Scientific Journal of Impact Factor(SJIF): 3.134
e-ISSN(O): 2348-4470
p-ISSN(P): 2348-6406
International Journal of Advance Engineering and Research Development
Volume 2,Issue 2, February -2015

Effects of Mechanical Properties of Medium Carbon Steel by Tempering Process at Different Temperature

[1]Amarishkumar J. Patel, [2]Sunilkumar N. Chaudhari
[1] *Mechanical Engineering Department, BBIT V.V.Nagar, ajpatelmech@gmail.com*
[2] *Mechanical Engineering Department, BBIT V.V.Nagar, sunil.bbit@gmail.com*

Abstract *— To study the effects of Tempering process at different temperature on the mechanical properties of medium carbon steel. These standard specimens were examined at 1000^0 C temperatures and soaking for 2 hours in a muffle furnace and quenched in oil. Then these specimens were carried out for Universal Izod testing machine for toughness, Rockwell hardness method for hardness testing and universal tensile testing machine for tensile test. After testing of the specimens, the hardness and tensile strength and yield strength was decrease and proportionally elongation, ductility and toughness increase. So it improved mechanical properties of medium carbon steel and modified by tempering process. The medium carbon steel is used at different purpose and application as per the requirement. Tempering is Heat treatment processes which can change and improve mechanical properties of medium carbon steel.*

Keywords- *Tempering process, Hardness, Tensile Strength, Yield Strength, Toughness, Medium carbon steel*

I. INTRODUCTION

This brief glossary of heat-treating terms has been adopted by the American Foundry men's Association, the American Society for Metals, and the American Society for Testing and the Society of Automotive Engineers [1].Heat treatment is a process to change certain characteristics of metals and alloys in order to make them more suitable for a particular kind of application [2] by controlling the rate of diffusion and the rate of cooling within the microstructure by changing the molecular arrangement and grain size at different phases of a material [3].Heat treatment is the term used for any process employed which changes the physical and sometimes chemical properties of a metal by either heating or cooling[4].Heat treatment techniques include annealing, case hardening, precipitation strengthening, tempering and quenching[5, 6]. Heat treating can modify mechanical properties such as strength, hardness, ductility, toughness, and wear and corrosion resistance [4, 6, 7]. The large number of service requirements and amount of alloys available make for a considerable variety of heat treating operations. Steel can be treated by intense heat to give it different properties of hardness and softness [4, 7]. This depends on the amount of carbon in the steel like in Mild steel up to 0.4% carbon, in Medium carbon steel up to 0.8% carbon, and in High Carbon Steel up to 2% carbon [4, 5, 7].Mild steel and medium carbon steel do not have enough carbon to change their crystalline structure and consequently cannot be hardened and tempered. Medium carbon steel may become slightly tougher although it cannot be harden to the point where it cannot be filed or cut with a hacksaw (the classic test of whether steel has been hardened) [4].If steel is heated until it glows red and is quenched in clean water immediately, it becomes very hard but also brittle. But, if the red hot steel is allowed to cool slowly, the resulting steel will be easier to cut, shape and file as it will be relatively soft. However, the industrial heat treatment of steel is a very complex and precise science [6]. Bolts, rods, crankshafts, Axles, gears and tunings in the automotive industry are generally made by medium carbon steel [8].

