FAILURE MODE APPRAISAL IN DIE BLOCK

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Abstract— The die fatigue life is determined by the design of metalformed product and die, forming process configuration, die stress and the entire metal-forming system. In the metal formed industries die is an important tool for fabrication of metal formed product. At the same time failure of tool steel take place because of many numbers of causes and insufficient material selection criteria. Main objective is to study the effect on the hardness of three sample grades of tool steel i.e. EN-31, D2, and D3 after heat treatment processes such as Annealing, Normalizing, and Hardening & Tempering. After selection of material & heat treatment processes further aims to perform mechanical & chemical analysis. After composition testing aims to do heat treatment processes i.e. Annealing, Normalizing, and Hardening & Tempering to be carried on such material & after treatment aims to perform hardness testing on the treated and untreated work samples.

Keywords — Heat treatment, Annealing, Normalizing, hardening, Tempering, Hardness.

I. INTRODUCTION

Die is an important tool for deformation or fabrication of metal-formed products. Die is a work holding device, designed specifically for a particular design of a product. Die is rigidly held on the base of the press. To have good die performance and service life, the die should be optimally designed and precisely fabricated. [9] The block or plate made from highquality steel and mounted on the bottom portion of the die set to which section or parts of the die. It is subjected to extreme pressures and wear conditions. Hence the die block is made of superior quality of tool steel. [10] Tool steels are broadly divided into six categories like cold work, shock resisting, hot work, high speed, water hardening, plastic mould and specialpurpose tool steels. Among them, cold work tool steels are the most important category, as they are used for many types of tools, dies and other applications where high wear resistance and low cost are needed. [2]

II. TOOL STEEL FAILURES

Failures of punch in manufacturing operation generally results one or more of the following causes:

1. Improper design
2. Defective material
3. Improper heat treatment and finishing operations
4. Overheating and heat checking (crack caused by

temperature cycling)

5. Excessive wear
6. Overloading
7. Misuse
8. Improper handling. [5]

A. Some of the major factors leading to die failures are described below

Although these factors apply to die block made of tool steel, many are also applicable to other tool materials. The proper design of die block is as important as the proper selection of die material. In order to withstand forces in manufacturing process, a die must have proper cross-sectional and clearance. Sharp corner, radii, and the fillets, as well as abrupt changes in cross section, act as stress raiser and can have detrimental effects on die block life. [4]

III. EXPERIMENTAL APPROACH FOR METHOD & MATERIAL SELECTION

Step 1: Literature has been collected from research papers, journals, books etc. and literature gap analysis related to die block failure.

In today’s industrial growth greater demands on products and materials, from which they are made. Years ago, many designers never figured out stress and strain, elasticity, fatigue, or similar values.

Fig. 1 Die Block Failure

Under this failure analysis main purpose is selection effective tool steel material with appropriate grade is necessary in most common manufacturing industry. A tool steel material grade EN-31, D-3 and D-2 is selected for project work. The main reason to select the material is availability of material their heat treatment process and cost of tool steel.

Step 2: Industrial survey for selection of tool steel and preparation of objective function.

More number of tools steel materials are used in manufacturing industry under these most preferable material selection criteria is to be used under the cost of raw material and related to its heat treatment process. Overall analysis is necessary for maintain the objective function of the project work.

Step 3: Cutting and turning of tool steel specimens.

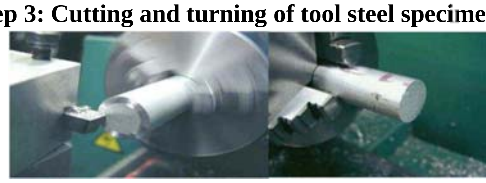

Fig 2 Turning of tool steel

There was requirement for two samples of each material for the heat treatment and testing purpose. So we cut the sample in 16 mm diameter with 250 mm to 100mm length. Three samples i.e. EN-31, D-3 and D-2 can be cut with power hack saw and turning which is carried out under the Lathe Machine.

Step 4: Composition testing of untreated tool steel i.e.

EN 31, D3, and D2.

Chemical composition is the most important influence upon shearing performance of the tool steel. Each alloying element in tool steel such as tungsten, chromium, molybdenum, vanadium, has a specific role in determining the mechanical properties. In chemical testing the components and purity of many raw or in-process materials, and finished product find out. Also Measure multiple constituents simultaneously. It 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 values Compared 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, D-3 and D-2 also.

Step 5: Tensile testing of tool steel with measure their all parameters.

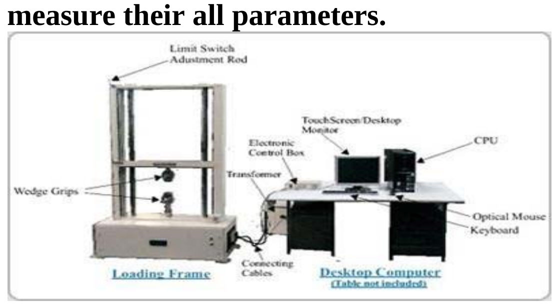

Fig. 3 Tensile test on Tool Steel

In tensile testing of tool steel measure the specimen Diameter, Gauge length also carried out yield load, ultimate load, yield stress, ultimate tensile strength and percentage of elongation. Overall tensile test is carried out on the Universal Testing Machine.

