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Effect Of Quenching Medium On Hardness Of D3 Tool Steel

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ABSTRACT
The Aim Of The Work Is To Study The Effect Of Different Quenching Medium On Hardness Of Tool Steel. In Conventional Heat Treatment Either Vegetable Oil Or Engine Oil Is Used. Here We Use Both The Combination Of Engine Oil And Vegetable Oil In Different Proportion As Quenchant. The Process Involves Heating The Samples Above Austenitic Temperature And Quenching Them In Different Quenching Mediums.Heat Treatment Process Generally Involves The Controlled Heating And Cooling Of Engineering Materials In Order To Achieve Desired Physical And Mechanical Properties Without Changing The Product Shape. Nowadays Petroleum Based Quenchants Are Widely Preferred Over Water As The Main Quenching Medium Under Low Cooling Rates Due To Their Better Distortion Control And Crack Prevention Properties. The Major Drawback Of This Petroleum Based Quenchants Are Their Poor Biodegradability, Toxicity, Flammability And Non-Renewability. In An Attempt To Find A Suitable Alternative And To Provide Best Possible Results Gingelly Oil And Mineral Oil Are Used As Quenching Medium In The Heat Treatment Of D3 Steel. The Heat Treatment Helps In The Evaluation Of Change In Mechanical Properties Of The Material. In This Experiment, We Used 5 Samples Of High Carbon Steel (D3) Specimens Of 2% To 2.14% Carbon Content. The Main Processes Carried Out In This Experiment Are Annealing, Soaking And Quenching. The Material Is Austenised Above Its Critical Temperature I.E. About (1050 Celsius), Then It Is Soaked About 30 Minutes And Quenched In Specified Quenchant. Then The Specimen Is Highly Polished And The Microstructure Analysis Is Done By Using The Metallurgical Image Analysis Software(Mias). Hardness Of The Specimen Is Determined By Using Rockwell Hardness Testing Machine. The Main Scope Of This Study Is To Analyse The Proportions Of Quenchant And Temperatures Selected For The Quenching Process On The Specimens And As A Result Of This Its Effect In Microstructure And It Hardness.

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I. INTRODUCTION

Steel Is Defined As An Alloy Of Iron And Carbon With The Carbon Content Up To About 2% With A Vast Application Almost In Every Part Of Our Life. D3 Is A Popular Grade Of Alloy Steel Which Is Widely Used In Automobile Industry For Production Of Axle, Roller Bearings, Shear Blades, Spindle, Moulding Dies, Ball Bearings, Spinning Tools, Beading Rolls, Forming Rolls, Powder Compaction Tooling,Lamination Dies, Punches And Dies, Shafts, Studs, Bolts, Used In High Stress And With A Large Cross Section. It Includes Aircraft And General Engineering Applications For Propeller Or Gear Components. The Typical Composition Of D3 Steel Is As Shown Table 1.

% Carbon	% Silicon	% Manganese	% Chromium	% vanadium
2 to 2.14	0.6	0.6	11 to 13.5	1.00

Table 1

The Properties Of The Carbon Steels Vary With Their Composition And Microstructure, Which Depends On The Alloying Elements Present In The Steel And The Kind Of Heat Treatment Process. Steel Is Heated To The Austenitization Temperature And Then Cooled At A Faster Rate To Avoid Ferrite Or Pearlite Transformation And Allow The Formation Of Bainite And Martensite To Obtain Maximum Hardness And Strength. The Factors That The Critical Cooling Rate Is Depend Upon Both The Specific Heat Capacity And Thermal Conductivity Of The Steel As Well As The Quenchants In Addition To Quench-Bath Temperature And Agitation.

Among The Quenchants Used, Water Is The Most Common One. Whenever Lower Cooling Rates And More Uniform Cooling Is Desired For Better Distortion Control And Crack Prevention Petroleum Oil Derived Quenchants Are Used. Petroleum Oil Quenchants Possesses A Number Of Significant Disadvantages, Including Poor Biodegradability, Toxicity, Flammability And Non-Renewability In Addition To Being Susceptible To Global Supply Issues. Hence It Is Of Continuing

Interest To Identify Alternative Quenchants To Petroleum Oil. Currently, Vegetable Oils Like Gingelly, Canola, Soya Bean, Corn, Cotton Seed And Sunflower Oils Are Most Commonly Available. Out Of These, Gingelly Oil Exhibit A Narrow Viscosity Range, High Boiling Point, Nontoxic, Renewable And Highly Biodegradable. Hence We Use The Combination Of Both Gingelly And Engine Oil (15w-40) As Quenchant And Identifying The Best Proportion (Table 2) Of Quenchant Which Provide Desired Micro-Structural Characteristics And Hardness.

