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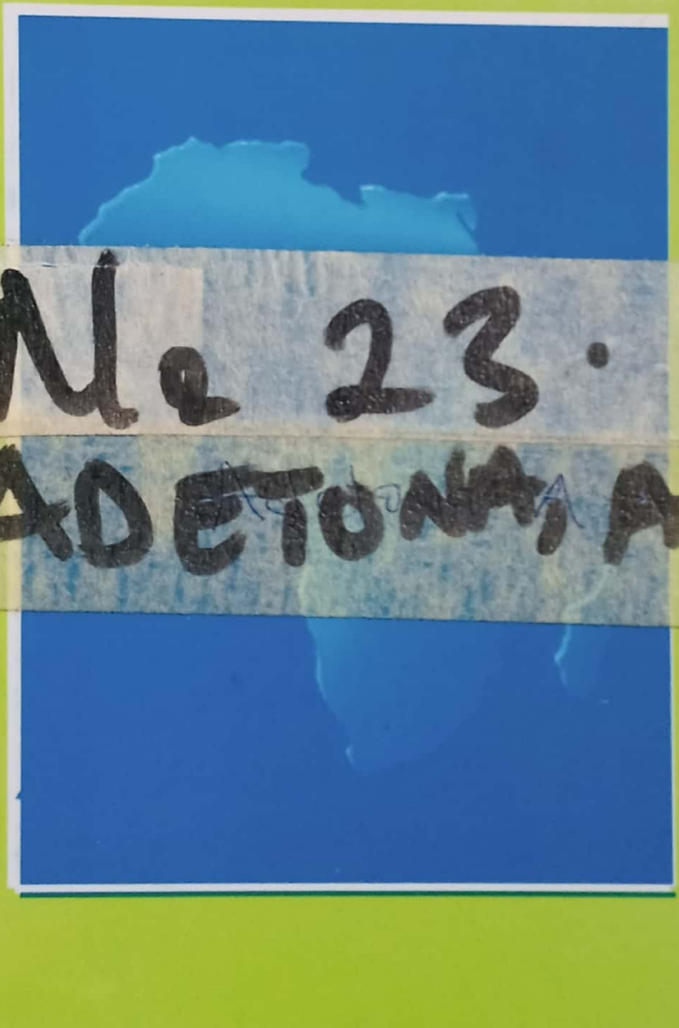

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ALYSIS AND DESCRIPTION OF THE THREE STAGE HEAT TREATMENTS REQUIRED IN THE FABRICATION OF AN ADJUSTABLE DIE (THREAD CUTTING TOOL) FROM A HIGH CARBON SPRING STEEL

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ABSTRACT

This work constituted the appropriate heat treatment required in Converting high carbon steel (spring steel) to a machine-able sample or tool steel. The study of their mechanical and microstructural properties, to further determine the application of these materials in the manufacturing industry, and engineering purposes. The sample for the research is a high carbon steel (2.0 percent carbon) cut out of a lorry spring. The sample is hot worked to the required shape and size. It is then annealed from a temperature of about 850°C to room temperature, over a period of six hours in an oven. The mechanical property and microstructural analysis test were carried out after annealing. A hole is drilled at the centre of the sample using a 4.5mm drill bit; the hole is threaded using a 0.25mm standard screw tap after which it is cut into two equal halves. The resulting Die (a thread cutting tool) is now heated to a temperature of about 650°C and quenched in red oil austentically to room temperature, to increase its hardness and toughness. Brinnell hardness test was carried out on the resulting tool. The resulting Die (thread cutting tool) was used to thread several samples of steel from low to medium carbon steel. The result of our analysis shows that, with proper heat treatment high carbon steel can be converted to sample that is ductile to be machine; also the ductile and machine-able sample can be re-hardened and made tough, thereby acquiring the properties of tool steel.

