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Effect of Tempering Process on EN-24 Steel Alloy

[1]Prashant S D Assistant Professor, Dept of Mechanical Engineering BGTI (BRIG), Hyderabad, India
[2]Sushil Dange Assistant Professor, Dept of Mechanical Engineering BGTI (BRIG), Hyderabad, India
[3]Shyam Sundar Luha Assistant Professor, Dept of Mechanical Engineering BGTI (BRIG), Hyderabad, India
[4]Prabhu Kurthkoti Assistant Professor, Dept of Mechanical Engineering Sri Indu College of Engineering and Technology, Hyderabad, India

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Abstract - *EN-24 combination steel is extensively utilized as a part of assembling of high tractable clasp and jolts where both rigidity and lengthening assumes critical part .High elastic jolts has noteworthy influence in the field of machine building, earth moving hardware, scaffolds and petrochemical industries. In this work the material is subjected to arrangement of warmth medicines forms, extinguishing, treating at 300,400,500,600 and 700 c. Mechanical properties like rigidity, rate of extension and rate of zone decrease, strength and hardness values and decided previously, then after the fact heat treatment of the material. the small scale basic investigation was completed utilizing optical magnifying instrument to concentrate on the stage change that happen amid the treating procedure. result appears in rigidity , hardness and yield quality diminishing as treating increments, and rate of extension, rate of lessening in zone and sturdiness increment altogether.*

***Key Words*: Maximum Tensile strength, Maximum Yield strength, % of Elongation, % of Reduction in Area**

1. INTRODUCTION

while we probably am aware here is a tiny small piece of steel in everyone being. strengthen has numerous commonsense applications within every parts of living. Steel through helpful properties be the finest between the products. The steel is being separated as low down carbon steel, high carbon steel, middle carbon steel, high carbon steel under the foundation of carbon substance. low down carbon steel contain less than the 0.3% of carbon, Medium carbon steels are contain 0.3% to 0.8% carbon content and high carbon steels have a more than 0.8% of carbon content. small carbon steel is the most regular type of steel as it is gives substance properties to are satisfactory used for some applications. It be neither remotely fragile nor malleable because of it is lesser carbon content. It have minor rigidity and pliable. Steel among little carbon steel have properties like flatten. while the carbon satisfied builds, the metal gets to be stronger with more grounded however not so much flexible but rather more hard to weld. The procedure heat treatment is done first by warming the metal and after that cooling it in water, oil and brackish water. The reason for warmth treatment is to diminish the metal, to change the grain size, to adjust the structure of the material and remember the anxiety set up in the material. The different warmth treatment procedure are strengthening, normalizing, solidifying, austempering, spoil treating, treating and surface solidifying. Case solidifying is the procedure of solidifying the surface of metal, regularly low carbon steel by imbuing components into the metal surface shaping a hard, wear resistance skin however protecting an intense and flexible connected to riggings, metal rollers, railroad wheels. seeing that my venture worried it is fundamentally focus on carburizing is to be a container solidifying progression. It is a procedure of count carbon toward plane. These are finished via presenting the element to carbon well-off air on the raised heat as well as permit dispersion toward exchange the carbon molecules addicted to the steel. This dissemination chip away at the standard of differential focus In any case, it is difficult to experience all the carburizing procedure like gas carburizing, space carburizing, plasma carburizing and brackish shower carburizing. therefore we experience group carburizing which be able to undoubtedly finished during test system. within this procedure the piece toward be carburized is set in a steel holder, thus that it is totally encompassed through granules of charcoal which has initiated by barium carbonate. The carburizing procedure do not go hard the steel it just builds the carbon substance on the way to a few pre decided profundity beneath the surface to an adequate level to permit consequent extinguish solidifying. The most essential warmth medicines and their motivations are: Stress calming - a low-temperature treatment, to diminish or assuage Internal anxieties staying in the wake of throwing Tempering - to enhance malleability and strength, to decrease hardness and to evacuate carbides Normalizing - to enhance quality with some malleability Hardening and treating -to expand hardness or to give enhanced Strength and higher verification stress proportion. Austempering - to yield bainitic structures of high quality, with huge malleability and great wear resistance. Surface solidifying - by incitement, fire, or laser to create a nearby wear safe hard surface

2.RESEARCHMETHODOLOGIES(EXPERIMENTAL PROCEDURE)

2.1 Material Selection

Entrance of Non Metallic Material has given new point to building materials and Producing Field. These Non-Metallic materials show low weight. Metallic materials will show brilliant properties specifically high quality, great Thermal and Mechanical properties. To select a legitimate application originator ought to have sound learning of building materials and their properties.

Blend of high quality and flexibility makes steel much better when looked at than nonmetallic materials and different amalgams. Exceptionally focused on segments like apparatuses,
interfacing bars, axles, crankshafts and gear's for mineral preparing commercial ventures are fabricated from amalgam steels subjected to routine warmth treatment to accomplish coveted mix of strength also, high quality.

EN-24 Steel is a low amalgam steel, this classification of steel is utilized for high malleable latches where both pliable and extension is principle criteria, high malleable jolts has huge part in the field of Machine building, earth moving equipment's, extensions, Petrochemical commercial ventures, weight valves and all overwhelming commercial ventures. Vibrating screening hardware is one of the surely understood gear tends to wear amid mineral handling. EN-24 Steel is likewise utilized as a part of car driving components, for example, crankshaft, front vehicle axels, pivot diary, high ductile jolts, studs and propeller shaft joints, apparatus holders and device joints, oil industry drill collars, water driven hardware shafts, apparatus holders, controlling parts. This sort of steel is classified as "extinguished Tempered" steel, which is predominant stage after traditional warmth treatment is tempered martensite as reported in ASM Handbook (1991)

Considering above perspectives, the EN-24 material is chosen to concentrate on the impact of treating treatment on its hardness and rigidity, which are critical mechanical properties in the applications.

