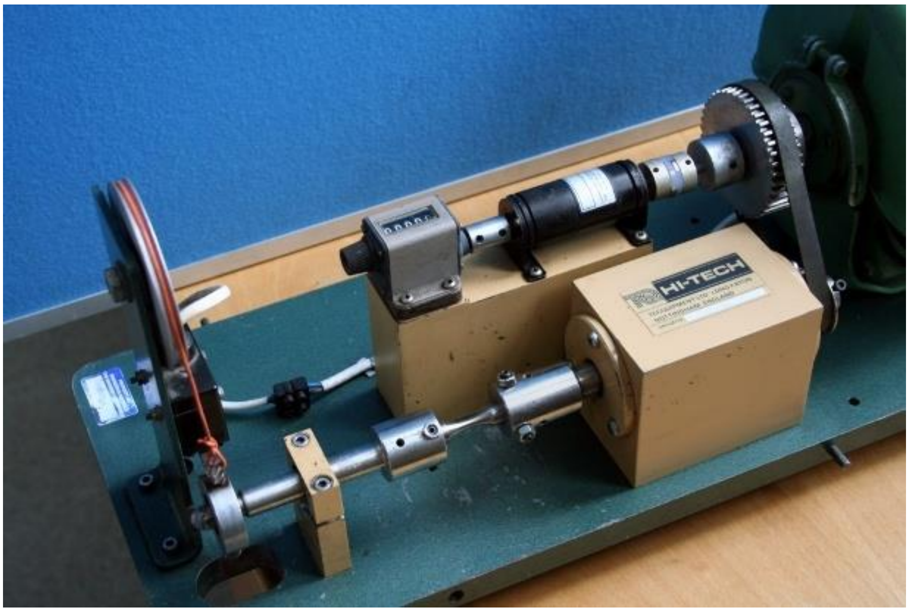

Fig. 3.5 Fatigue test [15]

3.6 MAGNETIC PARTICLE INSPECTION

The defects near the surface are detected by this test. This test is limited to ferromagnetic materials at the surface to be checked. A solution having tiny magnetic particles is spread. This surface is subjected to a strong magnetic field. Due to discontinuity of the surface, free poles are created during magnetization; the metal attracts the magnetic particles in the solution used. After removing the magnetic field, magnetic particles are left at the site, thereby defect is detected.

There are two methods to setup the magnetic field.

1. Passing the current through component
2. Powerful electromagnet is used

In the first method, AC or DC both may be used. Advantage of AC is high sensitivity at the surface. DC shows better subsurface defects. Sometimes the field current is provided by current carrying conductor.

Fig.3.6 Magnetic particle inspection [15]

3.7 LIQUID PENETRATION INSPECTION

By this method large cracks or opening are detected by using liquid dyes fluorescent liquid penetrants. Some other defects such as fatigue cracks and cold shut are detected. Surface of test piece is cleaned and dyes are spread on the surface. Dye is removed through surface by water, and thoroughly dried. Then a developer is spread on the surface, color in cracks or pin holes are bring out and hence, the defect is detected. Care is necessary during the using testing dyes.

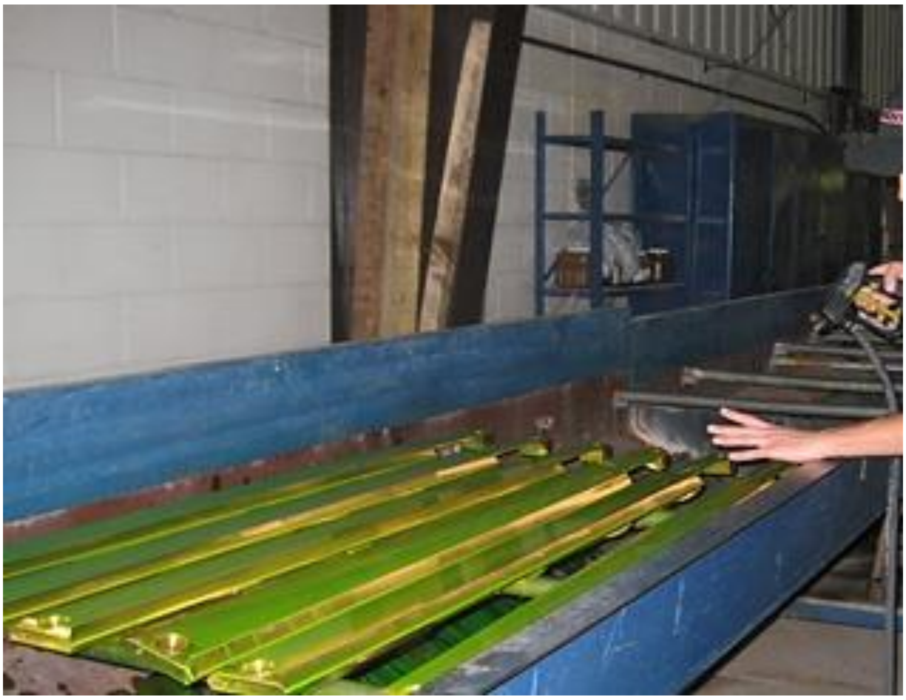

Fig. 3.7 Liquid penetration inspection [15]

3.8 EDDY CURRENT INSPECTION

It is the method to detect discontinuity and flaws. In this method, AC is used. AC current carrying conductor coil is brought near test piece, eddy current are introduced in test piece due to electromagnetic effect. Eddy current produce their own magnetic field which oppose the field of AC current carrying coil. Due to this, impedance by coil can be observed. When the flaws come under AC current carrying coil, local eddy current varies in the test piece. This in turn changes the impedance of coil which actuates a flash light, position of the flaw can be detected hence defect can be detected.

3.9 RADIOGRAPHIC INSPECTION

In industry radiography test is very popular non destructive method. Defects which are detected by this method are

1. Blow holes
2. Shrinkage
3. Inclusion
4. Sand Casting

In industry this method is very frequently used in non – destructive testing method because this method detects both position and volume of defect

Main disadvantage of this method are:

1. Special safety precautions are required.
2. Method is inexpensive.

Fig. 3.8 Radiographic inspection [15]

3.10 ULTRASONIC INSPECTION

This method is used where radiography inspection cannot be used. An electronic oscillator sends out AC current to electric transducer which converts the electric energy to acoustic energy with same frequency. This acoustic energy wave is then sent to the test piece. If there is a flaw, the acoustic wave bounces back from the crack and return to the same transducer as an echo.

Fig. 3.10 Ultrasonic inspection [15]

PROBLEM DESCRIPTION & EXPERIMENTAL WORK

CHAPTER 4

4.1 PROBLEM DESCRIPTION

In this project, the problem is to find the effect of varying chemical composition on mechanical behavior of ferrous cast product.