INTRODUCTION

One of the ways in which man has been known to have superiority over the result of the creatures in our wor
is his ability to make tools and use them in various ways that suit him. The production of tools by man start
during the era of the 'early man' when man made tools from steel in order to supplement his strength a
produce some simple machines to process food and materials for health. It is interesting to note that th
production of these machines would have been practically impossible if tool materials for threading, cuttin
forming and shaping of various components were not developed. herefore, the need for annealing the tool ste
then arise, the tool steel are a large group of steels which upon being heat treated exhibit a high streng
hardness and wear resistance. Tool steels which have been hot forged or cold hob bed must be annealed befo
processing with further operations such as machining or hardening. Many grades of tools steel are a
hardening or partially air hardening which results in build up of internal stress in tools forged and air coo
prior to machining. Tapes and die tools which may need to be re hardened for various reasons must
annealed. Many grades of tools steel posses' thermal stability (i.e. capability of retaining its mechanic
properties) which often occurs in working edges of tools. Tools steel is normally delivered in the soft anneal
condition; this is to make the material easy to machine with cutting tools and to give it a microstructu
suitable for hardening. The microstructures consist of a soft matrix in which carbides are embedded. T
problem associated with production of tools in Nigeria. Especially thread cutting tools are Lack of requ
special machines for the production of tool steels with required mechanical properties, there are no adequa
furnaces that are required to heat the raw material (ingots) to the temperature for alloying to produce speci
steels and finally, the country lacks the fundamental basis even though the country is blessed with a lot of hi
grade raw material. The versatility of steel as an engineering material arises from the fact that their proper
are very amendable to heat treatment. Heat treatment principle governs the procedure required to obt
particular microstructure in a given metal to suit the desired applications in design and structures. Quench
heat treatment is commonly used to induce Hardening effect in steel. The resulting microstructure is used

microstructure. Structure-sensitive properties such as strength, ductility and toughness establish the ease of manufacturing, service performance and limitation of service condition of heat treatment metals. [6]

Purpose of Heat Treatment

Heat treatment is done to achieve the following objectives:

i. Relief stresses induced during cold working
ii. Secure the proper grain structure.
iii. Dec rease the hardness and increase the ductility.
iv. Increase the hardness so as to increase the resistance to wear or to enable the steel to withstand more service condition
v. Improve the machinability
vi. Improve the cutting properties of tool steels
vii. Change or modified the magnetic properties of steel
viii. Increase the toughness; that is to produce a steel having both a high tensile strength and good ductility, enabling it to withstand high impact.

Theory of Heat treatment

Carbon and iron exist together in several different phases depending on carbon percentage and temperature from Fig 2.0, there are four phases in the Fe – C phase diagram, which are ferrite, cementite, austenite and martensite. This diagram only shows the steel portion of the system. For carbon contents of 2-6.67%, the alloy is cast iron. Above 6.67% carbon, the alloy consists of cementite and graphite [4]. An alloy consisting of exactly 0.76% carbon and 99.24% Fe has the lowest temperature at which the conversion from ferrite and cementite to austenite is complete. This is known as eutectoid steel. Increasing carbon above this amount, as well as the addition of other alloying elements, also increase the temperature complete phase transformation (ie hardening).

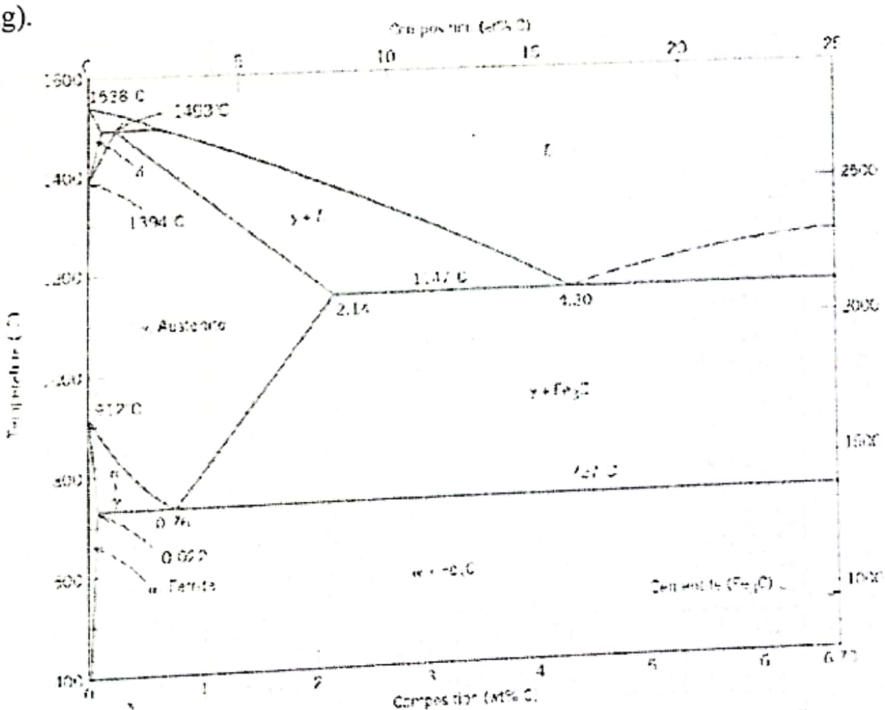

FIG 1

The iron-iron carbide phase diagram. [Adapted from *Binary Alloy Phase Diagrams*, 2nd edition, Vol. 1, T. B. Massalski (Editor-in-Chief), 1990. Reprinted by permission of ASM International, Materials Park, OH.]