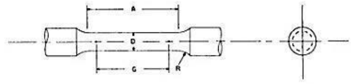
2.2 Chemical Composition Test

Before getting the material, the synthetic structure test is directed to assess the rate of alloying components present in the EN-24 Material. Shift in the rate of alloying components will change the microstructure and partnered mechanical properties. one of the primary alloying component in the EN-24 steel is carbon which is in charge of its hardness. Taking after Table shows ordinary arrangement of EN24 Material

Typical Chemical Composition of EN-24 Steel	
Carbon	0.36-0.44%
Silicon	0.10-0.35%
Manganese	0.45-0.70%
Nickel	1.30-1.70%
Chromium	1.00-1.40%
Molybdenum	0.20-0.35%

I. Preparation of Test Specimen For Tensile Test

ASTM E8M Standard EN-24 Material examples are set up as per ASTM E8M Standards which is the measures endorsed by the ASTM for rigidity test for steel. Fig 3.3 Shows the ASTM E8M standard Test Specimen for Tensile Test. Which demonstrates the measurements and resistance which is to be embraced while outlining the test piece example test. in this work Standard specimen which has the width 12.5mm is utilized. It is encouraged to utilize the principles as indicated by Universal testing machine (UTM) detail furthermore which fits ASTM guidelines. Utilization of little size specimen gauges is utilized when the UTM detail does not fit to Standard size.



	Dimensions, mm				
	Standard Specimen	Sall-Size Specimens Proportional To Standard			
	12.5	9	6	4	2.5
G—Gage length	62.5 6 0.1	45.06 0.1	30.0 6 0.1	20.06 0.1	12.5 6 0.1
D—Diameter (Note 1)	12.5 6 0.2	9.0 6 0.1	6.0 6 0.1	4.0 6 0.1	2.5 6 0.1
R—Radius of fillet, min	10	8	6	4	2
A—Length of reduced section, min (Note 2)	75	54	36	24	20

NOTE 1—The reduced section may have a gradual taper from the ends toward the center, with the ends not more than 1 % larger in diameter than the center (controlling dimension).

NOTE 2—If desired, the length of the reduced section may be increased to accommodate an extensometer of any convenient gage length. Reference marks for the measurement of elongation should, nevertheless, be spaced at the indicated gage length.

NOTE 3—The gage length and fillets shall be as shown, but the ends may be of any form to fit the holders of the testing machine in such a way that the load may be axial (see Fig. 9). If the ends are to be held in wedge grips it is desirable, if possible, to make the length of the grip section great enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips.

NOTE 4—On the round specimens in Figs. 8 and 9, the gage lengths are equal to five times the nominal diameter. In some product specifications other specimens may be provided for, but the 5-to-1 ratio is maintained within dimensional tolerances, the elongation values may not be comparable with those obtained from the standard test specimen.

NOTE 5—The use of specimens smaller than 6 mm in diameter shall be restricted to cases when the material to be tested is of insufficient size to obtain larger specimens or when all parties agree to their use for acceptance testing. Smaller specimens require suitable equipment and greater skill in both machining and testing.

Fig 1 ASTM E8 M Standard for tensile testing of metallic materials

II. PREPARATION OF TEST SPECIMEN FOR CHARPY IMPACT TEST

E23-02 STANDARD The Charpy Impact Test Specimens were set up as indicated by ASTM E23-02 Standards. demonstrates the 3D model of the charpy test example After the part drawing is readied, the example is machined as sown in the fig2

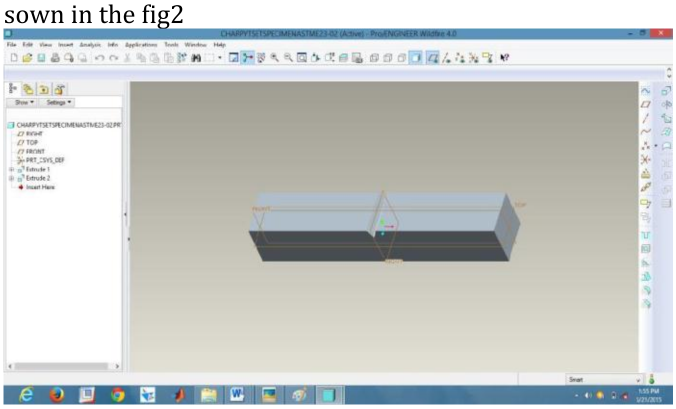


Fig 2 3-D Model of Chrapy Test Specimen

2.3 CONVENTIONAL HEAT TREATMNET PROCESS

2.3.1 Quenching

At first the material has austenitic structure when it is in as got condition. At the main stage the material is subjected to extinguishing process. The vital target of this procedure is warming the steel from austenitic territory is to get a structure of martensite, or to a great extent martensite, thought the focused on segment of the part. The extinguished material has a martensitic structure which is in charge of weakness property. These extinguished materials still have leftover burdens affected in them. In the wake of warming the material up to 900°C the material is quickly cooled in water. Rather than water one can likewise utilize other cooling mediums, for example, oil and saline solution arrangements.

Fig 3 Quenching Tank

2.3.2. Treating

As got martensitic condition steel is more weak to use in the majority of the applications. Moreover the martensite development impels high remaining anxieties in the steel. In this way the material is subjected to treating in the wake of extinguishing. The fundamental goal of treating is to remember the remaining stresses instigated in the material and to get ideal blends of sturdiness and pliability of the steel. In this work, the material is tempered atvarious temperatures to be specific 300°C, 400°C, 500°C, 600°C, 700°C. What's more, it is
doused at these temperatures for time of 2hours.

Fig.4 Sequence of heat treatment process of EN-24 Steel

2.4 Rockwell Hardness Test

"Hardness is the resistance of the material to indentation". This technique is simple since the material is not decimated likewise the gear is less costly. This Method is regularly utilized for solidified material. It is not reasonable for delicate toughened condition. In this testing, funnel shaped jewel is squeezed with a power of "F0", and afterward with power (F0+F1) against the

example. After expulsion of "F0", the expansion e. top to bottom of the impression brought about by "F1" is resolved. At that point the profundity of the entrance e. is changed over to hardness number which can be seen from dial marker. Fig 5 shows guideline of Rockwell Hardness Test.

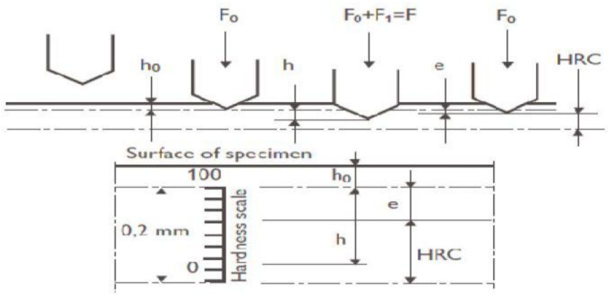


Fig5 Principle of Rockwell Hardness Test

2.5 Tensile Test

Fundamental target of ductile test is to decide a definitive elasticity (UTS) of the example. The test is performed on the Universal Testing Machine (UTM). The accompanying Procedure is received amid the elastic test

1. Gage length of 60mm is set apart on the example utilizing punch. This is done in light of the fact that it is simpler to perceive the disappointment spot after test. The disappointment ought to happen inside the scope of gage length. Additionally these Punches measures last gage length

2. The example is grasped at the base of the UTM bite the dust.

3. Consideration ought to be taken while putting the example; it ought to note that the pivot of the example and the machine pass on ought to concur, in light of the fact that heap ought to act pivotally.
4. In the wake of putting the example in the Machine. Test ought to be begun by giving the little additions of the heap.
5. Note down the Deflection and Load readings.
6. Compute the anxiety for every perusing.
7. Draw a chart amongst Stress and Strain.
8. Extreme rigidity Value can be acquired from both Theoretical and Graphical strategies.