To solve the problem, I selected five important alloy element for composition of alloy steel from the available process and take practical data’s knowing the

- Effect of manganese percentage change in casting of steel while rest elements of composition remain same during process.
- Effect of chromium percentage change in casting of steel while rest elements of composition remain same during process.
- Effect of nickel percentage change in casting of steel while rest elements of composition remain same during process.
- Effect of carbon percentage change in casting of steel while rest elements of composition remain same during process.
- Effect of Molybdenum percentage change in casting of steel while rest elements of composition remain same during process.

After taking the practical data’s these have been analyzed.

To find the above data, I had close observation on casting processes of steel castings in manufacturing unit of defense. Lot of data found, these selected data have been used to solve the problem. Data has been taken from running process hence description of process is necessary and is given below in fig 4.1.

Observation has been taken from a running Process.

The process is done according the given process flow chart

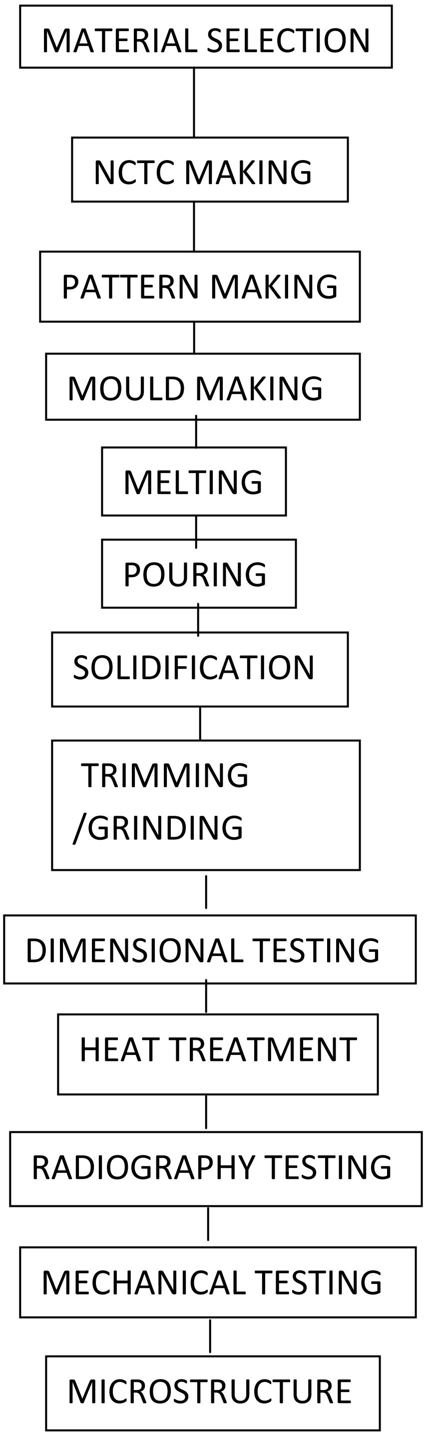

Fig. 4.1 Shows flow chart of ferrous casting

4.2 MATERIAL SELECTION

Since Observation has been taken from a running Process of a defense Manufacturing Unit, Hence, material is taken according to design and strength as per customer's requirement. Main customers are Air force, Navy and Army. According to the requirement, a NC: TC (notification criteria for test certificate) has been prepared for each product.

4.3 NC:TC (notification criterion for test certificate)PREPARATION

As per requirement NC:TC is made, it is written document which shows chemical composition, heat treatment and all other processing conditions to be followed.

4.4 PATTERN MAKING

It is actual replica of cylindrical circular bar which we have casted for various mechanical strength tests.

4.5 MOULDING

MANUFACTURING OF MOULD

There are different methods to make the mould for different casting. For heavy casting, for running mass production sand mould are generally used in this manufacturing unit.

STEPS TO MAKE THE SAND MOULD

1. Select a moulding box to accommodate cavity, riser, gate, runner and sprues.
2. Place the drag pattern with parting surface down on the bottom board.
3. Sprinkle the facing sand carefully all around the pattern.
4. With loose moulding sand, fill the drag.
5. In the moulding box around the pattern, Ram the sand uniformly.
6. Strike off the excess sand.
7. Over the top of the drag, sprinkle parting sand.
8. Place the pattern on the drag.
9. Place cope over the ramed drag.
10. Sprinkle parting sand all around the cope pattern
11. Fill the cope with sand

12. Ram the sand in cope
13. Take out excess sand
14. Take out sprue and riser pins
15. Vent the cope with vent wire
16. Sprinkle parting sand over the top of the cope surface
17. Bake the mould in case of dry sand
18. Set the cope in the mould if required
19. Assemble the mold with cope and drag. Mould is ready for pouring

Fig. 4.2 Mould making process [15]

4.6 MELTING

Melting is the major factor after the mould preparation, it defines the characteristics of product. There are a number of furnaces available for melting the alloys in foundry such as cupola, rotary furnace, open hearth furnace and pit furnace etc. choice of furnace depends on the amount and type of alloy being melted.

For melting of cast iron, a cupola furnace in its various forms is used. It has lower initial cost and lower melting cost. In this manufacturing unit, electric arc open hearth furnace and induction open hearth furnace are used.

4.6.1 ELECTRIC ARC OPEN HEARTH FURNACE:

Due to heavy steel casting, in this manufacturing unit electric arc open hearth furnace is used. Electric arc open hearth furnace is very suitable for ferrous materials. This furnace draws an electric arc that rapidly heats and melts the charge material. The bowl – shaped bottom of the furnace, called the hearth. It is lined with refractory bricks and granular refractory material. From electric arc to charged metal, the heat is transferred directly. The electric arc hearth furnace has a tilting mechanism allowing it to be forward for material tapping or backward for deslaging.