Fully annealed carbon steel consists, in addition to impurities and other alloyed elements, of a mechanical mixture of iron and iron carbide. The iron takes the crystalline from ferrite, and the iron carbide takes the crystalline form of cementite. The overall structure consists of bands of these two components and is known as pearlite. In this state the steel is soft and workable. As the steel is heated above the critical temperature, about

1335^0 (724^{0}c), it undergoes a phase change, recrystallizing as austenite. Continued heating to the hardeni temperature, 1450 - 1500^0 f (788 - 843^{0}c) ensures complete conversion to austenite. At this point the steel is longer magnetic, and its colour is cherry- red. If the austenite steel is cooled slowly (the process known annealing), it will return to the pearlite structure. However, it is cooled suddenly by quenching in a bath of a new crystal structure, martensite, is formed. Martensite is characterized by an angular needle – like structu and very high hardness. While martensite steel is extremely hard, it is also extremely brittle and will brea chip and crumble with the slightest shock. Furthermore, internal stresses remain in the tool from the sudde quenching; these will also facilitate breakage of the tool. Tempering relieves these stresses and causes parti composition of the martensite into ferrite and cementite. The amount of this partial phase change is controlle by the tempering temperature. The tempered steel is not as hard as pure martensite, but is much tougher [2,3,

Determination of Temperature of Heat Treatment from Color Chart

Steel exhibits different colors depending on temperature. Temperature above 800^{0}f (427^{0}c) produ incandescent colors, the atoms in the steel are so energized by heat that they give off photons. Temperatur below 800^{0}f (427^{0}c) produces oxidation colors. As the steel is heated, an oxide layer is formed on the surfac its thickness (and thus the interference color as light is reflected) is a function of temperature [9,11]. The colors are employed in tempering tool steel. Since it is not always possible to measure the temperature of t sample using thermometer, color determination is the most available method of temperature determination f heat treatment.

2000°F	Bright yellow	1093°C
1900°F	Dark yellow	1038°C
1800°F	Orange yellow	982°C
1700°F	Orange	927°C
1600°F	Orange red	871°C
1500°F	Bright red	816°C
1400°F	Red	760°C
1300°F	Medium red	704°C
1200°F	Dull red	649°C
1100°F	Slight red	593°C
1000°F	Very slight red, mostly grey	538°C
0800°F	Dark grey	427°C
0575°F		302°C
0540°F	Dark Purple	282°C
0520°F	Purple	271°C
0500°F	[illegible]	260°C
0480°F	Brown	249°C
0465°F	Dark Straw	241°C
0445°F	Light Straw	229°C
0390°F	Faint Straw	199°C

Fig 2: Temperature Chart

Forms of Heat Treatment

Annealing

Annealing is a generic term denoting a treatment that consist of heating to and holding at a suitable temperature followed by cooling at an appropriate rate, primarily for softening of metallic materials. It can be applied to produce designed changes in other properties or in microstructure. Metals may be annealed to facilitate cold working or machining, to improve mechanical or electrical properties or to promote dimensional stability.As the hardness of metal increases during cold working, ductility decreases and additional cold reduction becomes so difficult that the material must be annealed to restore its ductility. Such annealing between processing steps is referred to as "in – process" or simply "process" annealing.

Tempering

This is a process in which previously hardened or normalized' steel is heated to a temperature below the transformation range and cooled at a suitable rate, primary to increase ductility and toughness. Metals are tempered by reheating after hardening to obtain specific values of mechanical properties and to relieve quenching stresses and ensure dimensional stability. Tempering usually follow quenching from above the critical temperature normally at atmospheric temperature . [12]

Quenching

Quenching is the rapid cooling of steel from a suitable elevated temperature. This generally is accomplished by immersion in a media.The type of property obtained when an heated sample is quenched in red oil result to an hardened alloy, which is capable of being brittle and can easily break. [13]

METHODOLOGY

Equipment and Apparatus

a. Optical microscope: This is an instrument used to determine the micro structural grain structure of the specified sample
b. Digital camera:This is an instrument used to snap the grain structure which was viewed on the microscope.
c. Manual polishing table:These are specified standard manual for polishing.
d. Nital solution (5%): This is a chemical used to expose the internal structures of metals. Usually called etchants.
e. Quenching media (red oil): These are fluids in which metals are quenched in.
f. Silicon carbide paper: This are materials used for smoothen metal surface.
g. Hardness testing machine: This is a machine used for determining the hardness of a material.
h. anvil and hammer: this is used for hotworking the steel to size and shape.
i. electric drill and drill bit: to drill a hole 0.45mm at the center of the sample.
j. 0.25 screw tap and hack saw: to cut the require thread and slice the die into two equal halves.