Designations	Proportions
A	100% Vegetable Oil
B	70% Vegetable Oil & 30% Engine Oil
C	50% Vegetable Oil & 50% Engine Oil
D	30% Vegetable Oil & 70% Engine Oil
E	100% Engine Oil

Table 2

Mechanisms Of Heat Removal During Quenching

The Mechanism Of Cooling Largely Depends On Geometry Of A Given Material That Dictates The Requirements Of The Quench System.

Generally, We Talk About Three Distinct Phases Of Cooling.

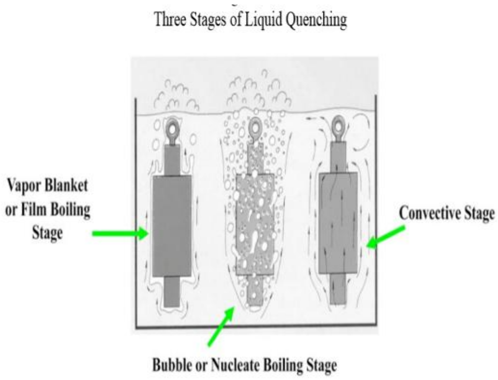
Phase 1 Is Called The "Vapour Blanket" (Or "Film Boiling") Stage. It Is Characterized By The Leidenfrost Phenomenon, Which Is The Formation Of An Unbroken Vapour Blanket That Surrounds And Insulates The Work Piece. It Is Formed When The Supply Of Heat From The Surface Of The Material Exceeds The Amount Of Heat That Can Be Carried Away By The Cooling Medium. The Stability Of The Vapour Layer, And The Ability Of The Oil To Harden Steel Is Dependent On The Metal's Surface Irregularities, Oxides Present, Surface-Wetting Additives Which Accelerates The Wetting Process And Destabilize The Vapour Blanket, And The Quench Oil's Molecular Composition, Including The Presence Of More Volatile Oil Degradation By-Products. In This Stage The Cooling Rate Is Relatively Slow In That The Vapour Envelopes Acts As An Insulator And Cooling Is A Function Of Conduction Through The Vapour Envelope.

Phase 2 Is The Second Stage Of Cooling Known As The "Vapour Transport" (Or "Nucleate Boiling" Or "Bubble Boiling") Stage. It Is During This Portion Of The Cooling Cycle That The Highest Heat Transfer Rates Are Produced. The Point At Which This Transition Occurs And The Rate Of Heat Transfer In This Region Depends On The Oil's Overall Molecular Composition. It Begins When The Surface Temperature Of The Part Has Cooled Enough So That The Vapour Envelope Formed In Phase 2 Collapses. Violent Boiling Of The Quenching Liquid Results, And Heat Is Removed From The Metal At A Very Rapid Rate, Largely Due To Heat Of Vaporization. The Boiling Point Of The Quenchant Determines The Conclusion Of This Phase. Size And Shape Of The Vapour Bubbles Are Important In Controlling The Duration Of This Phase. The Majority Of Material Distortion Occurs During This Stage.

Phase 3 Is The Third Stage Of Cooling Called The "Liquid" (Or "Convection") Cooling Stage. The Cooling Rate During This Stage Is Slower Than That Developed In The Second Stage And Is Exponentially Dependent On The Oil's Viscosity, Which Will Vary With The Degree Of Oil Decomposition. Increasing Oil Decomposition Will Result Initially In A Reduction Of Oil Viscosity Followed By Increasing Viscosity As The Degradation Process Increases. Heat Transfer Rates Increase With Lower Viscosities And Decrease With Increasing Viscosity.