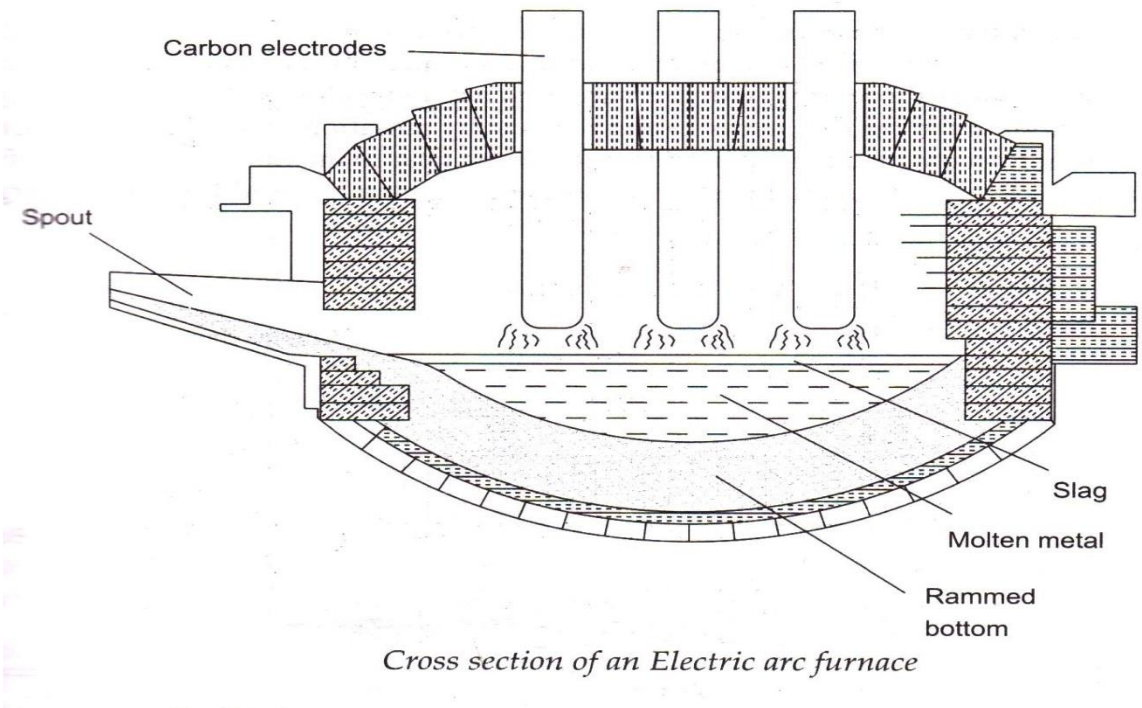

Fig. 4.3 Electric arc furnace [11]

4.6.2 INDUCTION OPEN HEARTH FURNACE

This furnace is used for all types of material. The main advantage being that the heat source is isolated from the charge, slag and flux get the necessary heat directly from the charge instead of the heat source. In this furnace, high frequencies help in stirring the molten metal and thus help in using the metal swarf. With this furnace, better control of temperature and composition can be achieved. The main advantages of this furnace are

- Compact installation
- Natural stirring
- Higher yield
- Faster start up
- Cleaner melting

After selecting the furnace, the charge calculation is done and then furnace is charged with metal. Now furnace is started. First of all, slag is taken out from the top of furnace then sample is taken out for spectro. After spectro checking composition of metals is known. According to the metal composition, mixing is done in lower quantity after proper mixing again sample is taken for spectro checking and again mixing is done. In the same manner about four samples are taken then final composition is received.

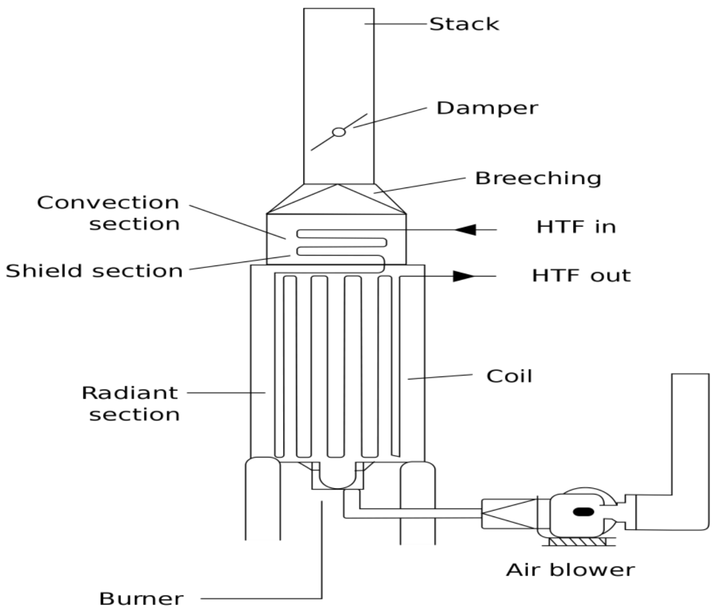

Fig. 4.4 Induction furnace [15]

4.7 POURING

After melting, pouring is done in mold by the ladle. Molten metal is poured into the mold by ladle. The molten metal from the furnace is tapped into the ladle at requisite interval. There are different sides of ladle depending on the amount of metal. Ladles range between 50 kg to 30 tons.

Fig. 4.5 Pouring [15]

4.8 SOLIDFICATION

Solidification is the very important part of process, because it prevents the defect of casting and provides the different beneficial characteristics to casting. Hence in brief basic concept of solidification is such as:

- Molten metal processes high energy.
- When metal tools , it loses energy to form crystal.
- Due to rapid heat lose near mold walls than any other place, the first submicroscopic metal crystallites called Nuclei form.
- Melt experience difficulty in starting to crystallize if no nuclei in the form of impurities are present to start the crystallization.
- Nuclei grow at the second stage of solidification.
- The crystal growth occurs in dendritic manner.
- By the evolution of small arms on the original branches of individual dendrites, dendritic growth takes place.

- More and more grow on an existing dendrite and also more and more dendrite form until the whole melt is crystallized as solidification proceeds.
- The growth of dendrite arms occurs because metal atoms attach themselves to the solid dendrite.
- During the crystal growth atoms arrange themselves in a three dimensional pattern which is repeated many times.
- This unit of repetition is called a unit cell (B.C.C, F.C.C., H.C.P. etc.).
- These unit cells arrange themselves in straight lines.
- Straight lines thus formed in geometric pattern at right angles to each other produce dendritic structure.
- Dendrites grow outward until they contact the neighboring dendrites and generate grain boundaries.
- Dendrite arms become thickened and ultimately a solid crystal or grain may remain with no indication of dendritic growth.

4.8.1 COOLING AT ROOM TEMPERATURE / QUENCHING

According NC: TC (Process Plan) after pouring at requisite time, mold is opened. Casting is cooled at room temperature OR Quenching is done.

Fig.4.6 Water quenching [15]

4.9 TRIMMING / GRINDING

In casting Process due to riser, runner, gate and allowances access material occurs at the casting renewing from mould. Hence, to give proper size and proper dimensions trimming / grinding is required.

Fig. 4.7 Trimming and grinding [15]

4.10 DIMENSIONAL TESTING After training and grinding, dimensional measuring is done to remove the extra material and to give proper size.