Taking after segments depicts recipes that are utilized as a part of Tensile Test To calculate the stress induced in the metal at an interval of load equation 3.1 is used

σ=P/A N/mm2 (3.1)

Where P is Load Applied in KN, A is Cross Section Area in mm2
Strain Induced in the Material is calculated by equation 3.2
⊿L /L (3.2)
Where ⊿L Change is in length in mm, L is the Original Gauge length in mm. Percentage Elongation is calculated by equation 3.3
Percentage of Elongation = Lf - Lo/Lo× 100
(3.3) Where Lf is change in length and Lo is the original length

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2.6 Charpy Impact Test

Charpy test examples having measurements 10mm x 10mm x 55mm are set up as appeared in the fig 5 the score of profundity 2mm is made

Fig 5 Charpy Test Apparatus

The general strategy to lead the charpy sway test is as per the following

1. The example is put in the bad habit of the blacksmith's iron
2. The pendulum sledge is spot at an edge of 135° regarding even plane. This decides the stature at which the pendulum is discharged.
3. Arrival of pendulum results in discussion of Potential vitality (P.E) into motor vitality (K.E) just before it strikes the example.
4. After pendulum stick the example the example retains the K.E and results in the break of example.
5. The measure of the vitality consumed by the example is controlled by taking the perusing from the dial gage gave in the test contraption.
6. The vitality consumed by the example amid breaking is given by condition 3.5

2.7 Specimen Preparation for Microstructure analysis

Principle point of the warmth treatment procedure is to adjust the microstructure of the steel to get craved mechanical and substance properties. Microstructure examination is utilized to

investigate the transformational changes that happen amid warmth treatment processes. in this study the impact of treating process on EN-24 materials microstructures is broke down utilizing Optical Microscope

i. Inspecting

The Material is sliced by length by force hacksaw. Notwithstanding if disappointment examinations is to be made then the example ought to be sliced closer to the break

ii. Unpleasant Grinding

The example is sliced to much a length that it is helpful to handle. The example is made delicate also, smooth. Cooling ought to give while crushing. Example ought to be moved opposite to the current scratches so that the past scratches can be killed. The harsh granulating is proceeded until the burrs, nocks and so on., and all scratches that have happened amid hacksaw or cutoff wheel are no more obvious.

iii. Middle Polishing

Here the material is cleaned utilizing emery papers having distinctive sizes viz. 180,220,320,400 GSM that contains progressively better abrasives .Polishing is required on the grounds that the example should be level to get the great microstructure picture. At first the 180 GSM sand papers is used to harsh shine the example to evacuate major scratches that have happened amid metal cutting. After harsh cleaning the example is turned to 90° and cleaning is made on 220 GSM sand papers, here the scratches instigated amid past stage are evacuated making the example all the more level and smooth. At that point the strategy is taken after for 320,400GSM Papers

moreover. After the Arrangement of cleaning with various size of sand papers, the example turns out to be much smooth and level

iv. Fine Polishing

In the wake of Polishing with emery papers, the example turns out to be level and smooth, in any case this completing is not reasonable for microstructure investigation in light of the fact that these are still have the minor scratches. To evacuate these scratches, the material cleaning is utilized. Examples are fine cleaned utilizing granulating and cleaning machine which has wet turning wheel that is secured with extraordinary kind of material that is accused of grating particles. Table 3.1 demonstrates the rundown of abrasives and materials are utilized as a part of the procedure of fine cleaning. Infact the decision of cleaning material relies on upon the kind of materials being dissected.

v. Scratching

Principle reason for the drawing is to distinguish stages in the microstructure. That is the etchant is responds with the stages to give diverse shading so it can be effortlessly distinguished. Here it is imperative to note that the best possible etchants ought to be arranged and used to recognize diverse stages and the etchant utilized ought to respond with cleaned surface of the example. Compound assault by the scratching results in appearance of grain limits which will look like valleys on the cleaned surface. Light frame the magnifying instrument hitting the side of calleys will reflect making grain limit show up as dull lines. Present work utilizes the 5 % nitile as scratching specialists.

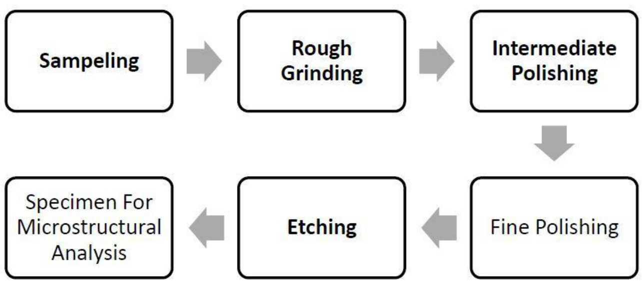


Fig 6 Procedure of Preparing the Specimen for Microstructure Analysis

3.RESULTS AND DISCUSSION

This area demonstrates the exploratory results. The EN-24 material is subjected to various treating temperatures viz. 300°C, 400°C, 500°C, 600°C, and 700°C as appeared in table 4.1. The mechanical properties like hardness, elasticity, sway vitality are measured by leading tests. Absolutely 16 tractable test examples, charpy test examples are readied, for the purpose of accommodation, the accompanying assignments are utilized as a part of the procedure of warmth treatment and experimentation.

3.1 Results of Tensile tests

Tensile test is done by the help of Universal Testing Machine, and bellow shown the stress-straincurve for different temperatures.