II. LITERATURE REVIEW

Most widely used engineering metals and alloys are the ferrous metals and their alloys in form of wrought iron, cast iron, carbon steels, alloys steels etc. steel is malleable alloy of iron and carbon [9]. Two different grades of Steel (one with copper and another without copper) have been used .Current work reports and analyze result of mechanical testing performed on various heat treated samples of two grades of steel. The samples are tempered at 200°C, 400°C and 600°C for 1 hr. Heat treated samples were then mechanically tested for hardness (Rockwell) ,tensile properties (ultimate Strength, ductility) and the microstructure, The comparison of mechanical properties and microstructure of two grades of steel has also been studied. The results revealed that steel with copper has high hardness, ultimate tensile strength and low ductility [10].The steel was heated to the austenizing temperature of 830^0 C. The steel was then rapidly quenched in water and tempered at 480^0 C. The result shows that the steel developed has excellent combination of tensile strength, impact strength and ductility which is very attractive for structural use [1].Quenched part has to be tempered, so as to impact some toughness and ductility. The reports and analyses results of mechanical testing was performed on variously heat treated medium carbon steel samples, to arrive at an optimum heat treatment strategy for judicious combination of hardness and tensile properties. The optimum heat treatment strategy was found to be at tempering temperature of 250ºC for well balanced mechanical properties [11].The best combination of hardness, strength, toughness and strain to fracture was achieved with the use of an initial cold rolling and two cycles of inter critical annealing at 770^0C[12] .The conditions of heat treatment consisted of isothermal quenching of the specimens to a temperature range of 250 to 550°C, where they were held for 600 and 1800 s. Increasing the carbon concentration to 0.55% in TRIP-type steels makes possible to obtain very high strength properties without a deterioration of the ductility. The retained austenite of the 19% volume fraction can be obtained after the isothermal quenching of the steel to a temperature of 250°C [13].Samples of medium carbon steel were examined after heating between 900ºC- 980ºC and soaked for 45 minutes in a muffle furnace before quenching in palm oil and water separately. This behaviour was traced to the fact that the carbon particles in palm oil quenched samples were more uniform and evenly distributed, indicating the formation of more pearlite structure, than those quenched in water and the as-received samples [14].Representative samples of as-rolled medium carbon steel were subjected to heat treatment processes which are; Quenching, Lamellae Formation and Tempering in the following order (Q + Q + L + T), (Q + L + T) and (L + T). The steel was heated to the austenizing temperature of 830 °C and water quenched. Mechanical tests were carried out on the samples and the results shows that the steel developed has excellent combination of tensile strength, hardness and impact strength which is very good for structural applications [2].

III. MATERIALS AND METHODS

A. Tempering process

Martensite formed during the quenching process is extremely hard and brittle, and lacks toughness. Thus these steels are not suitable for some application requiring impact resistance. Hence, a secondary heat treatment process called ‘Tempering’ is carried out on quenched steels, to achieve the necessary toughness and ductility by marginally sacrificing hardness. This process also relieves the internal stresses thus improving the ductility [15]. First, the metal substrate is heated to the whole work piece to a specific area. This focus area will becomes red- or white-hot before long. The hardness of the metal lessens while the toughness increases. Once the work piece has been adequately heated, it is cooled in water. Steam exhausts from the heated work piece, and the metal grows incredibly brittle. This process is fast process and quick cooling will result in brittle metal. Next, the cooled metal is reheated and concentrated directly on the focus area. The heated metal is placed on a steel surface to cool in furnace. The piece cools by heat transfer from the work piece to the steel surface metal. Once this piece is completely cool, the piece has increased toughness and is considered tempered. The initial heating stage, it creates austenite which is the combination of iron and carbon. When steel gets above a certain temperature (730°C), it becomes austenite. When the austenite steel is submerged in water, or quenched, it becomes martensite. Martensite is a hard and brittle crystalline structure so it reheated to reduce the hardness [16].

B. Chemical composition

The materials used for this research work are Medium carbon steel with the chemical composition shown in Table 1

Table 1. Chemical composition of the medium carbon steel sample

Element	C	Si	S	P	Mn	Ni	Cr	Mo	Fe
Avg. content	0.35	0.20	0.04	0.03	0.70	0.08	0.05	0.01	Rest of Fe (Balanced)

C. Mechanical properties testing methods

1. Rockwell Hardness Testing:

Hardness is a characteristic of a material, not a fundamental physical property. It is defined as the resistance to indentation, and it is determined by measuring the permanent depth of the indentation. More simply put, when using a fixed force (load) and a given indenter, the smaller the indentation, the harder the material. Indentation hardness value is obtained by measuring the depth or the area of the indentation using one of over 12 different test methods.
The Rockwell method measures the permanent depth of indentation produced by a force/load on an indenter. First, a preliminary test force (commonly referred to as preload or minor load) is applied to a sample using a diamond indenter. This load represents the zero or reference position that breaks through the surface to reduce the effects of surface finish. After the preload, an additional load, call the major load, is applied to reach the total required test load. This force is held for a predetermined amount of time (dwell time) to allow for elastic recovery. This major load is then released and the final position is measured against the position derived from the preload, the indentation depth variance between the preload value and major load value. This distance is converted to a hardness number [17].

2. Universal testing machine:

Tensile testing is a destructive test process that provides information about the tensile strength, yield strength and ductility of a material.