Fig. 4.8 Dimensional Testing [15]

4.11 HEAT TREATMENT

In heat treatment, a define temperature is given and maintained for define interval. Also cooling is done at necessary rate to obtain desired properties associated which change in nature of size and distribution of micro constituents. Main advantages of heat treatment in casting process are:

- Stress relief is obtained.
- Harden and strengthen metals.
- It improves machinability.
- It changes grain size.
- Soften Metals for cold working.
- It improves ductility and toughness.
- It increases wear and corrosion resistance.
- It improves electrical and magnetic properties.

4.12 RADIOGRAPHY TESTING

The purpose of radiography is to detect the defects which affect the mechanical properties as well as other characteristics of materials. Defects detected by the radiography may be-

- Blow holes
- Gas inclusion
- Shrinkage
- Sand inclusion
- Foreign particle inclusion
- Cavity

Radiography is the technique based upon the exposing the components to short wave length radiation in inform of X-Rays or Gamma Rays.

In radiography process, radiography plates are exposed with casting products. These radiography plates (such as negative of photo graphs) are processed and then check in front of illuminator. During checking at illuminator defects are detected.

4.13 MECHANICAL TESTING

Castings free from defects detected in radiography are tested mechanically.These tests are such as

- Tensile tests
- Hardness test.
- Impact tests.
- Bend tests.
- Fatigue test.
- Creep test.

4.14 MICRO STRUCTURE TEST

After checking of mechanical testing, microstructure test is also done.

Fig. 4.9 Microstructure testing [15]

RESULTS AND DISCUSSION

CHAPTER 5

5.1 Effect of ***Manganese*** in alloy steel

More than 1.65% manganese is considered in alloy steel group. Manganese is added in the range of 1.65 -1.90% to improve the strength

Hardness

Workability

Yield Strength

Manganese lowers ductility and weld ability.

Such an improvement in properties of steel is obtain at almost no extra cost or at marginal increase in cost as manganese is expensive element.

Observation: If base elements of a steel alloy are such as

C –0.26 %

Si- 0.43 %

S-0.006 %

P-0.007 %

With Chemical Composition given above an observation for change in percentage of

Manganese vs Yield Strength has been taken and shown in table 5.1.

Table 5.1- Manganese vs Yield Strength

SAMPLE NO	% OF MANGANESE	YEILD STRENGTH
1	1.08	28.55 PSI
2	1.11	28.95 PSI
3	1.23	30.15 PSI
4.	1.276	34.18 PSI
5.	1.329	38.15 PSI

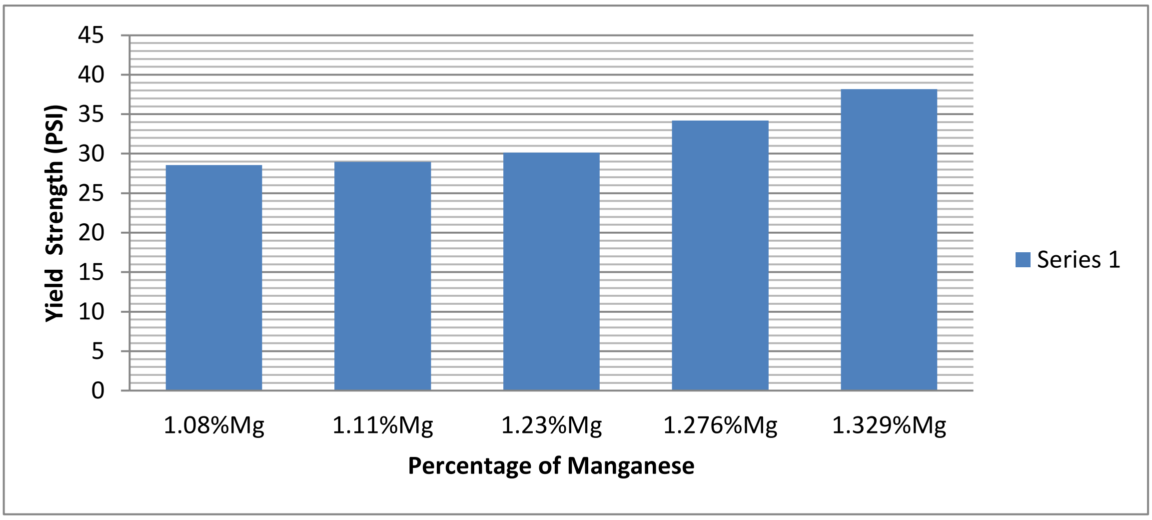

Fig 5.1 Manganese vs Yield Strength

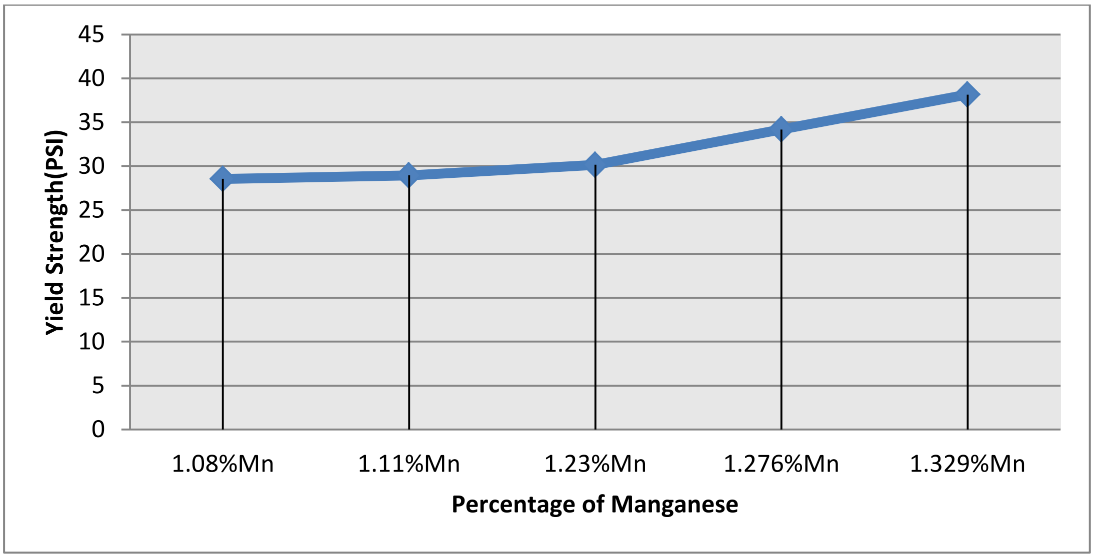

Fig.5.2 Manganese vs Yield Strength

<u>Advantage of Manganese Steel</u>

A wide range of engineering components are manufactured from these steels. Application include

- Gun Barrels
- Rails
- Gears
- axles
- Connecting Rods
- Crank Shafts
- Bolts
- Nuts
- Studs
- Steering Levels
- Air Craft Fittings

5.2 **Effect of *<u>Chromium</u>* in alloy steel**

Addition of chromium increases

- Tensile strength
- Hardness.
- Ultimate Tensile Strength.