The Final Phase, Begins When The Temperature Of The Metal Surface Is Reduced To The Boiling Point (Or Boiling Range) Of The Quenching Liquid. Below This Temperature, Boiling Stops And Slow Cooling Takes Place By Conduction And Convection. The Difference In Temperature Between The Boiling Point Of The Liquid And The Bath Temperature Is A Major Factor Influencing The Rate Of Heat Transfer In Liquid Quenching. Viscosity Of The Quenchant Plays A Major Role In The Cooling Rate In This Stage.

Figure 1 Shows The Three Distinct Phases Of Cooling



II. LITERATURE REVIEW

Soaking Is The Process Of Dissolving Carbides In To The Matrix. The Hardness Depends On The Amount Of Carbide Dissolved In It, The

Carbide Which Are Not Dissolved Are Called Primary Carbide Or Undissolved Carbides.

In The Process Of Annealing The Steel Is Exposed To A Very High Temperature And Then Soaked At This Temperature For A Particular Time And Then It Is Very Slowly Cooled So As To Relieve Stresses And Thereby Increasing Its Ductility And Toughness And Produce Its Desired Microstructure.

In Hardening Process, The Steel Is Heated To An Austenising Temperature And Then Quenched In Water Or Oil To The Desired Hardness By The Production Of Martensitestructure In It. While At The Same Time Steel Becomes Brittle In Nature. To Reduce The Brittleness And To Improve The Internal Toughness, The Steel Is Tempered After The Quenching Process. The Hardness Is Marginally Reduced, But Toughness Is Greatly Improved.

The Strength And Hardness Of Some Metal Alloys May Be Enhanced By The Formation Of Very Small Uniformly Dispersed Particle To Second Phase Within The Original Phase Matrix. The Is Accomplished By Heat Treatment Process Of Precipitation Hardening.

In Many Application, To Improve Wear Resistance Only The Outer Case Of The Component (I.E. Surface Of The Component) Needs To Be Hardened As In The Case Of Surface Of The Gears, Rollers And Screws. The Main Surface Hardness Techniques Are Flame Hardening, Induction Hardening, Laser And Electron Beam Hardening.

Normalising Is Used To Refine The Grains And To Produce Uniform And Desirable Grain Size Distributions, As Fine Grained Steels Are Tougher Than Coarse Grained Steels. Normalising Is Accomplished By Heating The Steel Approximately 55 To 85 Degree Celsius. Above The Upper Critical Temperature Of Specific Steel Then, Sufficient Time Allowed For The Alloy To Completely Transform Into Austenite, And The Component Is Cooled In Air.

Medium And High Carbon Steel With Coarse Pearlite Structure Are Spheroidized. The Process Consists Of Heating The Alloy At Temperature Just Below 700degreescelsius In The Pearlite Region, And The Temperature Is Maintained For 15 To 25 Hours, So That The Cementite Coalesces To Form Spheroidized Particles. By This Process, The Steel Becomes Soft And Brittleness Is Removed.

III. METHODOLOGY

The Following Steps Were Carried Out In The Present Experimental Investigations,

- Samples Of D3 Cold Work Tool Were Prepared For The Metallographic And Hardness Test.
- Microstructure Were Examined Before The Heat Treatment Process Of The Tool Steel.
- Heat Treatment Process And Quenching With Different Mediums Were Conducted.
- Microstructure Analysis Were Examined After The Heat Treatment Process And Rockwell Hardness Test Were Conducted.
- From The Different Readings And Data Obtained, The Results Were Inferred And The Specimen With Better Hardness Were Identified.

Experimental Details

1. Sample Preparation

The Procured Sample Of D3 Steel Of Length 300mm And 16mm Diameter Is Cut In To 6 Pieces Of Length 15mm From One End Of The Sample Using A Power Hacksaw,While Cutting With The Power Hacksaw Sufficient Amount Coolant Is Provided To The Power Hacksaw So That Cutting Temperature Does Not Affect The Material Structure.

2. Annealing

Annealing Is A Heat Treatment Process That Alters The Physical And Sometime Chemical Properties Of A Material To Increase Its Ductility And Reduce Its Hardness Making It More Workable. It Involves Heating A Material Above Its Recrystallization Temperature, Maintaining A Suitable Temperature For A Suitable Amount Of Time, And Then Cooling. Here All Specimens Were Placed Inside An Electrical Furnace At Some Distance Apart From Each Other So That They Do Not Stick Together. Adjust The Temperature In Furnace About (1050°C)I.E. Above Its Austenitization Temperature. It Requires About 2.5 Hours To Reach The Desired Temperature.