The tensile test or tension test involves applying an ever-increasing load to a test sample up to the point of failure. This process creates a stress verses strain curve showing how the material reacts throughout the tensile test. The data generated during tensile testing is used to determine mechanical properties of materials and provides the following quantitative measurements:

- Tensile strength or Ultimate Tensile Strength (UTS) is defined as the maximum load divided by the original cross-sectional area of the test sample.
- Yield strength is the stress at which time permanent (plastic) deformation is observed to begin.
- Ductility is defined as the strain at the point of fracture, and reduction of area after the fracture of the test sample [18].

3. The Izod impact test:

The Izod impact test consists of a pendulum with a determined weight at the end of its arm swinging down and striking the specimen while it is held securely in a vertical position. The impact strength is determined by the loss of energy of the pendulum as determined by precisely measuring the loss of height in the pendulum's swing. The Specimen size and shape vary with the Izod impact test according to what materials are being tested. Specimens of metals are usually square, and polymers are usually rectangular being struck perpendicular to the long axis of the rectangle. The Ductile to Brittle Transition Temperature may be obtained by testing a number of identical specimens at different temperatures, and then plotting the impact energy as a function of temperature, the ductile-brittle transition becomes apparent as the resulting curve shows a rapid decline in impact strength as the temperature increases. This is essential information to obtain when determining the minimum service temperature for a material [19][20].

IV RESULTS AND DISCUSSIONS

These standard specimens were heated at 1000^0 C temperatures and soaking for 2 hours in a muffle furnace and quenched in oil. These specimens were carried out for at different tempering temperature like 200° C to 650°C at interval of 50°C temperature. Then perform different test on different machine like Universal testing machine for tensile strength and yield strength, Rockwell hardness testing machine for hardness and Izod testing machine for toughness test at different temperature. After testing of the specimens, elongation, ductility and toughness increase and proportionally the hardness and tensile strength was decreased. So it improved mechanical properties of medium carbon steel and modified by tempering process.

1. **Hardness:** For different tempering temperature, values of hardness (HRC) for specimens also differ. The observations are shown in following table no.2.The data from the observation table plotted on graph. The relation between tempering temperature and hardness is inversely proportional.

Table no 2: Data for Tempering Temperature Vs. Hardness

Tempering Temperature (°C)	200	250	300	350	400	450	500	550	600	650
Hardness (HRC)	59	55.6	51.4	48.7	45.8	42.1	38.7	36	33.5	28

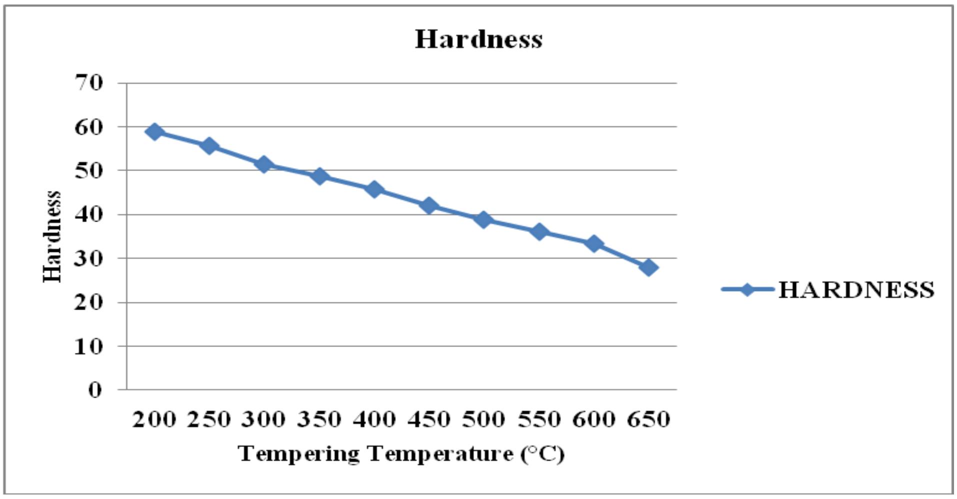

Fig.1Hardness (HRC) verses Tempering Temperature (°C)

2. Tensile strength: For different tempering temperature, values of Tensile strength (N/mm^2) for specimens also differ. The observations are shown in following table no.3.The data from the observation table plotted on graph. The relation between tempering temperature and Tensile strength is inversely proportional.