Observation: If Base Elements of a steel alloy are such as

C –0.29%

Si- 0.30%

Mn-0.67%

S-0.012%

P-0.018%

Ni-1.56%

Mo-0.22%

V-0.12%

With Chemical Composition given above an observation for change in percentage of

Chromium vs Ultimate Tensile Strength has been taken as shown in table 5.2.

Table 5.2-Chromium vs Ultimate Tensile Strength

Sample No.	% Of Cr	Ultimate Tensile Strength
1	1.30	813 MPa
2	1.41	815 MPa
3	1.53	832 MPa
4	1.63	881 MPa
5	1.67	1001 MPa

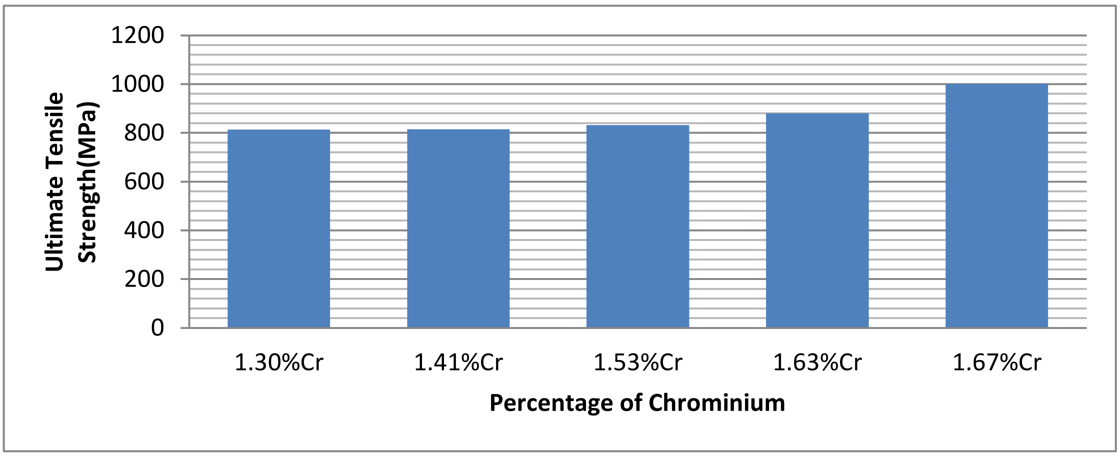

Fig. 5.3 Chromium vs Ultimate Tensile Strength

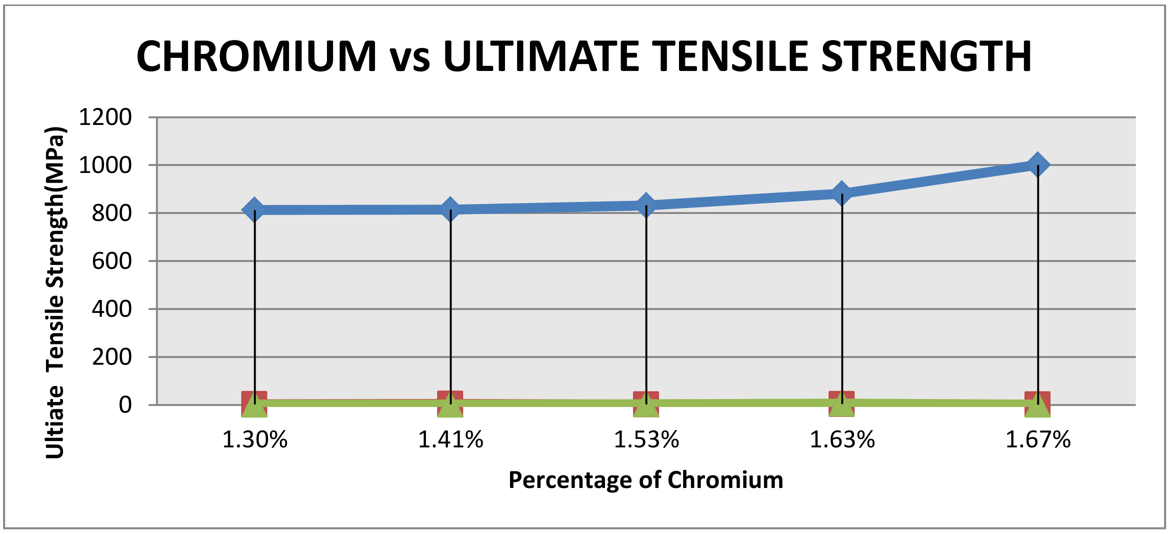

Fig.5.4 Chromium vs Ultimate Tensile Strength

Advantages of Chromium Steel

Low Chromium (.5% Cr), Medium Carbon (.35% C) steels find applications in manufacturing

- Machine Gun Barrels
- Gears
- Jaws of Wrenches
- Axles
- Shafts
- Valve steels
- Tool steel
- Heat resisting steel
- stainless Steel

High Carbon Low Chromium Steels Find many Application as Tool Steels

- Twist Drills
- Hacksaw Blades
- Knives
- Hammers

5.3 Effect of ***Nickel*** in Alloy steel

Addition of nickel in alloys, as compared to plane carbon steel, are characterized by

- Higher tensile strength
- Higher toughness values
- Improved fatigue strength
- Improved impact resistance
- Improved shear strength

Observation: If Base Elements of a steel alloy are such as

C –0.32 %

Si- 0.28 %

Mg-1.35 %

S-0.009 %

P-0.024 %

Cr-0.62 %

Mo-0.41 % .

With Chemical Composition given above an observation for change in percentage of Nickel vs Ultimate Tensile Strength has been taken as shown in table 5.3.