3. Soaking

The Temperature Of The Furnace Must Be Held Constant During The Soaking Period, Since During This Period That Rearrangement Of The Internal Structure Of The Steel Takes Place. Length Of The Soaking Period Depends Upon The Type Of Steel And The Size Of The Part. Naturally Heavier Parts Require Longer Soaking To Ensure Equal Heating Throughout. As A General Rule A Soaking Period Of 30 Minutes To One Hour Is Sufficient For The Average Heat Treating Operation. Here After Reaching The Desired Temperature, The Samples Were Soaked About 30 Minutes.It Is Not Possible To Maintain The Temperature Of The Furnace At 1050°C As The Heater Cutoff Automatically To 1049°C And Again

Get Heated To The Initial Temperature.So There Is Fluctuation Of About 1°C During Holding Period.These Small Variations Are Usually Neglected And Assumes It Be Constant.

4. Quenching

Quenching Is The Rapid Cooling Of Work Piece In Water To Obtain Certain Mechanical Properties. Quenching Prevents Undesired Low Temperature Processes Such As Phase Transformations From Occurring.

Here After The Soaking Period, The Samples Are Taken Out One By One From The Furnace With Help Of Tong And Dipped In Five Different Sand Pots Consisting Of Different Proportions Of Quenchant.Each Pot Is Designated Depend On The Proportion Of Quenchant Contained In It.The Designation On Pot Is Shown In Table 3.

Designation On Pot	Proportion Of Quenchant
A	100% Vegetable Oil
B	70% Vegetable Oil& 30% Engine Oil
C	50% Vegetable Oil& 50% Engine Oil
D	30% Vegetable Oil& 70% Engine Oil
E	100% Engine Oil

Table 3

Once Each Sample Is Sudden Quenched In Each Pot, It Is Made To Lay Inside The Pot For About 3 To 4 Minutes. The Temperature Of Quenchant After Quenching Rises To About 50°C.

5. Removing Scales

The Scales Present In The Samples Were Removed In Order To Get True Surface So That Polishing Work Can Be Performed.The Scales Are Formed By Chemical Composition Of Iron Or Other Elements Contained In Steel With Oxygen From Air Or From The Atmosphere Of Electric Furnace.

6. Rough Grinding

The First Step In Grinding Is To Make The Surface Absolutely Flat, In Order To Make It Suitable For Viewing At Higher Magnification Through Microscope. This Can Be Done Using File, Rotating Grinding Wheel Or A Motor Driven Energy Belt. If A File Is Used, It Is Preferable To Keep The File Stationery And To Rub The Specimen Fixed And Filing In The Conventional Way. Again, Care Must Be Taken To Ensure Not To Get The Specimen Heated.

7. Intermediate And Fine Grinding

This Is Carried Out Using A Sequence Of Emery Papers Of Progressively Finer Abrasive Grit Sizes. Grit Sizes Of 180,220,280,320,380,400,600,1200,1500 And 2000 Are Usually Used Forthis Purpose. The Emery Paper Held On A Hard Flat Surface Like A Glass Plate And The Specimen Rubbed Against It With Reasonable Pressure. Rubbing Should Be Done Only In One Direction, Preferably Away From The Operator.

After Grinding On Every Paper, The Specimen As Well As The Hands Of The Operator Are Thoroughly Washed And Dried. The Specimen Is First Ground On 180 Emery Paper So That New Scratches Due To Present Grinding Are Produced At Right Angles To Those Were Produced During The Previous Filing Or Grinding. Grinding On 180 Paper Is Continued Till All The Previous Scratches Are Disappeared. Specimen Is Then Washed And Dried. The Same Procedure Is Repeated With 220,280,320,400,600,1200,1500 And 2000 Grit Papers One After The Other. While Transferring The Specimen To Next Finer Grade Of Paper, The Specimen Should Be Turned Through 90°C And Ground. This Procedure Is Repeated Till The Finest Emery Paper Has Been Used And The Specimen Would Be Apparently Scratch Free.