Table no 3: Data for Tempering Temperature Vs. Tensile strength

Tempering temperature(°C)	200	250	300	350	400	450	500	550	600	650
Tensile strength (N/mm^2)	413	404	393	385	374	362	357	346	339	328

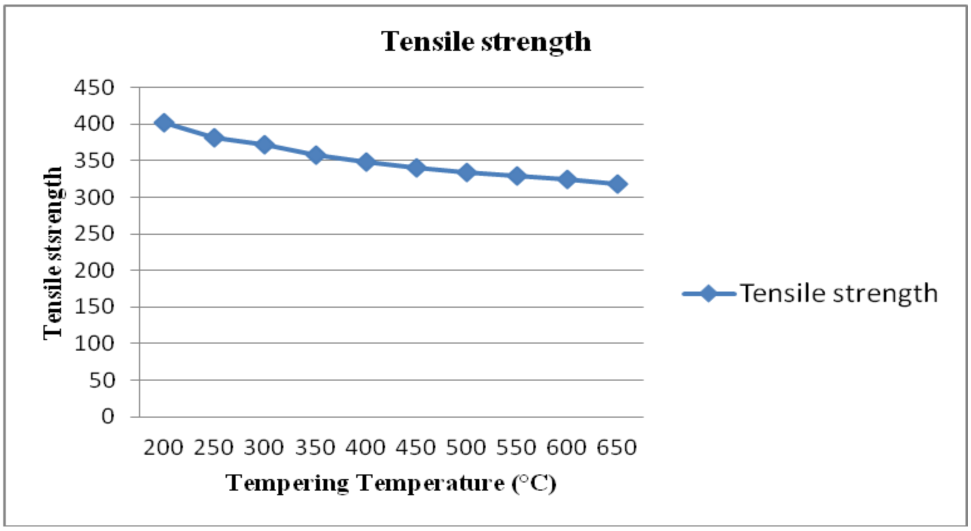

Fig.2 Tensile strength (N/mm2) verses Tempering Temperature (°C)

3. Yield Strength: For different tempering temperature, values of Yield Strength (N/mm^2) for specimens also differ. The observations are shown in following table no.4.The data from the observation table plotted on graph. The relation between tempering temperature and Yield Strength is inversely proportional.

Table no 4: Data for Tempering Temperature Vs. Yield Strength

Tempering temperature(°C)	200	250	300	350	400	450	500	550	600	650
Yield Strength (N/mm2)	310	283	270	273	265	271	260	239	224	213

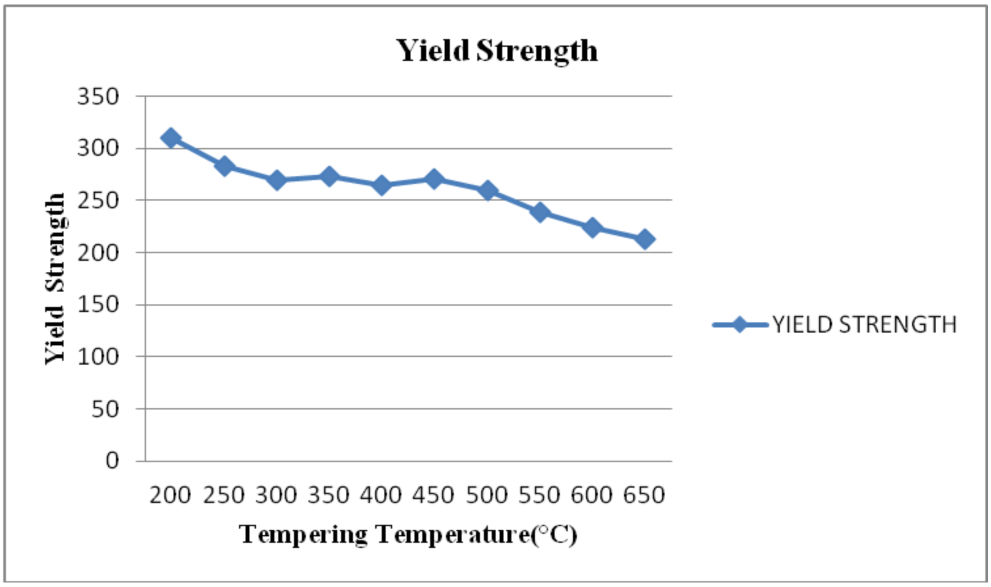

Fig.3 Yield Strength (N/mm2) verses Tempering Temperature (°C)

4. Toughness: For different tempering temperature, values of Toughness (Joule) for specimens also differ. The observations are shown in following table no.5. The data from the observation table plotted on graph. The relation between tempering temperature and Toughness is proportional increase in nature.