1. Stress-Strain relationship curve for as received specimen

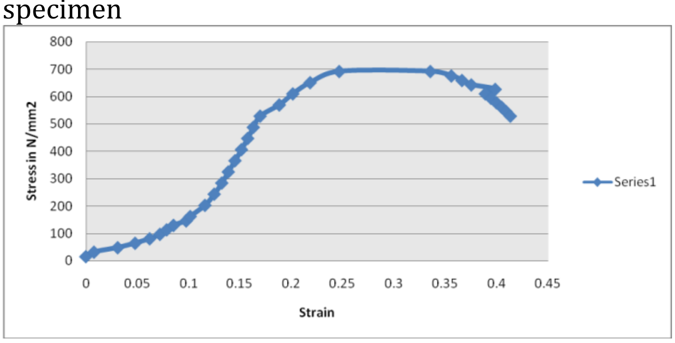


Fig 7 Stress Strain relationship curve for as received specimen

The EN-24 material is subjected to elastic test in as got condition, which has austenitic structure. Fig 7 demonstrates the Stress Strain relationship bend for as got example. The extreme rigidity is 709.75 N/mm2; bend takes after the standard Stress Strain relationship bend for malleable materials

2. Stress Strain relationship curve for U Specimens tempered at 300°C

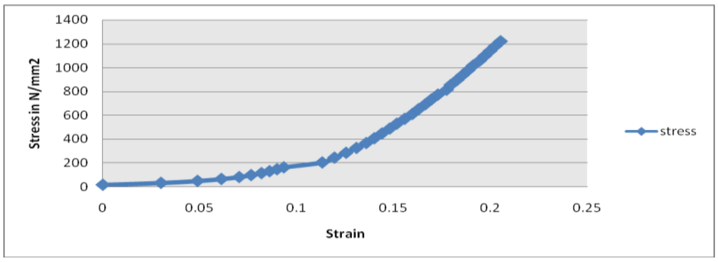


Fig 8 Stress Strain curve for U Specimen tempered at 300°C

At first as got steel is subjected extinguishing then taken after by treating at 300°C, in the process austenite gets changed into martensite. Martensite being a weak in nature which results in an alternate anxiety strain relations as appeared in Fig 8. Material breaks all of a sudden which is clear from the above figures. Three diverse specimens were tempered at same temperatures; in any case one can see the adjustment in the estimation of extreme elastic qualities which is having minute variety.

3. Stress Strain relationship curve for B Specimens tempered at 400°C

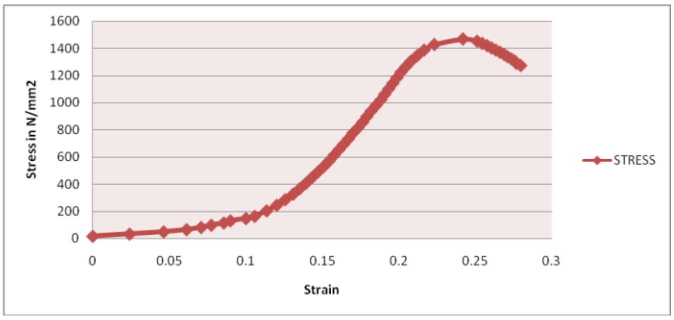
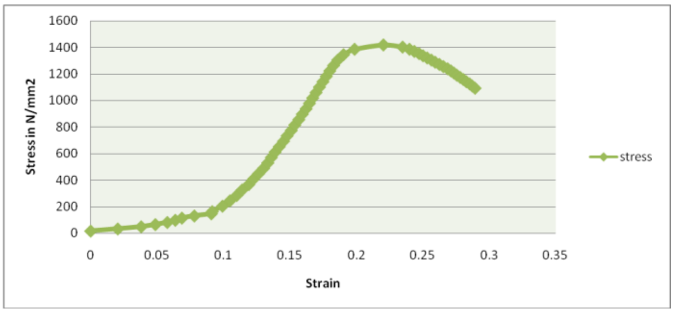


