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To Study the Effect on the Hardness and Microstructural Behaviour of 3 Different Tool Materials En-31, En-8 and D-3after Heat Treatment

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ABSTRACT

This Study is based upon the experimentalwork which means it is derived from practicaland observations ratherthan theory. Theobjective is to study the effect on the hardness of three Sample Grades of Tool Steel i.e. EN -31, EN-8, and D3 after heat treatment processes such as Annealing, Normalizing, Hardening and Tempering. Literature review shows the lack of research in specific field and helps to design the survey focusing on the heat treatment performance Index HTPI 2012. Industrial survey has been carried out in form of questioner at Ludhiana to develop the experimental setup and to select the various parameters such as techniques, time and cost. Material and heat treatment processes have been selected on the basis of survey; various mechanical and chemical analysis, such as Composition testing of tools, are performed before the heat treatment. After heat treatment, hardness test has been carried out with treated and untreated work samples.

KEYWORDS: Annealing, Normalizing, Hardening, Tempering.

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I. INTRODUCTION

Heat Treatment is the controlled heating and cooling ofmetals to alter their physical and mechanical properties without changing the product shape. Heat treatment is sometimes done in advertently due to manufacturing processes that either heat or cool the metal such as welding or forming. Heat Treatment is often associated with increasing the strength and other properties of material, but it can also be used to alter certain manufacturability objectives such as improve machining, formability, restore ductility after a cold working operation. Thus it is a very enabling manufacturing process that can not only help other manufacturing process, but can also improve product performance by increasing strength or other desirable characteristics.

Thus, the main aim of heat treatment operations is to control the properties of a metal or alloy through the alternation of structure of metal or alloy. The purposes of the various heat treatment operations are as given below:

- To refine or relieve strains or stresses is induced by cold working (drawing, bending and more) or non-uniform cooling of worm material for example. welding: Annealing
- To increase power or hardness of the material for improved wear resistance: Hardening.
- To upgrade machinability : Annealing
- To soften the material: Annealing
- To reduce hardness and increase ductility and toughness to with high impact.
- To refine the cutting and bending properties of tools.
- To change the physical properties of material for example electrical
- properties, magnetic
- Properties are corrosion resistance and heat resistance etc.

II. RESEARCH BACKGROUND

2.1. Literature Review

Literature has been collected from numerous journals, books and papers; and has been reviewed some facts. Steels are mostly suitable for heat treatment, since they respond well to heat treatment. The commercial use of steels exceeds that of any other kind of material. Steels are heat treated for one of the some reasons as explained in following:

1. Softening
2. Hardening
3. Material Modification

1.Softening: The properties, such as strength or hardness, remove residual stresses, improve toughness, restore ductility, refine grain size, or change the electromagnetic properties have been reduced by softening. Restoring ductility or removing residual stresses is aessentialprocess when a large amount of cold working is to be executed, such as in a cold-rolling operation or wiredrawing, Annealing, Normalizing and tempering Austempering, Martempering are the principal ways by which steel is softened. It is also decrease to their strength and hardness.

2. Hardening: The strength and wear properties could be increased by hardening. One of the fundamentals for hardening is sufficient carbon and alloy content. If there is sufficient Carbon content, the steel will be directly hardened. Otherwise the surface of the part has to be Carbon supplemented using some diffusion treatment hardening techniques.

3. Material Modification: Heat treatment is used to modify properties of materials instead of hardening and softening. These processes modify the performance of the steels in a beneficial manner to maximize service life, e.g., stress relieving, or strength properties, e.g., cryogenic treatment, or some other desirable assets, e.g., spring aging. This makes the matrix richer in carbon and alloying elements with the hardness finally achieved depending mainly on the amount of carbon dissolved. The alloying elements mostly regulate the speed at which the steel must be quenched and the depth of hardness achieved in it.

Quenching consists of cooling the heated work piece rapidly by immersing it in a liquid, surrounding it with gas or air, or submerging it in a fluidized bed to keep the carbon in solid solution in the harden.

Tempering consists of reheating the quenched steel one or more times to a lower temperature, 150 to 650 °C., and cooling it again to cultivate the desired levels of ductility and toughness.

- Steel in the annealed condition is soft and ductile; and has low tensile strength.
- At hardening temperature the steel is identical soft and has very low tensile strength. Structure: Austenite + residual Carbides Later quenching the steel is hard and brittle. Structure: Martensitic (highly stressed) + other transformation products + soft retained Austenite + residual Carbides.
- After Temper 1 the steel is hard but tougher Structure: Tempered (less stressed) Martensitic, + highly stressed un-tempered. Martensite or other transformation products + small quantity of retained Austenite + residual carbides
- After Temper 2 the toughness is further increased (best impact strength) Structure: tempered Martensite and further transformation products + residual Carbons.