8. Advanced Polishing

Here The Specimen Once Polished Manually Is Bought On To The Double Disc. Double Disc Polishing Machine Consist Of Two Disc Rotated By A Motor. Emery Paper With 2000 Grid Is Attached To The Polishing Disc To Aid The Polishing. The Specimen Is Placed Against The Rotating Disc By Firmly Holding It With The Hand. Here The Entire Polishing Takes Places Without Using Any Lubricant. The Material Is Polished Until All The Scratches Are Removed And A Mirror Finished Surface Is Obtained.

9. Etching

Before Being Etched The Specimen Can Be Viewed For Inclusions, Slags, Flakes Etc. The Mechanism Of Polishing Is Such That It Leaves A Flowed Or Amorphous Layer Of Metal On The Surface. Unless The Layer Is Removed, The True Structure Will Not Be Revealed. Etching Is Done On A Polished Specimen To Remove The Flowed Layer Produced By Polishing. An Etchant Is Used To Dissolve This Layer And Remove It So That The Microstructural Features Are Visible Under Microscope.

The Principle Of Etching Is Based On The Preferential Staining Or Preferential Dissolution Of One Or More Phases Present In The Microstructure. This Happens Primarily Due To The Differences In Chemical Composition And Secondly Due To Differences In Orientation Of Grains. The Atoms Oriented Along The Region Between Two Adjacent Grains Will Dissolve Easily Than Other Atoms. This Would Expose The

Grain Boundary And It Can Be Clearly Seen Under A Microscope. Before Etching The Specimen Must Be Absolutely Clean, Otherwise It Will Stain During Etching. In Most Cases After An Initial Washing In Running Water, The Surface Is Swabbed With Cotton Wool Dipped In A Soap Solution And Again Washing In Running Water Will Be Enough. After The Final Washing The Surface Should Be Dried Immediately By A Hot Air Dryer.

The Polished Specimen Is Etched By Using The Etching Medium (4% Nitric Acid And 96% Ethanol). The Material Will Be Etched Few To Several Seconds. After The Etching Process The Material Is Quickly Transferred Into Running Water To Wash Away The Etching Reagent. Then The Material Is Dried Using A Hot Air Blower. After Drying Properly, The Specimen Is Taken Out For The Microstructure Analysis.

10. Microstructure Analysis

Microstructure Is The Very Small Scale Structure Of Material, Defined As The Structure Of Prepared Surface Of Material Is Revealed By A Microscope. Herethe Processed Specimen Is Placed In An Inverted Microscope. The Microscope Used Was Of Qs Metrology Which Uses Metallurgical Image Analysis Software (Mias). The Software Is Totally Automated And Provides Analysis Of Microstructure. The Microstructure Of Material Can Strongly Influence Physical Properties Such As Strength, Toughness, Ductility, Hardness, Etc.

The Specimen Is Placed Over A Table On Microscope Which Can Be Moved With The Knob Provided The Side Of Microscope To Get The Desired Microstructure. Focusing Knob Is Provided To Focus The Image Of Microscope. By Pressing The Snap Button Take And Store The Picture Of Microstructure At Each Position. In Order To Discriminate The Phases Of Steel Select The Required Microstructure And Click On Phase Button, Enter The Name And Select A Colour That Distinguishes Each Phase. Similarly Mark The Name And Identification Colour Of All Phases. Once Every Phase Is Marked, Click On The Run Button To Get The Percentage Details Of Each Phase And Click On The Report Button To Get Detailed Percentage Composition Represented With The Help Of Pie Chart Along The Original Microstructure Image And Phase Distinguished Image.