Tool steels samples

a. Control sample A: This is a steel sample that has not undergone heat treatment process
b. Annealed sample B: This is when sample A is being heated and allowed to be cooled in the furnace at temperature between 816°C-871°C
c. Quenched sample C (Hardened): This is a sample of B that was quenched in red oil at a temperature between 760°C-816°C

Specimen Preparation

Grinding

The specimen surface is required to be plan and smooth to obtain accurate results from our analysis. To achieve this, the sample is grinded using grinding stone then wet ground. A better result was obtained on flat wheels using silicon carbide paper

Polishing

The polishing abrasive used was cerium oxide in distilled water suspension. The abrasive was then poured on the polishing wheel. The wheel was switched on after which the samples were then held one by one against the surface.

Etching

The etchant used was Nital (5%) and applied to the face of the samples. It was then ready for microscopi examination

Fabrication

The sample is hot worked to the required shape and size using hammer on an anvil . It is then annealed from temperature of about 850°C to room temjperature, over a period of six hours in an oven. The above specime surface preparation was then perform. The mechanical property and microstructural analysis test were carrie out after annealing. A hole is drilled at the centre of the sample using a 4.5mm drill bit.this hole should b about 30 percent smaller compared to the diameter of the standard screw tap so as to achieve a very sha cutting edge. The hole is threaded using a 0.25mm standard screw tap after which it is cut into two equ halves. The resulting Die (a thread cutting tool) is now heated to a temperature of about 760°C and quenched red oil austentically to room temperature. This last procedure requires a lot of patient and technical abili After heating to require temperature (760°C) the sample is deep into red oil. that is at a temperature sligh above room temperature, for about ten to fifteen seconds and remove to heat-up in air before it return to the o this process is repeated several times till the sample cools to room temperature. This process will increase strength, hardness and toughness. Brinell hardness test was carried out on the resulting tool.

MECHANICAL TESTS

Brinell hardness Testing

Hardness is a measure of a material resistance to localized plastic deformation. The degree of hardness of material can be manifested in a number of different ways depending upon the condition to which the material subjected. In metals, the most commonly used measure of hardness depends upon the resistance to penetrati by a much harder body. The hardness test is carried out by pressing a ball with a predetermined force into t surface of the specimen.

Procedure

The surface of the samples on which the hardness testing was to be performed was filed, ground and polish with emery paper to enhance the degree of accuracy obtained and clarity of indentation diameter. A li constant load on a hardened steel bell 1mm diameter was applied to the flat surface of the already measur work piece and maintained for 15 sec. The diameter of indentation made on the surface of the angles using low power graduated microscope. The mean diameter was taken and the Brinell hardness number HB_N w computed.

$$HB_N = \frac{\text{Load (kg)} \times 5}{\text{Area of curved surface indentation}}$$

$$HB_N = \frac{T}{\frac{1}{2}\pi D\,(D - \sqrt{D^2 - d^2})\ mm^2}$$

T = Load in kg
D = Diameter of ball, mm
d = diameter of indentation
g = Acceleration due to gravity = 10.0 m/s

Microscopic Examination

The specimen which had been prepared was placed perpendicular to the axis of the microscopic. It was th illuminated by light from a condenser through the objective lens into a beam. The optical axis of t microscope was made to lie parallel to the beam allowing light from the specimen to reflect into the object lens from features normal to the optical axis. The final image which revealed the various microscopic featu such as grain boundaries, coring and precipitated particles were formed on the eyepiece. Photomicrogra were then taken by the camera on the microscope.