Table no 5: Data for Tempering Temperature Vs. Toughness

Tempering temperature(°C)	200	250	300	350	400	450	500	550	600	650
Toughness (Joule)	62.3	61.2	59.2	57.4	59.8	61.1	62.8	64.8	65.2	67

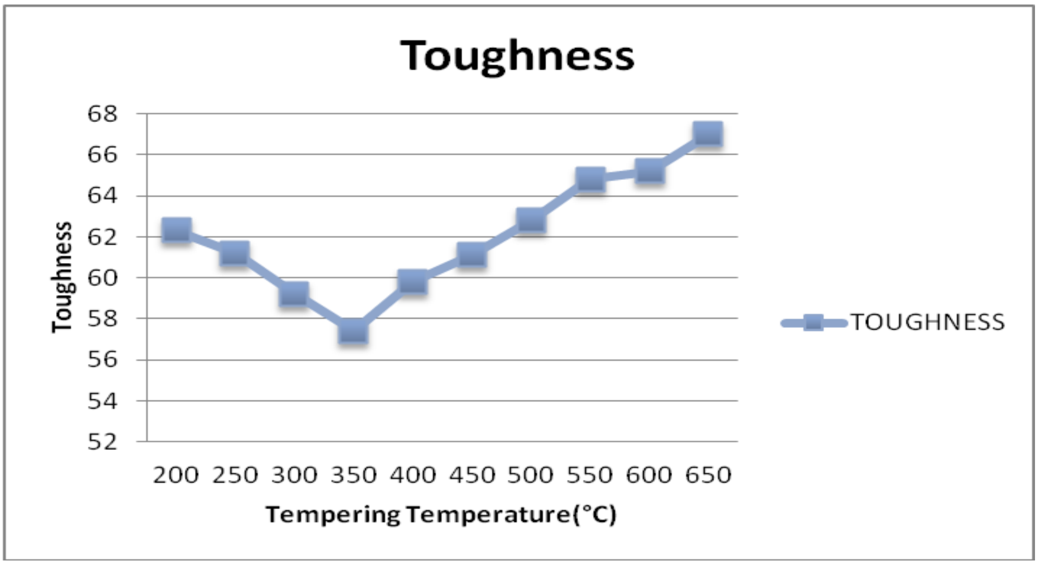

Fig.4 Toughness (N/mm2) verses Tempering Temperature (°C)

5. Elongation: For different tempering temperature, values of Elongation for specimens also differ. The observations are shown in following table no.6.The data from the observation table plotted on graph. The relation between tempering temperature and Elongation is proportional increase in nature.

Table no 6: Data for Tempering Temperature Vs. Elongation

Tempering temperature(°C)	200	250	300	350	400	450	500	550	600	650
Elongation (%)	36	37.4	36.3	35.5	38.4	41.6	43.7	45.9	47.6	50.4

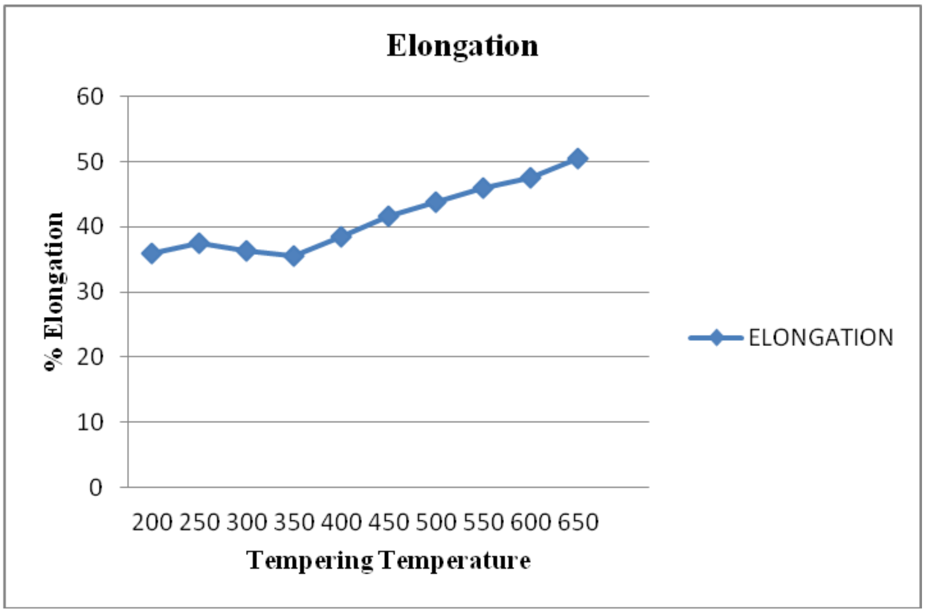

Fig.5 Elongation verses Tempering Temperature (°C)

IV. CONCLUSION

From the various experiments carried out, the following observations were made.