Heat treatment is a combination of scheduled heating and cooling applied to a particular metal or alloy in the solid state in such ways as to produce certainmicrostructure and preferred mechanical properties such as hardness, toughness, yield strength, ultimate tensile strength, Young's modulus, percentage elongation and percentage reduction. Annealing, normalizing, hardening and tempering are the most significant heat treatments often used to modify the microstructure and mechanical properties of engineering materials particularly steels. Hardening is the most conjoint heat treatment applied to tool steels. It consists of following three operations:

1. Heating
2. Quenching
3. Tempering.

III. MATERIALS AND METHODS

3.1 Empirical Approach

Empirical Approach means resulting from experiment and observation rather than theory.

Step 1 Literature Gap analysis & ConductingIndustrial Survey for the selection of Tool Steel Grades for experiment & Index preparation of objective function

Step 2 Cutting and Grinding of Specimens

Step 3 Composition testing of Untreated Tool Steeli.e. EN-31, EN-8, and D3

Step 4 Heat Treatment Processes Such As Annealing,Normalizing, and Hardening & Tempering of Tool Steels i.e. EN-31, EN-8, and D3.

Step 5 Hardness Testing of Untreated & Treated ToolSteel i.e. EN-31, EN-8, and D3

3.2 Experimental Procedure

Step 1

Literature Gap analysis & Conducting Industrial Survey for the selection of Tool Steel Grades for experiment & Index preparation of objective function Literature Gap study has been collected by referring various journals, books, papers etc. for the purpose of the Selection of tool steels grades material on and work piece material on which lesser study will be carried out. Another objective selection of Place where to Perform Experiment, Market availability of the recommended tool steel & their Cost Analysis, Time Analysis to complete the experiment etc. The purpose of Selecting Tool Steel is that they are Mostly Used in the Manufacturing Industry. Tool Steel Grades like EN-31, EN-8 and D-3 is selected for project. These steel grades were suggested to be the best during Surveying Numerous Industries for that objective we designed an industrial based questioner. The Carbon Composition is diverse from each other in these materials. So we can easily differentiate between selected Parameters after Heat Treatment. These Materials are purchased From Material Shop of C.T.R Ludhiana. For defining the main objective of study to be carried out more effectively and specific we designed Heat Treatment Performance Index HTPI 2012.

Step 2

Cutting and Grinding of Specimens Sample Mark: EN-31, EN-8, and D3 Instrument Used: Power Hack saw & Grinding Machine Units of Sample Prepared: Six for each material for different objectives there was a Requirement for 6 Samples of Each Material for the Treatment and Testing Purpose. So we cut the Samples Using Power Hack-Saw .All the Samples are 20mm in Diameter and 2.5" to 3.5" in length. Chamfering was done using Bench Grinder.During Chamfering we also Performed Spark Testing of the material which is commonly used in the Industries to analyze Different Material on the basis of the Intensity of Spark Produced and Flowers evolved during Spark Testing. Figure Below shows the three Material undergoing Spark testing.

EN-8 **EN-31** **D-3**

Fig 1. Pictorial View of Spark Testing for Various Materials

Step 3

Composition testing of Untreated Tool Steel i.e. EN-31, EN-8, and D3 Chemical Composition is Important Testing for making sure that the Chemical Composition of the Purchased Material Matches with that of the International Standards of Materials. This Testing is done By Using the Glow Discharge Spectrometer. Surface finishing of Single Sample of Each material is done on the Belt Grinding Machine of 100Grit Belt. After Grinding giving the material a good Surface finish Sample EN-8 is inserted in the Machine. The Machine Holds the Material by Vacuum Holder of the machine .Then the Door is closed for further Operation to be performed on the material and command is given to the Specific Software on the Computer. This is done by using the glow discharge method, experimental material is uniformly sputtered Spit up in an explosive manner from the surface.