Fig 9 Stress Strain curve for B Specimen tempered at 400°C

4. Stress Strain relationship curve for C Specimens tempered at 500°C



5. Stress Strain relationship curve for E Specimens tempered at 600°C

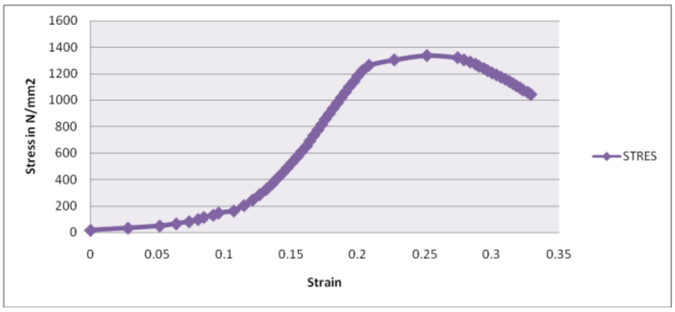


Fig 10 Stress Strain curve for E Specimen tempered at 600°C

6. Stress Strain relationship curve for T Specimens tempered at 700°C

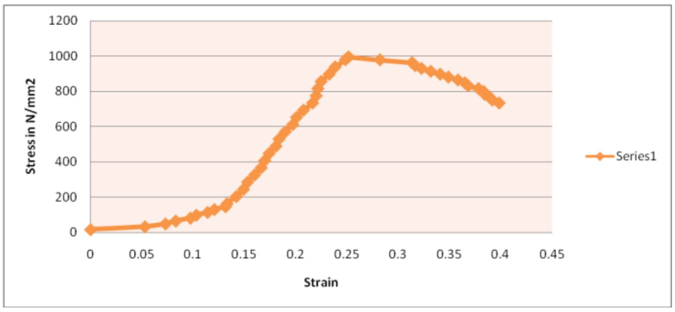


Fig 11 Stress Strain curve for T Specimen tempered at 700°C

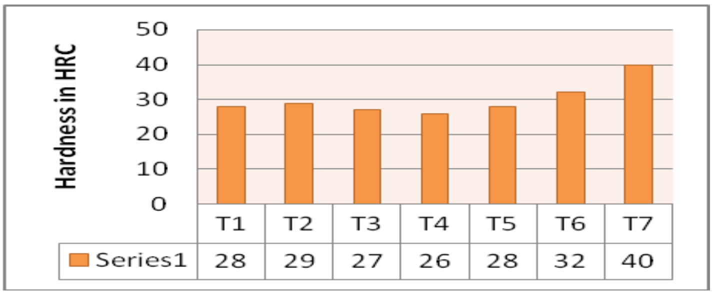


Fig 12 Hardness value Specimens is Tempered at 500°C, 600°C an. 700°C

4.2 Results of hardness test

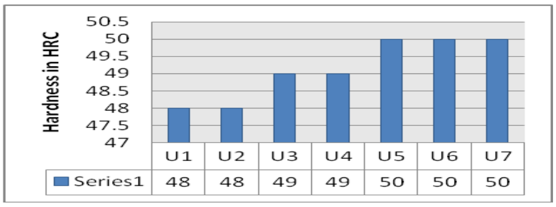


Fig 12 Hardness value Specimens is Tempered at 300°C

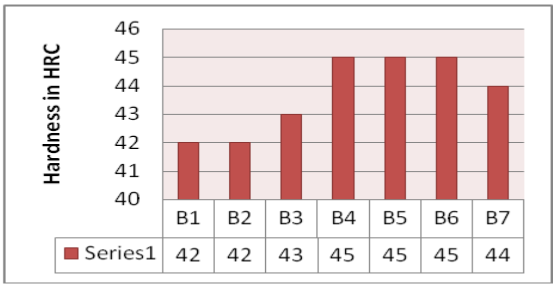
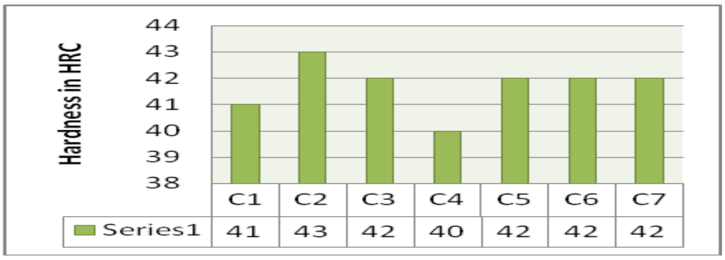
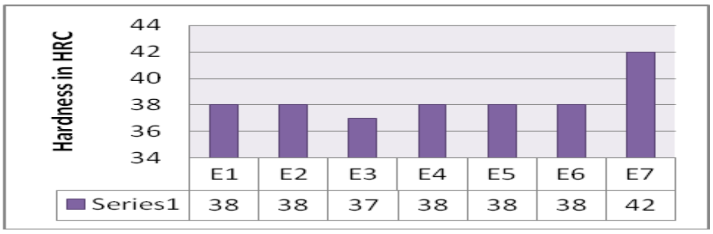
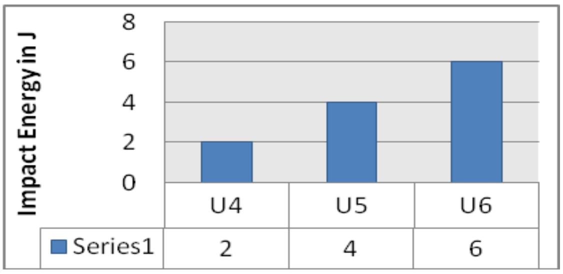


Fig 13 Hardness value Specimens is Tempered at 400 °C

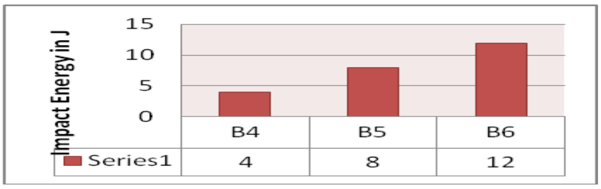




4.3 Charpy Impact Test Results



(a)



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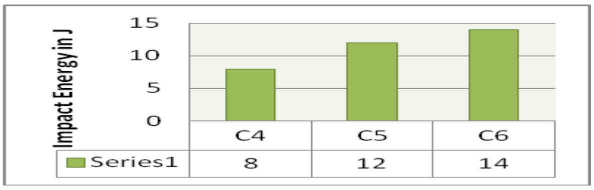

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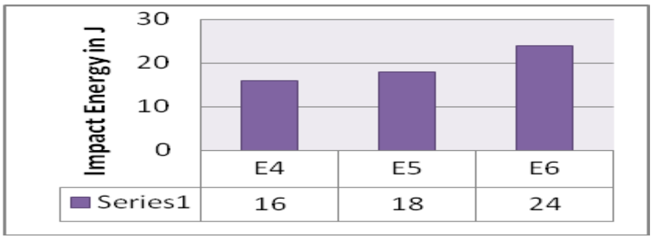

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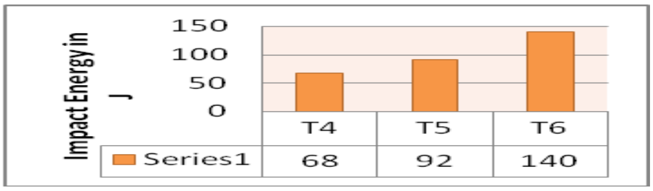

(e)

Fig 13 Impact energy (Toughness) in Joules , Specimens is Tempered at a. 300°C, b. 400 °C, c. 500°C, d. 600°C and e. 700°C

4.4 Comparison of Mechanical Properties of Tempered EN 24 Steel

Following graphs describes the relation between tempering temperatures and mechanical properties namely ultimate tensile strength, young's modulus, hardness, percentage elongation, percentage reduction in area and impact energy

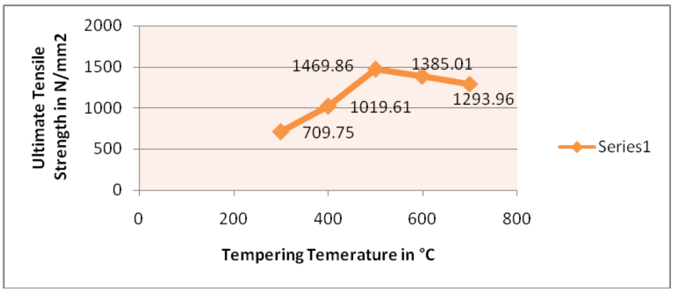

Fig 14 Effect of tempering temperature on ultimate tensile strength

Fig 14 demonstrates the diagram plotted by taking treating temperature as x-pivot and extreme pliable quality as y-pivot. As got test has extreme elasticity of 709.75 N/mm2. After the steel were tempered at 300°C the outcome indicated extreme elasticity of 1019.61 N/mm2.at 400°C a definitive elasticity is 1469.86 N/mm2 where it expanded when contrasted with past examples At the point when tests are tempered at 500, 600, and 700°C, a definitive elastic quality decline as temperature is expansions

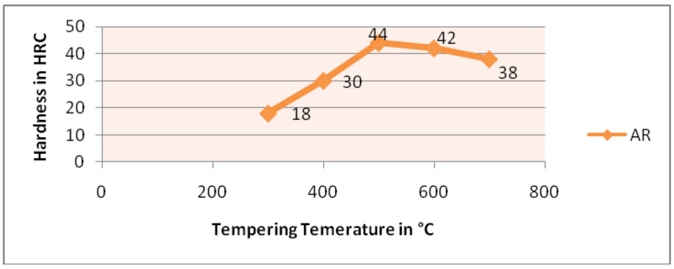

Fig 15 Effect of tempering temperature on hardness

As got test has hardness of 25HRC. At the point when tests are tempered at 300, 400, 500, 600 furthermore, 700 °C the hardness esteem continues diminishing as appeared in fig 15. This happens on the grounds that as treating temperature expands the martensite present in the structure begin changing into distinctive stages which are flexible in nature ,hence brings about diminishing in hardness values.