11. Hardness Testing

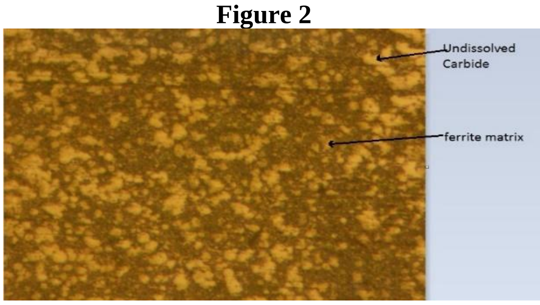
The Hardness Of The Specimen Is Founded By Using The Rockwell Hardness Testing Machine. The Rockwell Hardness Machine Consist Of An Intender Which Strikes The Specimen Surface To Measure Its Hardness. A Dial In The Machine Gives The Measure Of Hardness (Hrc No.) Two Or Three Indentations Are Made On The Specimen And The Average Value Of Hrc No Is Noted Down. 150kgf Of Load Is Applied On The Specimen For The Indentations By The Machine. The Specimen With The Highest Value Of Hrc Number Will Be The Hardest One.

IV. RESULT AND DISCUSSION

Microstructure Analysis Results Of D3 Steel

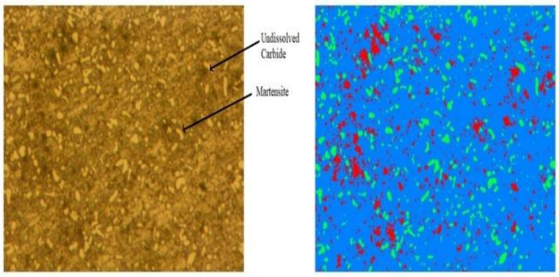
Untreated D3

Figure 2



D3a

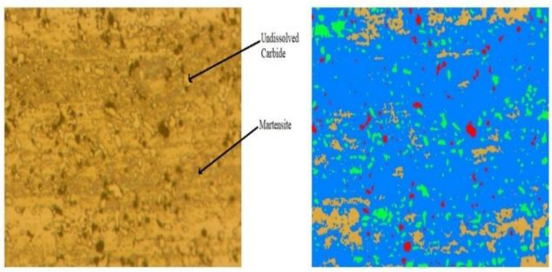
Figure 3



The Figure Shows The Microstructure And Phase Distinguished Microstructural Image Of D3 Steel Quenched With 100% Of Vegetable Oil. It Contains 4.97% Of Retained Austenite, 5.94%Of Undissolved Carbide, 89.09% Of Martensite.

D3 B

Figure 4

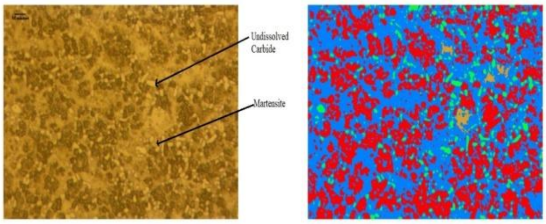


The Figure Shows The Microstructure And Phase Distinguished Microstructural Image Of D3 Steel Quenched With 70% Of Vegetable Oil And 30% Of Engine Oil. It Contains 2.42% Of

Retained Austenite, 4% Of Undissolved Carbide, 94.47% Of Martensite.

D3 C

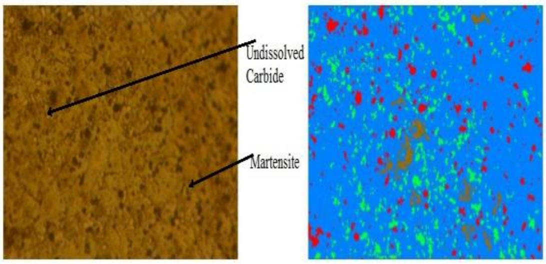
Figure 5



The Figure Shows The Microstructure And Phase Distinguished Microstructural Image Of D3 Steel Quenched With 50% Of Vegetable Oil And 50% Of Engine Oil. It Contains 25% Of Retained Austenite, 6% Of Undissolved Carbide, 65% Of Martensite.

D3 D

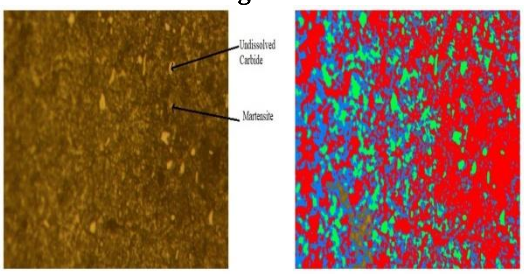
Figure 6



The Figure Shows The Microstructure And Phase Distinguished Microstructural Image Of D3 Steel Quenched With 30% Of Vegetable Oil And 70% Of Engine Oil. It Contains 62% Of Retained Austenite, 16% Of Undissolved Carbide, 11% Of Martensite.