1. The mechanical properties vary depending upon the tempering processes.
2. When increase the Tempering Temperature the mechanical properties like Toughness and Elongation were found increase.
3. When increase the Tempering Temperature the mechanical properties like Hardness, Tensile Strength and Yield Strength were found decrease.

REFERENCES

[1] http://www.wisoven.com/technical/heat-treat-definitions (access on 21/02/2015)
[2] https://www.fastenal.com/web/en/73/heat-treatment (access on 21/02/2015)
[3] http://en.wikipedia.org/wiki/Heat_treating (access on 21/02/2015)
[4] Daramola O. Oluyemi, Oladele Isiaka luwole, B. O. Adewuyi ,"Studies of the Properties of Heat Treated Rolled Medium Carbon Steel",Materials Research. 2011; 14(2): 135-141, 2011, DOI: 10.1590/S1516-14392011005000040
[5] Sanjib kumar jaypuria," Heat Treatment Of Low Carbon Steel ", Project Report, NIT-Rourkela,p-11-13, 2008-09
[6] V.K.Murugan, Dr.P.Koshy Mathews,"Effect of Tensile Properties on Heat Treated 0.38% Medium Carbon Steel", International Journal Of Engineering Sciences & Research Technology, [Murgan, 2(2): Feb., 2013]
[7] O.O. Daramola, B.O. Adewuyi and I.O. Oladele, "Effects of Heat Treatment on the Mechanical Properties of Rolled Medium Carbon Steel" , Journal of Minerals & Materials Characterization & Engineering, Vol. 9, No.8, pp.693-708, 2010
[8] http://www.ehow.com/info_8520946_uses-mediumcarbon-steel.html (access on 21/02/2015)
[9] V.K.Manchanda,G.B.S.Narang, "Materials and Metallurgy", Khanna Publishers, Six Edition ,2009
[10] B.S. Motagi, Ramesh Bhosle, "Effect of Heat Treatment on Microstructure and Mechanical Properties of Medium Carbon Steel", International Journal of Engineering Research and Development ISSN: 2278-067X, Volume 2, Issue 1 (July 2012), PP. 07-13
[11] S.A Tukur , M. M Usman, Isyaku Muhammad, N. A Sulaiman, "Effect of Tempering Temperature on Mechanical Properties of Medium Carbon Steel", International Journal of Engineering Trends and Technology (IJETT) – Volume 9 Number 15 - Mar 2014
[12] K. K. Alaneme ,O. J. Adejumo,J.O. Borode, "Influence of different cyclic inter critical Heat treatment schedules on the microstructure and Mechanical behaviour of a dual phase medium carbon low alloy steel", Association of Metallurgical Engineers of Serbia (AMES) ,Scientific paper UDC: 669.14

[13] A. Grajcar, "Heat treatment and mechanical stability behavior of medium-carbon TRIP aided bainitic steel",Archives of Materials Science and Engineering, Volume 33 ,Issue 1,September 2008, Pages 5-12

[14] Jamiu Kolawole Odusote, Tajudeen Kolawole Ajiboye, Abdulkarim Baba Rabiu, "Evaluation of Mechanical Properties of Medium Carbon Steel Quenched in Water and Oil", AU J.T. 15(4): 218-224 (Apr. 2012)

[15] P.N.Rao, "Manufecturing Technology" Tata Mcgraw Hill, Second edition,2008

[16] Bozidar Liscic, Hans M. Tensi, Lauralice C.F. Canale, George E. Totten "Quenching Theory and Technology" CRC publication ,Second Edition

[17] V. S. Vutukuri, R. D. Lama, S. S. Saluja, "Handbook on mechanical properties of rocks: testing techniques and results" Trans Tech Publications,Volume 4, 1978

[18] Joseph R. Davis, " Tensile Testing" , ASM international ,2nd Edition,2004

[19] William Bolton, "Engineering Materials" Elsevier, Volume 2

[20] S. K. Mandal, "Steel Metallurgy" Tata Mcgraw Hill