Table 5.3-Nickel vs Ultimate Tensile Strength

Sample No	% Nickel	UTS
1	0.75	100.85 Kgf /mm^2
2	0.807	102.39 Kgf /mm^2
3	0.81	107.15 Kgf /mm^2
4	0.815	109.17 Kgf /mm^2
5	0.84	114.24 Kgf /mm^2

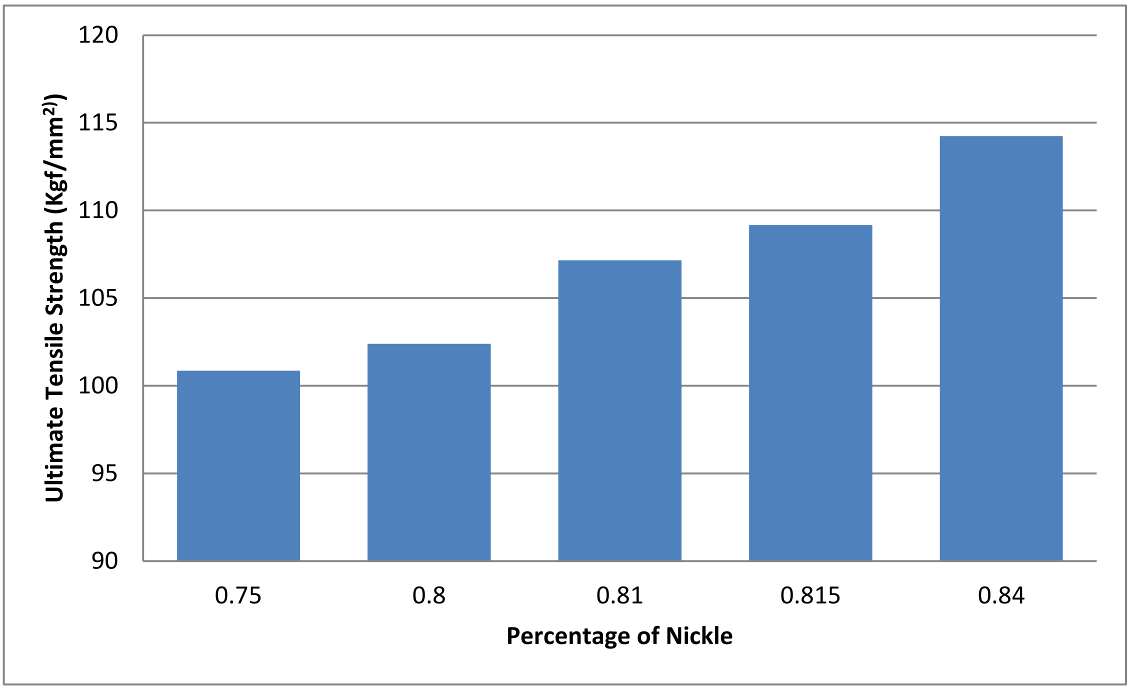

Fig. 5.5 Nickel vs Ultimate Tensile Strength

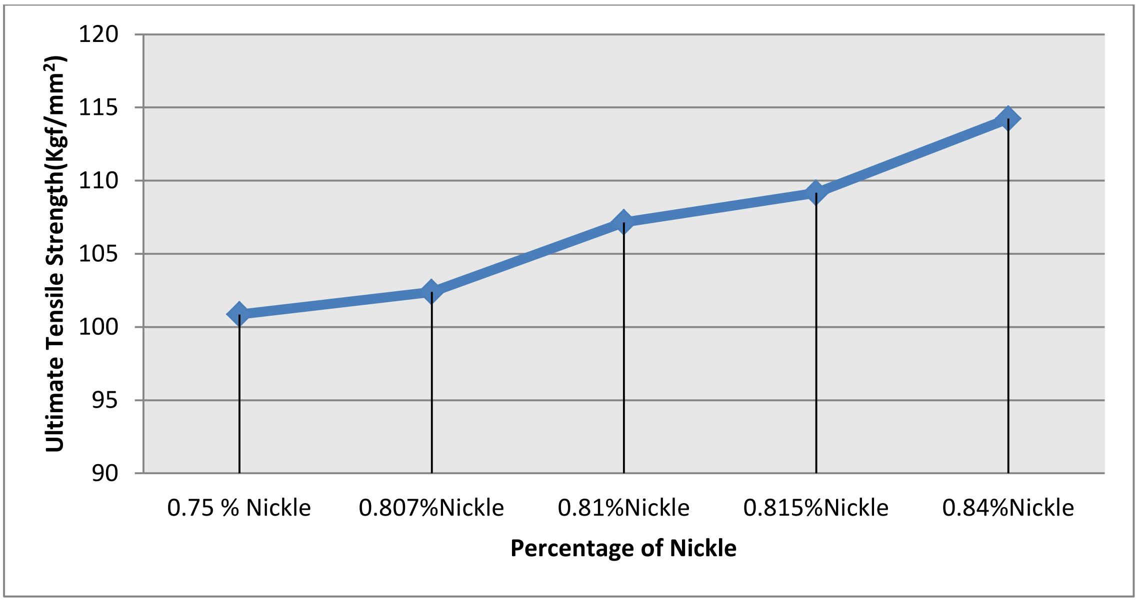

Fig. 5.6 Nickel vs Ultimate Tensile Strength

Advantages of Nickel Steel

Low Nickel Low Carbon steels are widely used for.

- Wrist pins
- Pinions
- Engine Cams
- Transmission gears
- Severe Service Condition Parts

Medium Carbon Low Nickel Steel are mainly used for

- Aeroplane parts
- Crank Shafts
- Pinion Shafts
- Propeller Shafts
- Turbine shafts

5.4 Effect of ***Carbon*** in Alloy Steel

In alloy steel carbon contents effects the

- Machine ability
- Melting point
- Tensile strength
- Hardness

Observation: If Base Elements of a steel alloy are such as

Si- 0.25 %

Mn-0.81 %

S-0.007 %

P-0.016 %

Ni-0.020 %

Cr-0.087 %

Mo-0.01 %

V- 0.005 %

With Chemical Composition given above an observation for change in percentage of **Carbon vs Ultimate Tensile Strength** has been taken as shown in table 5.4.

Table 5.4-Carbon vs Ultimate Tensile Strength

Sample No	% Carbon	UTS
1	0.50	955 MPa
2	0.51	957 MPa
3	0.53	965 MPa
4	0.54	970 MPa
5	0.55	977 MPa