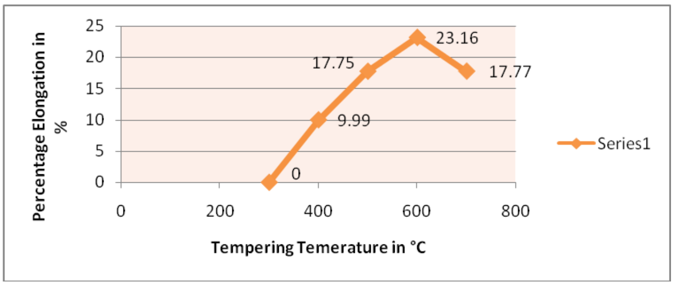

Fig 16 Effect of tempering temperature on percentage elongation

Fig 4.36 shows impact of treating temperature on the rate in extension. As got test has 15%. At the point when test is tempered at 300°C the rate of stretching is diminished quickly from 15 to 2.12%. This happens on the grounds that, material gets to be harder and more weak creating the sudden crack consequently bringing about low rate lengthening. At the point when tests tempered at 300, 400, 500, 600 and 700°C the lengthening begins expanding as appeared in fig 4.34, this is on the grounds that as temperature of treating builds, the materials free its quality furthermore, hardness truly turning out to be more pliable.

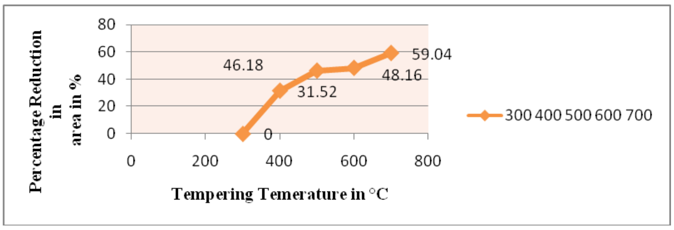

Fig 16 Effect of tempering temperature on percentage reduction in area

As got test has 59.09% of diminishment in range. Fig 16 shows rate lessening in territories of various tempered examples. At 300°C steel acts as a weak material along these lines the diminishment ranges is likewise low. As steel is tempered at higher temperature i.e. 400, 500, 600 furthermore, 700°C it loses the quality and hardness along these lines getting to be pliable which results in expansion of lessening in territory.

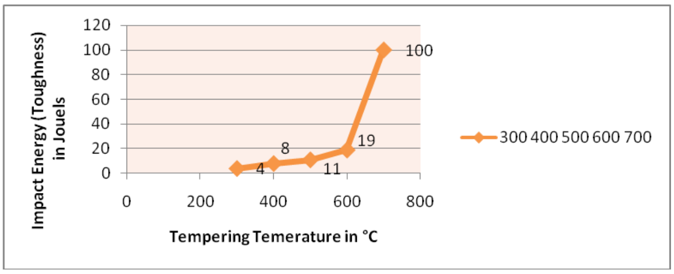

Fig 17 Effect of tempering temperature on impact energy (toughness)

Fig 17 demonstrates the effect energies of tests tempers at various temperatures. As got test has durability of 18 Joules. Sway vitality increments as temperature increments. The component behind this is not yet saw obviously.

Table 2 Overall Results

RESULTS									
Tempering temperature	Series number	Hardness In HRC	UTS N/mm2	Final length in mm	Percentage of elongation	Neck diameter in mm	Final area in mm2	Percentage area in reduction	Charpy impact strength in joules
As Received	AR	25	709.75	69	15	8	50.265	59.09	18
300	U1	48	1247.40	00	00	00	00	00	2
	U2	48	800.36	00	00	00	00	00	4
	U3	49	1011.09	00	00	00	00	00	6
	Avg	48	1019.61	00	00	00	00	00	4
400	B1	42	1478.17	65	8.33	11	95.033	22.56	4
	B2	42	1464.32	68	13.33	10	78.53	36	8
	B3	43	1467.09	65	8.33	10	78.53	36	12
	Avg	42	1469.86	66	9.99	10.33	84.031	31.52	8
500	C1	41	1369.80	73	21.6	9	63.61	48.16	8
	C2	43	1413.64	69	15	9	63.61	48.16	12
	C3	42	1371.59	70	16.66	9.5	70.88	42.24	14
	Avg	42	1385.01	70	17.75	9.16	66.03	46.18	11
600	E1	38	1331.17	75	25	9	63.6172	48.16	16
	E2	38	1262.56	73	21.16	9	63.6172	48.16	18
	E3	37	1288.15	74	23.33	9	63.6172	48.16	24
	Avg	37	1293.96	74	23.16	9	63.6172	48.16	19
700	T1	28	990.88	71	18.33	8	50.2654	59.09	68
	T2	29	971.32	69	15	8	50.2654	59.09	92
	T3	27	1005.96	72	20	8	50.2654	59.09	140

4.5 Theoretical equations of Stress Strain curves through curve fitting Tool-Mat Lab

The mat lab bend fitting instrument is utilized to locate the hypothetical condition which fulfills the trial stress strain connections. Taking after figures demonstrates the charts with conditions and coefficients are exhibited, additionally the integrity of fit for every bend is given with sure obligation of 95%

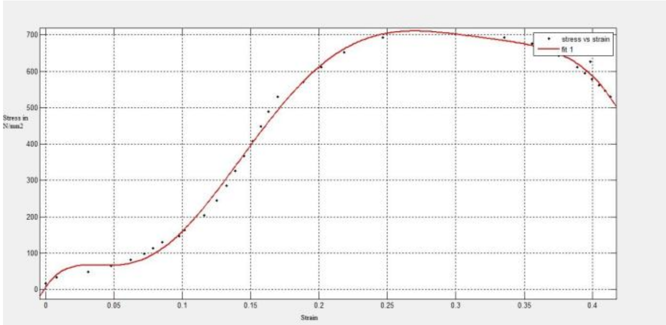

Fig 18 comparison between theoretical and experimental Stress Strain relationship curve for as received specimen