D3 E

Figure 7



The Figure Shows The Microstructure And Phase Distinguished Microstructural Image Of D3 Steel Quenched With 100% Of Engine Oil. It Contains 74.35% Of Retained Austenite, 7% Of Undissolved Carbide, 18.65% Of Martensite.

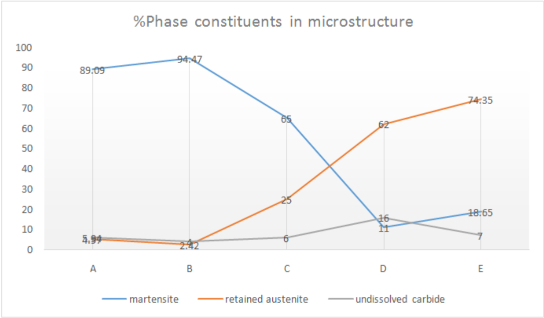


Figure 8

Hardness Testing Results

The Table Shows The Rockwell Hardness Of The D3 Tool Steel And Also Shows The Microstructural Analysis Test Results Of D3 Tool Steel. Rockwell Hardness Number Of D3 For Various Heat Treatment Presented In The Table Indicate The Increase Of Hardness Of Steels Samples Due To Heat Treatment And Also Show Their Percent Composition Of Different Elements In Microstructure. Hence The Amount Of Martensite Determine The Hardness Of The Material.

Nomenclature	Hardness Number (Hrc)	Ra-Retained Austenite (%)	Uc- Undissolved Carbide (%)	M-Martensite (%)
A	52.33	4.97	5.94	89.09
B	58.33	2.42	4	94
C	56.6	25	6	69
D	51	62	16	11
E	54.33	74.35	7	18.65

Table 4

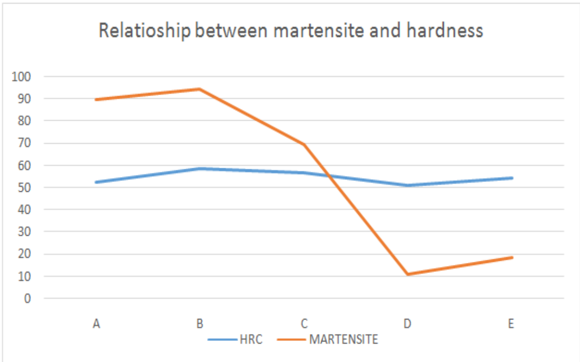


Figure 9

Inference

As From The Above Test Results The Highest Hardness Was Obtained For Sample B (Hrc – 58.33). Sample B Was Quenched With 70% Of Vegetable Oil And 30% Engine Oil. It Is Found That Maximum Percent Of Martensite Was In Sample B (94%). Hence The Increase In Percentage Of Martensite Increases the Hardness

Of The Sample. The Lowest Hardness Was Obtained With The Sample D (Hrc -51). Sample B Was Quenched With 30% Of Engine Oil And 70% Of Vegetable Oil. It Can Also Be Observed Sample D Has Minimum Percent Of Martensite (11%).

The Reason For Increase In Hardness When Martensite Phase Increase Is Due To The Body Centred Tetrahedral Cubic Structure Of Martensite As It Blocks The Movement Of Carbon Atom.

REFERENCE

[1]. Bhupindersingh And Prabhdeep Singh Bajwa, Study The Effect Of Microstructure AndHardnessAfterHeatTreatment"InternationalJournalOf Mechanical And Production Engineering", Volume- 4, Issue-8, Aug.-2016.

[2]. S.K. Saha, Lalta Prasad And Virendra Kumar, Experimental Investigations On Heat Treatment Of Cold Work Tool Steels: Part 1, Air Hardening Grade (D2), "International Journal Of Engineering Research And Applications (Ijera)", Vol. 2, Issue 2, Mar-Apr 2012.

[3]. Ashish Bhateja, Aditya Varma, Ashish Kashyap And Bhupinder Singh, 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, "The International Journal Of Engineering And Science (Ijes)", Volume1, Issue 2 ,2012.

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