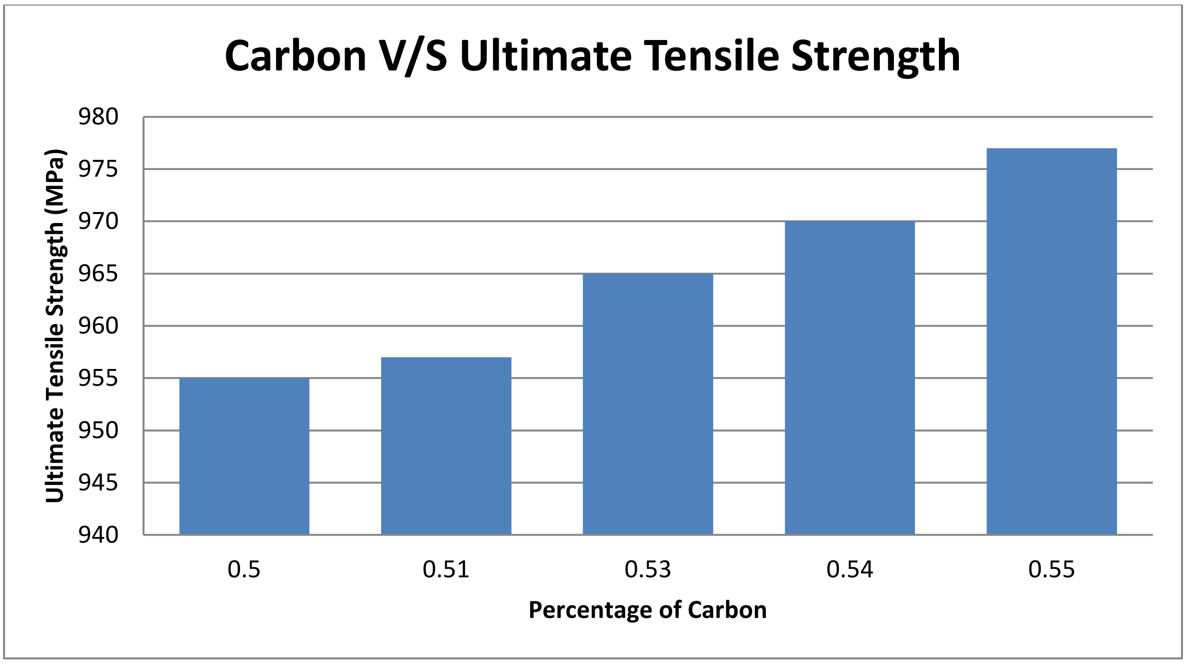

Fig. 5.7 Carbon vs Ultimate Tensile Strength

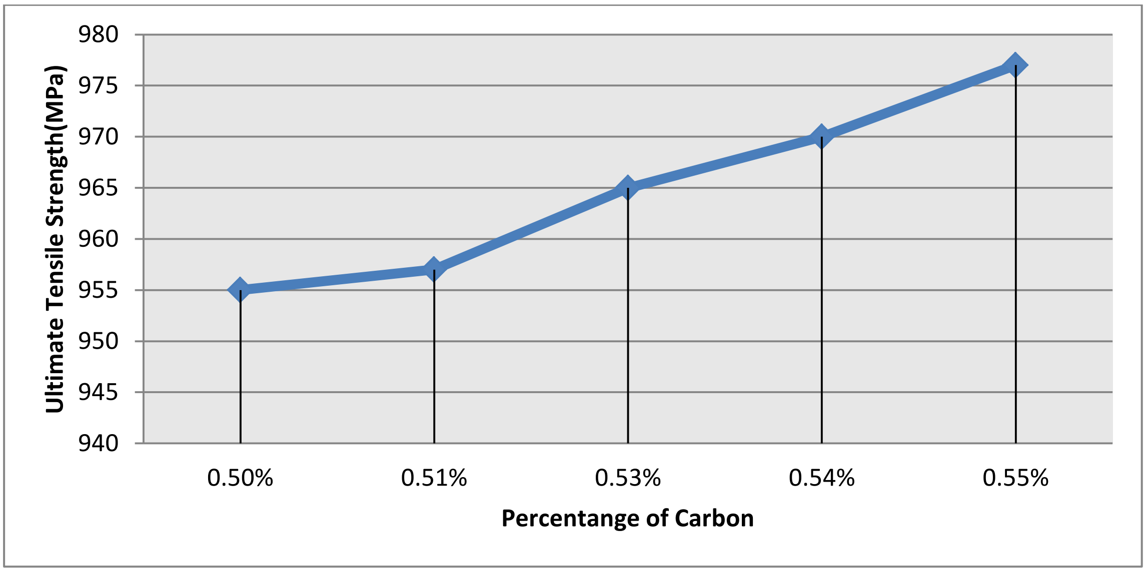

Fig. 5.8 Carbon vs Ultimate Tensile Strength

Advantages of Carbon Steel

Low carbon steel less than 0.10 percent have excellent formability .for this reason , these steels are employed for general engineering constructional work involving severe cold deformation such as

- Bending
- Riveting
- Deep drawing

Steel with 0.10-0.25 percent carbon possess high strength and toughness .some typical applications include.

- Ship plates
- Boiler plates
- Cams
- Shafts
- Stay bolts
- Wheels hubs
- Brake housing
- Brake paddle levers

Steels with carbon varying from 0.25 percent to 0.65 percent are referred to as medium carbon steels. Typical applications include

- Rifle barrels
- Spindles of machine tools
- Gears
- Bolts
- Shafts
- Axles
- Pinions
- Cams
- Crank shafts
- Keys
- Machine tools
- Ball mills balls

The carbon content of high carbon steels generally varies from 0.65 percent to 1.5 percent. The higher the percentage of carbon, more is the strength with brittleness.

Typical applications are

- Gauges
- Machine knives
- Piston rings
- Saws
- Cutting tools
- Chisels
- Hand Tools

5.5 Effect of Molybdenum in alloy Steel

By addition of molybdenum, these properties of steel alloy can be significantly improves

- Harden ability
- Ductility
- Toughness
- Temperature properties
- Tensile Strength

Observation: If Base Elements of a steel alloy are such as

C –0.33 %

Si- 0.20 %

Mg-1.34 %

S-0.016 %

P-0.030 %

Ni-1.08 %

Cr-0.75 %

With Chemical Composition as given above an observation for change in percentage of **Molybdenum vs Ultimate Tensile Strength** has been taken and shown in table 5.5.

Table 5.5-Molybdenum vs Tensile Strength

Sample No	% Molybdenum	Ultimate Tensile Strength
1	0.37	102.47 Kgf/mm^2
2	0.40	104.38 Kgf/mm^2
3	0.44	109.16 Kgf/mm^2
4	0.469	115.03 Kgf/mm^2
5	0.47	115.99 Kgf/mm^2