Type of Sample: Cut Pieces of Steel

SampleMark: EN-31, EN-8, and D3

Instrument Used:Glow Discharge SpectrometerIt takes about 5-6 minutes for the chemical composition testing of a single material. The readings of the test are shown on the Display of Computer in Tabulated Form. It Shows the Percentage Composition of Each Element .After Testing Chemical Composition of the material, the valuesCompared with that of Values as per International Standards. The Testing of a Single Sample is done 2-4 times from Different point on the smooth surface of the sample. The same Procedure for chemical testing is also done for EN-31 and D-3 also. The figure below show the Specimen where the Chemical Composition Testing is done leaving behind the impact of Argon Gas used at the time of testing. We can see three marks which states that Testing is Performed 3 times on the Material. Step 4 Heat Treatment Processes Such As Annealing, Normalizing, and Hardening & Tempering of Tool Steels i.e. EN-31, EN-8, and D3

Place of Experiment: Central Tool Room, Ludhiana

Heat treatment process: Annealing [A],Normalizing [N] and Hardening & Tempering [H&T].

Sample Mark: EN-31, EN-8, and D3

Instrument Used: Muffle Furnace [for EN-8] &Fulmina Furnace [for EN-31 & D-3]

Step 5 Hardness Testing of Untreated& Treated Tool Steel i.e. EN-8, EN-31, and D3

Place of Experiment: Central Tool Room, Ludhiana

Type of Sample: Round Piece, Material EN-8, EN-31, D3

Sample mark 1: Untreated Material EN-31, EN-8, and D3

Type ofSample: Round Piece, Material EN-31

Sample Mark 2: Annealing [A], Normalizing [N] andHardening & Tempering [H&T].

Type of Sample: Round Piece, Material EN-8

Sample Mark 2: Annealing [A], Normalizing [N] and Hardening & Tempering [H&T].

Type of Sample: Round Piece, Material D-3

Sample Mark 2: Annealing [A], Normalizing [N] and Hardening & Tempering [H&T].

Instrument Used: Rockwell hardness tester Steel Hardness Calculator Used for Conversion of Values. Using that, we calculated HRB value & Brinell Hardness HB, Vickers HV.

IV. RESULTS AND DISCUSSION

Composition Testing of Untreated Tool Steel i.e. EN-31, EN-8, and D3

Table 1. Composition of Tool Steel as per AISI Standard

Mark	C%	Si%	Mn%	P%	S%	Cr%
En-31	1.00	0.20	0.50	0.024	0.20	1.40
En-8	0.40	0.25	0.80	0.015	0.015	---
D-3	2.10	0.30	0.40	0.021	0.30	11.50

Table 2 Composition of Tool Steel after Composition Testing using Glow Discharge Spectrometer

Mark	C%	Si%	Mn%	P%	S%	Cr%
En-31	1.30	0.30	0.50	0.024	0.025	1.40
En-8	0.45	0.32	0.8	0.05	0.05	---
D-3	2.10	0.65	0.45	0.021	0.03	11.50

Table 3 Heat Treatment Conditions for Annealing Process for Tool Steel i.e. EN-31, EN-8, and D3

Materials	Annealing Temp.	Soaking Time
EN-8	800	2 hour
EN-31	800	2 hour
D-3	820	2 hour

Table 4 Heat Treatment Conditions for Normalizing Process for Tool Steel i.e. EN-31, EN-8, and D-3.

Material	Annealing Time Temp	Soaking Time	Cooling Medium
EN-8	880	1/2 hour	In air
EN-31	930	1/2 hour	In air
D-3	900	1/2 hour	In air

Table 5.Hardness of Untreated Tool SteelMaterial EN-31, EN-8, and D3.

Untreated Material	Rockwell C-HRC	Rockwell B-HRB	Rockwell A-HRA	Brinell Hardness HB	Vickers HV
EN-31	10	89	_---	180	180
EN-8	13	92	_---	190	186
D-3	18	95	_----	212	218

Table 6. Hardness of Treated Tool Steel Material EN-31,EN-8 and D-3

Tool Steel Materials	Sample Mark	Rockwell C-HRC	Rockwell B-HRB	Rockwell A-HRA	Brinell Hardness HB	Vickers HV
	A	12	91	55	186	184
EN-31	N	41	112	_	375	393

	H & T	55	0	_	552	649
EN-8	A	9	88	54	178	178
	N	25	101	_	250	255
	H&T	48	116	_	456	490
D-3	A	23	100	_	240	247
	N	55	0	_	552	649
	H& T	56	0	_	572	694

Annealing: After annealing value of hardness ofspecimen is 55 HRC as compared to untreated specimen annealed work specimen becomes softer. Therefore specimen machine-ability properties increase. We used HRA scale because after annealing EN-31 becomes soft and below 20 HRC value HRC scale is not gives the accurate value and as well as value is not valid.

Normalizing: After normalizing hardness is 40 HRCgiven result on Rockwell testing machine. It shows after the normalizing the specimen becomes harder then annealing specimen .this is due to formation of Bainite & Martensite.