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TEST RESULT AND ANALYSIS

Brinell Hardness Test for the Samples

For Sample A (control)

$$HB = \frac{2*278}{\Pi*1(1-\sqrt{1^2-0.5^2})}$$

$$=556/2.7207$$

$$204.4N/mm^2$$

For Sample B (Annealed)

$$HB = \frac{2*210}{\Pi*1(1-\sqrt{1^2-0.35^2})}$$

$$= 420/2.943$$

$$142.71N/mm^2$$

For Sample C (hardened)

$$HB = \frac{2*294.3}{\Pi*1(1-\sqrt{1^2-0.52^2})}$$

$$=588.6/2.683$$

$$219.35 N/mm^2$$

Material sample	Load(p) N	Time Sec	Diameter of indentor(D)	Average indentor diameter(d)	BrinellHardness test N/mm²
Sample A(control)	278	15	1mm	0.5mm	204.4
Sample B(Annealed)	210	15	1mm	0.35mm	142.71
Sample C(Hardened)	294.3	15	1mm	0.52mm	219.4

DISCUSSION

Sample A (control) reveals a microstructure of true steel which consists of austenite and little traces of ferrite. Sample A has a high solubility of carbon content. It is also an FCC structures. It has a hardness value of 204.4N/mm², meaning that carbon content is high and can not be machined. Sample B (Annealed) reveals a microstructure of austenite and pearlite, the present of austenite also determines the size of ferrite and pearlite.Due to the slow cooling of sample B, in the oven, the carbon content in the ferrite is being ejected into the cememtite, thereby making the sample structure finer, also introducing a high ductility. Annealing temperature is between 816°C-871°C.It has a hardness value of 142.71N/mm ².This is a ductile material, which can be easily machined. Sample C (Hardened) reveals a microstructural level of fine martensite structure in a banite matrix after it has being quenched in red oil at a temperature between 760°C-816°C. It has a bcc structure and it hardness value is given as219.35 N/mm² .Due to the quenching, the ssample is being hardened, the structure then becomes tough and there is increase in hardness of the material,this is the mechanical property require for a cutting tools which will have to withstand high stress and frequent increase in temperature.

CONCLUSION

From the investigation of this project,it can be concluded that heat treatment has a great effect on the mechanical properties of steel. It can be seen that hardness depends on the distribution of pearlite and ferrite structure in steels,which can be varied using an appropriate heat treatment. Also it is seen that from the appearance of microstructure, one can be able to predict some mechanical properties of a particular steel specimen for example it has been shown that there is a direct relationship between hardness and microstructures. As in the case of the control sample, the structure consists of mainly austenite, which is an FCC structure and has high carbon content. The amount of carbon content determine the hardenability of that material, while the annealed sample has a structure that is less of carbon content, which show a high level of ductility and can be machined . The hardened sample has a martensite structure, which shows that it is a very hard material .The work also showed the various ways in which properties of steel can be improved and change. This can be seen from the same steel sample that was given different heat treatment. These samples also ended with different microstructures. Finally. it can be deduced that the finer the grain structures, higher its hardness and hence it becomes brittle. The hardened sample which has the finest grain structure the highest hardness value.

RECOMMENDATIONS

This project work was done with a single steel specimen with the aim of determine the changes in mechanical properties and structure that occur when steel is given different heat treatment. This will enable researcher to known the right kind of material for a specific purpose. For future investigation, the work can extending to cover the following areas:

1. The use of different quenching media, example salt balt, polymer oil
2. The heat treatment can be carried out at a different temperature
3. Incorporation of impact test to give better understanding of changes in mechanical properties..
4. Bigger magnification such as 1000can also be used. The one used in this work was 500

Finally, the idea of this work is to show that with proper heat treatment. high carbon steel can be made ductile and malleable for machining or to fabricate a tape and die. Also with proper heat treatment the can be given enough hardness and toughness to serve as a cutting tool. This aims has been proven right the analysis of changes in the mechanical properties observed after the analysis of these project work.

REFERNCES

Avner S.H (1981); Introduction of physical metallurgy 2nd edition, Edard Arnold Ltd

Boyer H, Gall. T.L (1985); Metal hand book, 2nd edition, America society of metals

Higgin R.A, (1973); Engineering metallurgy, Hodd and Stougter Educational

Rollason E.C (1980); Metallurgy for engineer 4th edition. Edward Arnold Ltd

Hayden H.W et al (1963) mechanical behavior; The structure and properties of metal

Dieter G.E (1961) mechanical metallurgy vol 3 Mc Graw .Hill Bos

ok co. New York.

Kempster M.HA (1967) Engineering Material English University pres ltd London..

Willam D. C Jr (1997), materials science and Engineering fourth edition, John wiley and sons, inc, 393, 311pp.

Rajan T.U, Sharima C.R, Ashoks. (1998); Heat Treatment Principles and Techniques, eastern Edition, Prentic- Hall of India private limited India 345pp.

Howard E.B, James J.B, Paul M.U (1989); Heat treater's giuide standard Practices and procedures for fifth printing, 3pp

John V.B (1992); Introduction to Engineering Materials. Third edition. London, Macmillan press 225pp.

Karl-erik T. (1974); stell and its Heat treatment