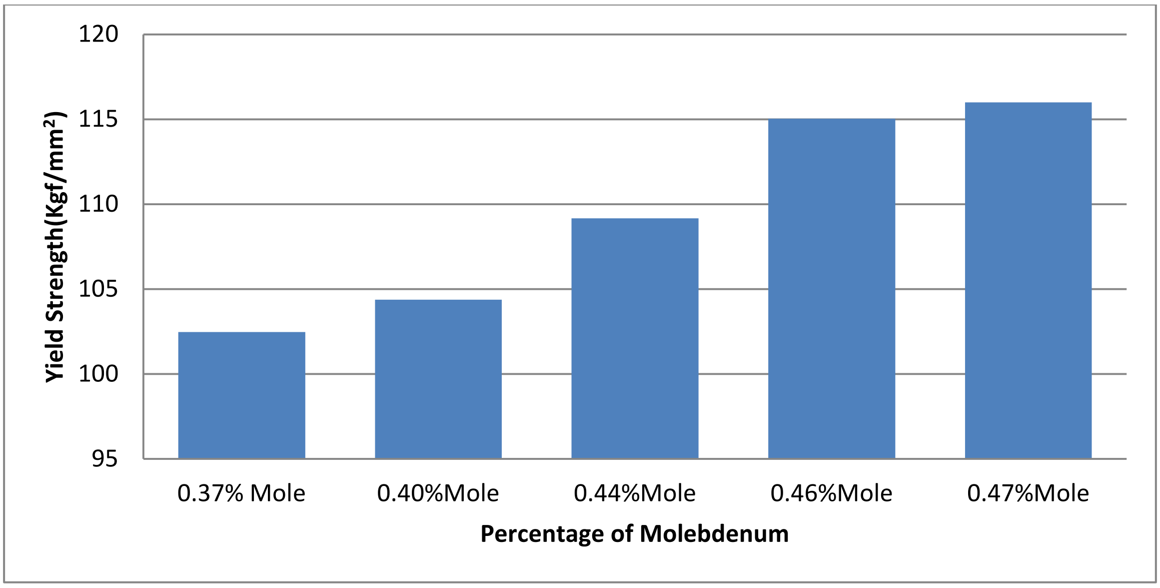

Fig.5.9 Molybdenum vs Ultimate Tensile Strength

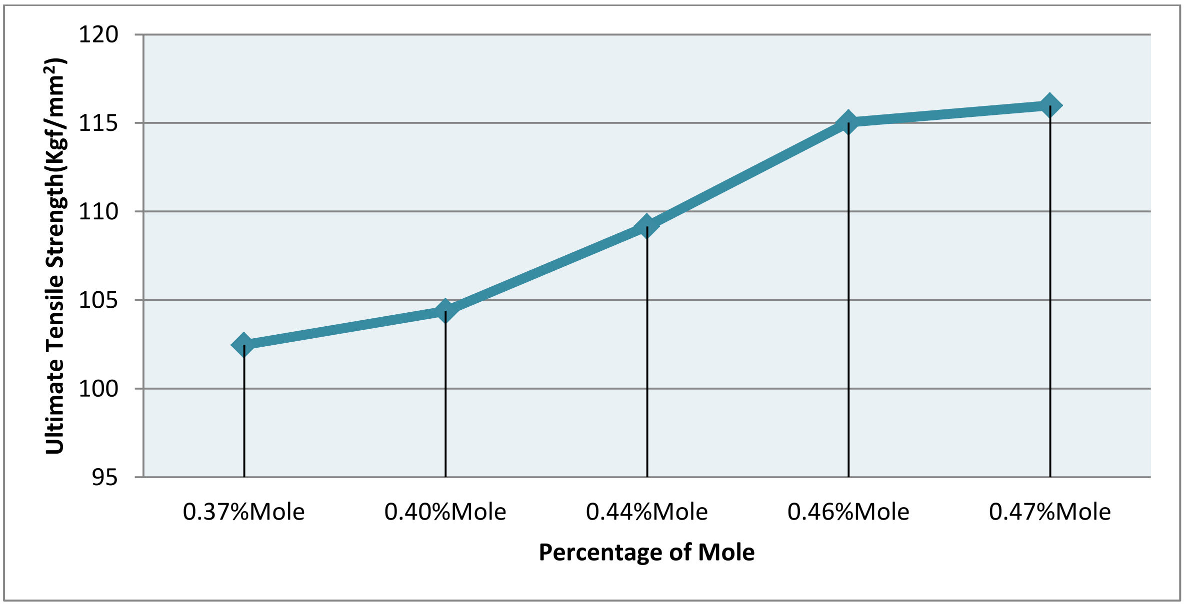

Fig. 5.10 Molybdenum vs Ultimate Tensile Strength

Advantages of Molybdenum steel

Molybdenum Steel are used for manufacturing

1. Air craft Landing Gear.
2. Pressure Vessels
3. Coil and leaf Springs
4. Transmission Gears.

CONCLUSIONS AND SCOPE OF FURTHER WORK

CHAPTER 6

CONCLUSIONS

The Present Study shows the effect of varying percentage of individual alloying elements on mechanical behavior of cast steel. In this study, the effects of individual percentage of alloy element varied keeping the constant percentage of rest of other elements in composition.

1. In Study of alloy element manganese with chemical composition (C-.26%, Si-0.43%, Mn-1.08%, S-0.006%, P-0.007%) steel is casted. Yield Strength has been found 28.55 TSI. It has been observed that as the percentage of manganese increases, yield strength increases.
2. In study of alloy element chromium with chemical composition (C-0.29%, Si-0.30%, Mn-0.675%, S–0.12%, P-0.018%, Ni-1.56 %, Cr-1.30%, Mo-0.22%,V-0.12%) steel is casted. The ultimate tensile strength (UTS) has been found 813 MPa. It has been observed that as the percentage of chromium increases, the ultimate tensile strength (UTS) also increases.
3. In the study of alloy element nickel with chemical composition (C-0.32%, Si -0.289% , Mn-1.356%, S- 0.009, P-0.24%, Ni-0.75%, Cr-0.618%, Mo -0.41%) steel is casted. The results shows that the ultimate tensile strength (UTS) has been found 100.85 kg force/mm^2 and UTS has been found increased on increase of percentage of nickel content.

4. In study of alloy element carbon with chemical composition (C-0.50%, Si -0.25%, Mn-0.81%, S- 0.007, P-0.016%, Ni-0.020%, Cr-0.087%, Mo-0.010%, V–0.005%) steel is casted. The ultimate tensile strength (UTS) has been found 955 MPa and found increased on increase of percentage of carbon content.

5. In study of alloy element molybdenum with chemical composition (C-0.33%,Si -0.20%, Mn-1.34%, S- 0.016, P-0.030%, Ni-1.08%, Cr-0.75%, Mo -0.37%) steel is casted. The ultimate tensile strength (UTS) has been found 102.47 Kg force /mm^2. When percentage of molybdenum increased, UTS also found increased.

Scope of Further Work

Steel drives its mechanical properties from a combination of chemical composition, heat treatment and manufacturing processes. While the major constituent of steel is iron, the addition of very small quantities of other elements can have a marked effect upon the properties of the steel. The strength of steel can be increased by the addition of alloys such as manganese, nickel and vanadium. However, these alloy additions can also adversely affect other properties, such as ductility, toughness and weld ability. In same manner heat treatment and manufacturing process may have positive effect on one property and diverse effect on other property.

Hence, a further research work may be done to find the practical data's of chemical compositions, heat treatment and manufacturing process in such a manner that achievement of required mechanical properties in steel may be done with out hit and trial method.

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