Linear model :
$$f(x) = p1*x^7 + p2*x^6 + p3*x^5 + p4*x^4 + p5*x^3 + p6*x^2 + p7*x + p8 \text{ ....(5.1)}$$
where x is normalized by mean 0.2053 and std 0.138

Coefficients (with 95% confidence bounds):

p1 = 24.73 (-9.552, 59.02)
p2 = -92.28 (-122.4, -62.2)
p3 = -80.42 (-213.7, 52.83)
p4 = 370.2 (269.6, 470.8)
p5 = -42.41 (-199, 114.1)
p6 = -527.8 (-613.5, -442.1)
p7 = 399.3 (339.1, 459.5)
p8 = 628.8 (612.9, 644.6)

Goodness of fit:
SSE: 7453
R-square: 0.9959
Adjusted R-square: 0.9948
RMSE: 16.93

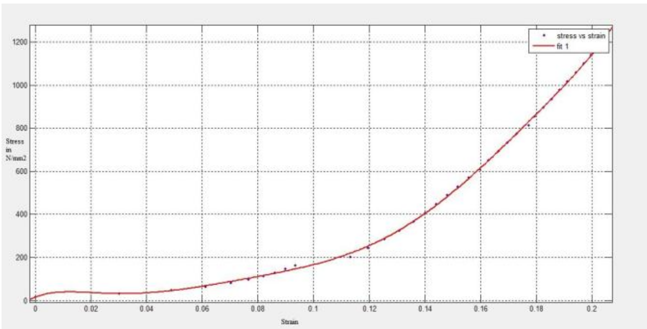

Fig 19 comparisons between theoretical and experimental Stress Strain relationship curve for specimen tempered at 300°C

Linear model:
$$f(x) = p1*x^7 + p2*x^6 + p3*x^5 + p4*x^4 + p5*x^3 + p6*x^2 + p7*x + p8 \text{...............(5.2)}$$

where x is normalized by mean 0.1371 and std 0.0537
Coefficients (with 95% confidence bounds):
p1 = 6.07 (2.644, 9.495)
p2 = 25.82 (12.68, 38.96)
p3 = 4.357 (-6.081, 14.8)
p4 = -86.98 (-121.2, -52.79)
p5 = -31.66 (-57.5, -5.825)
p6 = 246.7 (220.1, 273.3)
p7 = 465.6 (451.3, 480)
p8 = 378.7 (373.3, 384.1)
Goodness of fit:
SSE: 1450
R-square: 0.9997
Adjusted R-square: 0.9997
RMSE: 7.196

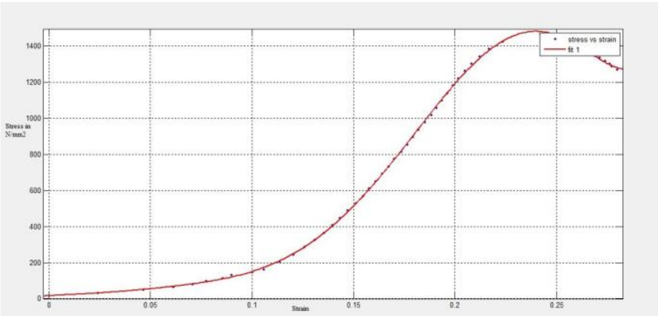

Fig 20 comparisons between theoretical and experimental Stress Strain relationship curve for specimen tempered at 400°C

Linear model Poly7:
f(x) = p1*x^7 + p2*x^6 + p3*x^5 + p4*x^4 + p5*x^3 + p6*x^2 + p7*x + p8.................(5.3)
where x is normalized by mean 0.1592 and std 0.06681
Coefficients (with 95% confidence bounds):
p1 = 5.36 (3.477, 7.243)
p2 = 26.07 (20.73, 31.4)
p3 = 5.485 (-2.462, 13.43)
p4 = -162.6 (-182.6, -142.5)
p5 = -244.9 (-260.2, -229.5)
p6 = 236.3 (215.9, 256.6)
p7 = 891 (881.6, 900.4)
p8 = 713 (709, 717.1)
Goodness of fit:
SSE: 2229
R-square: 0.9998
Adjusted R-square: 0.9998
RMSE: 7.286

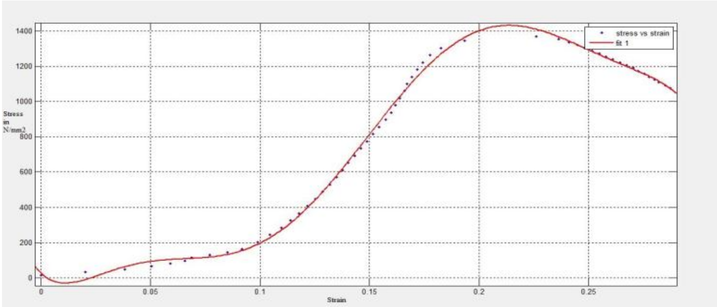

Fig 21 comparisons between theoretical and experimental Stress Strain relationship curve for specimen tempered at 500°C

Linear model Poly7:
f(x) = p1*x^7 + p2*x^6 + p3*x^5 + p4*x^4 + p5*x^3 +p6*x^2 + p7*x + p8..................(5.4)
where x is normalized by mean 0.1689 and std 0.07711
Coefficients (with 95% confidence bounds):
p1 = -34.06 (-41.35, -26.77)
p2 = -52.82 (-69.83, -35.81)
p3 = 241.7 (210.1, 273.4)
p4 = 285.6 (224.5, 346.7)
p5 = -700.2 (-756.8, -643.7)
p6 = -599.4 (-656.2, -542.6)
p7 = 1073 (1038, 1108)
p8 = 1102 (1091, 1113)
Goodness of fit:
SSE: 2.236e+004
R-square: 0.9981
Adjusted R-square: 0.9979
RMSE: 21.15