Hardening and Tempering: After H&T treatmentspecimen hardness is 55 HRC it shows H&T treatment makes hardest then other two treatments.That means experimental material has more wear and tear as compared two other two heat treatments.

Comparison: Afterward annealing specimen becomesmore softer then untreated specimen as hardness value shown.After normalizing hardness is more as compared to untreated specimen. After hardening and tempering specimen are hardest then other three specimens (Conclusion for EN-8) Before treatment EN-8 hardness value is 10 HRC.Hardness of untreated material is less due to low carbon percentage in EN-8. After done the three treatments

Annealing: After annealing value of hardness ofexperimental specimen is 55 HRA as compared to untreated specimen annealed specimen becomes softer. So machine-ability properties of specimen increase due to annealing we used HRA scale because after annealing EN-8 becomes soft and below 20 HRC. Value HRC scale is not gives the accurate value and also not valid.

Normalizing: After normalizing hardness is 25 HRCgiven on Rockwell testing machine.It shows after the normalizing the specimen becomes harder thanannealing specimen .this is due to formation of pearlite is more as compared to ferrite.

Hardening and Tempering: After H&T treatmentspecimen hardness is 48 HRC it shows H&T treatment makes hardest then other two treatments. This means material has more tear and wear as compared two other two heat treatments.

Comparison: After annealing specimen becomesmore softer then untreated experimental specimen as hardness value shown. After normalizing hardness is more as compared to untreated specimen.

After hardening and tempering specimen arehardest then other three specimens due to formation of fine tempered martensite. Conclusion for D-3

Before treatment D-3 hardness value is 13 HRC hardness of untreated material is less. After done three treatments

Annealing: After annealing value of hardness ofexperimental specimen is 23 HRC.As compared to untreated specimen annealed specimen becomes harder. This is due to formation of carbide particles.

Normalizing: After normalizing hardness is 55 HRCgiven on Rockwell testing machine. It shows after the normalizing the specimen becomes harder then annealing specimen .This is due to formation of greater no. of Un-dissolved carbide particles so specimen becomes brittle.

Hardening and Tempering: After H&T treatmentspecimen hardness is 56 HRC. It shows H&T treatment and normalizing have same hardness value. But we cannot use normalizing due improper microstructure. But in case of H&T hardness value is same but specimen consists of dissolved carbide particles. This means material has more corrosion resistance and hardness as compared two other heat treatments.

Comparison: After annealing specimen becomesmore harder then untreated specimen. After annealing hardness is more as compared to untreated specimen. But specimen has not obtained good microstructure. After hardening and tempering specimen are hardest then other three specimens also having a good corrosion resistance.

CONCLUSIONS

Literature gap analysis & industrial survey conduction are found to be very useful approach forselection of tool steel grade which will more beneficial for industrial point of view. From the literature review, it is observed that less research work has been seen for Tool Steel materials i.e. EN-31, EN-8, and D3 after Heat Treatment Processes Such As Annealing, Normalizing, and Hardening & Tempering. Also less work has been reported for AISI D3 Die Steel. It is observed that the effect of hardness of work piece material after treatment of Tool Steel i.e. EN-31, EN-8, and D3 have not been explored yet, so it‘s interesting to Study the Effect on the Hardness of three Sample Grades of Tool Steel i.e. EN-31, EN-8, and D3 after Heat Treatment Processes Such As Annealing, Normalizing, and Hardening & Tempering. All these aspects will be addressed in research work. Indexing of HTPI 2012 is found to be effective to defined objective function.After annealing specimen of EN-31 becomes more softer then untreated specimen as hardness value shown. After normalizing hardness is more as compared to untreated specimen. After hardening and tempering specimen are hardest then other three specimens.

After annealing specimen of EN-8 becomes more softer then untreated experimental specimen as hardness value shown. After normalizing hardness is more as compared to untreated specimen. After hardening and tempering specimen are hardest then other three specimens due to formation of fine tempered martensite. After annealing specimen of D-3 becomes more harder then untreated specimen. After annealing hardness is more as compared to untreated specimen. But specimen has not obtained good microstructure. After hardening and tempering specimen are hardest then other three specimens also having a good corrosion resistance.Future Aspects of this study to carry out further is wider. Choosing of different tool steel material and compare them the effects on their mechanical properties. Recommended material for further work done to be carried out for similar study D-2, mild steel, HC HCR cold working tool steel grades as so many. HSS found to be very tool steel grade difficult for such study as per investigation form industrial survey. Using Different analytical approaches is also making an effective outcome which is also recommended.

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