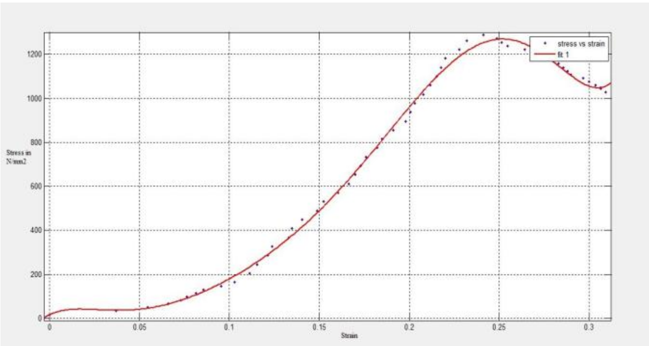

Fig 22 comparisons between theoretical and experimental Stress Strain relationship curve for specimen tempered at 600°C

Linear model Poly7:
f(x) = p1*x^7 + p2*x^6 + p3*x^5 + p4*x^4 + p5*x^3 +p6*x^2 + p7*x + p8..................(5.5)
where x is normalized by mean 0.1877 and std 0.08033
Coefficients (with 95% confidence bounds):
p1 = 12.12 (4.995, 19.25)
p2 = 51.97 (33.64, 70.31)
p3 = 25.74 (-3.399, 54.89)

p4 = -176.9 (-242.2, -111.6)
p5 = -329.8 (-380.3, -279.3)
p6 = 11.39 (-50.48, 73.26)
p7 = 801.8 (771.8, 831.9)
p8 = 837 (824.4, 849.7)

Goodness of fit:
SSE: 2.233e+004
R-square: 0.9978
Adjusted R-square: 0.9974
RMSE: 22.03

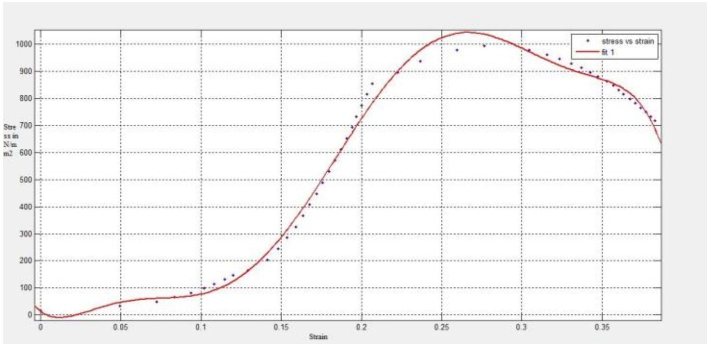

Fig 23 comparisons between theoretical and experimental Stress Strain relationship curve for specimen tempered at 700°C

Linear model Poly7:

f(x) = p1*x^7 + p2*x^6 + p3*x^5 + p4*x^4 + p5*x^3 +p6*x^2 + p7*x + p8..................(5.6)

where x is normalized by mean 0.2268 and std 0.1067

Coefficients (with 95% confidence bounds):
p1 = -44.62 (-61.9, -27.34)
p2 = -114 (-149, -79)
p3 = 185.4 (113.7, 257.1)
p4 = 494.8 (376.9, 612.6)
p5 = -389.2 (-496.1, -282.3)
p6 = -794.2 (-901.3, -687.1)
p7 = 636.6 (582.6, 690.5)
p8 = 926 (902.6, 949.4)

Goodness of fit:
SSE: 3.254e+004
R-square: 0.9935
Adjusted R-square: 0.9924
RMSE: 28.52

5. CONCLUSION

EN-24 steel is chosen for the undertaking work. Absolute sixteen specimens were set up for ductile and charpy tests. The specimens were subjected to extinguishing and treating process at different temperatures viz. 300, 400, 500, 600 and 700 °C .The specimens were then tried to decide extreme rigidity, rate lengthening, rate diminishment in territory, sway vitality (strength) and hardness. The charts are plotted to dissect the impact of treating temperature on the properties of steel.

Microstructure demonstrated the changes that happen amid the process .

Taking after inductions can be drawn from the present work

 Ultimate rigidity diminishes as treating temperature increments. The specimen tempered at 400°C has most noteworthy quality of 1469.86 N/mm2, rate lengthening of 9.99%, hardness is 42HRC and durability 8 J from these tempered steel gives the ideal blend of quality sturdiness.

 Since EN-24 steel is utilized as a part of high tractable jolts were lengthening is principle criteria. It is vital to pick the right treating temperature.. example Tempered at 300° C have Tensile Strength of 1019.60 N/mm2 .Whereas Example Tempered at 500° C has Tensile Strength 1385.01N/mm2 and Elongation 17.75 %. Both the example has practically same rigidity yet prolongation vary altogether.

 Above 500°C treating, the strength increments fundamentally in the meantime the quality and hardness brings down quickly as appeared in table 4.2

 At 700 °C, the durability expands barely to 140 J and hardness of 27 HRC though the examples tempered at 600°C has sway vitality of 19 Joules and hardness 37HRC.Likewise quality decreases quickly in these scopes of temperatures.

 Applications will choose the treating conditions, for example, temperature. In the event that one needs more

quality and lower durability then the treating temperature ought to be kept low about 300-400°C. in the event that one needs higher durability and impressive quality and hardness, then the ideal temperature is picked which is around 500°C.

 The change of stages amid extinguishing and treating demonstrated, a great many extinguishing the steel has martensite which is harder and fragile. At the point when steels are subjected to treating the martensitic gets changed to different items. These items incorporate changed martensite and untransformed martensite.

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BIOGRAPHIES

Mr. Prashant S D graduated B.E in Mechanical Engineering from East West Institute of Technology, Bengaluru. Completed M.Tech in CIM from Gogte Institute of Technology, Belagavi. Currently working as Assistant Professor in Brilliant Group of Technical Institutions (BRIG), Hyderabad.

Mr. Sushil Dange graduated B.E in Mechanical Engineering from Guru Nanak Dev Engineering College, Bidar. He completed M.Tech in PDM from National Institute of Engineering, Mysore. Currently working as Assistant Professor in Brilliant Group of Technical Institutions (BRIG), Hyderabad.

Mr. Shyam Sundar Luha graduated B.Tech in Mechanical Engineering from VSSUT, Burla. He completed M.Tech in Production Engineering from NIT Rourkela. He is currently working as Assistant Professor in Brilliant Group of Technical Institutions (BRIG), Hyderabad.

Mr. Prabhu Kurtakoti graduated B.E in Mechanical Engineering from BVB College of Engineering and Technology, Hubli. He completed M.Tech in PDM from Centre for PG Studies, VTU Belagavi. He is currently working as Assistant Professor in Sri Indu College of Engineering and Technology (SICET), Hyderabad.