Table No. 1 Tensile test parameters

Material	**EN-31**	**D-3**	**D-2**
Thickness/ Dia. Mm	16.96	16.56	16.37
Area mm2	226.00	215.47	210.55
Gauge Length Mm	85.00	83.00	82.00
Final GL Mm	104.98	85.26	91.68
Yield load KN	111.02	97.20	87.12
Ultimate Load KN	158.90	204.56	152.46
Yield Stress Mpa	491.23	451.11	413.77

UTS Mpa	703.08	949.37	724.09
% E	23.51	2.72	11.80

Step 6: Applying heat treatment process such as annealing, hardening and tempering for EN-31, D-3, and D-2.

Using the heat treatment process one after one to maintain the required mechanical properties under the temperature range i.e. 800 ^{0}c to 820^0 c in annealing process and in hardening process 750^0 C to 850^{0}C.

Step 7: Hardness testing of treated tool steel i.e. EN-31, D-3 and D-2.

Fig. 4 Rockwell Hardness Tester

There are many types of material testing equipment, hardness testing machines provide the simplest and most economical testing methods and they play a vital role in research through to production and commercial transactions. Under which most suitable Rockwell hardness tester is used also Steel Hardness Calculator Used for Conversion of Values. Using that calculator we calculated HRB value & Brinell Hardness HB, Vickers HV.

Type of sample: - Round piece, Material - EN-31, D-3 and D-2.

Heat treatment: - Annealing, Hardening & Tempering.

IV. RESULT AND DISCUSSION

Table No. 2 Composition of tool steel after composition testing of test materials

Material	EN-31	D-3	D-2
C %	0.92	2.34	1.58
Si %	0.29	0.43	0.58
Mn %	0.34	0.28	0.3
S %	0.007	0.005	0.005
P %	0.02	0.026	0.02
Cr %	1.42	12.2	11.01
	---	0.11	1.02
W %	---	0.001	---
Mo %	---	---	1.05
Ni %	---	---	---

Type of the sample: - Round piece

Material sample: - EN-31, D-3 and D-2.

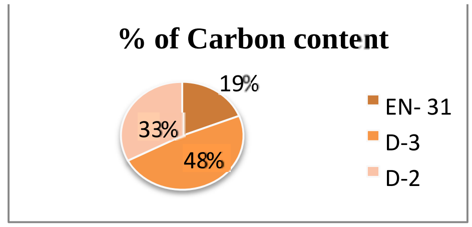

Fig.5 Carbon % of Tool steel material

To check the maximum and minimum carbon contents and chromium contents in EN-31, D-3 and D-2 samples tool steel materials.

Conclusion- In various types of material original carbon contents Shows the originality of Material used for testing leads to validity of performances outcomes that carried out in further comparative statements. Using this pie chart shows the maximum carbon contents in particular type of material.

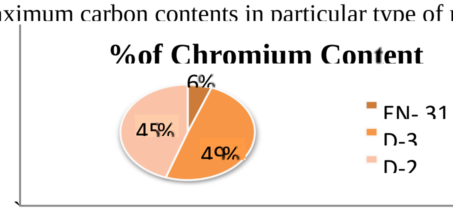

Fig.6 Chromium % of Tool steel material

Conclusion: - In above graphical representation shows the maximum chromium content in each type of material. As a result, chromium is very frequently used as a decorative, and simultaneously corrosion-resistant, coating. Under this conclusion D-3 and D-2 material chromium contents are high as compared to OHNS, EN-31 and EN-9.

Table No. 3 Hardness of tool steel EN-31 after Heat Treatment

Test Material	Heat Treatment	Rockwell CHRC	Rockwell BHRB	Brinell Hardness	Vickers HV
EN-31	Annealing	18	95	212	218
	Hardening & Tempering	50	117	469	505

Conclusion For EN-31:- In annealing and hardening and tempering process the Rockwell hardness grade HRB of material is to be change from 95 Rockwell HRB in annealing and 117 Rockwell HRB in hardening and tempering is to be shown in table.

Table No. 4 Hardness of tool steel D-3 after Heat Treatment

Test Mate ri al	Heat Treatm e nt	Rock w ell CHR C	Rock w ell B-HRB	Brin ell Hard n ess HB	Vicke rs HV
D-3	Anneali ng	27	103	262	262
	Harden ng & Temper i ng	56	-	572	694

Conclusion for D-3:- In the above table shows the Rockwell C-HRC hardness of D-3 material under annealing heat treatment process is 27 C-HRC and after hardening and tempering it is 56 C-HRC.

Table No. 5 Hardness of tool steel D-2 after Heat Treatment

Test Materi al	Hea t Trea t men t	Rock w ell C-HRC	Ro ck w ell B-H R B	Brine ll Hard ness HB	Vick e rs HV
D-2	Anne al ing	12	91	186	184
	Hard en ing & Temp e ring	60	-	627	-

Conclusion for D-2:- In the above table shows the Rockwell C-HRC hardness of D-2 material under annealing heat treatment process is 12 C-HRC and after hardening and tempering it is 60 C-HRC.

V. COMPARATIVE RESULTS AFTER HEAT

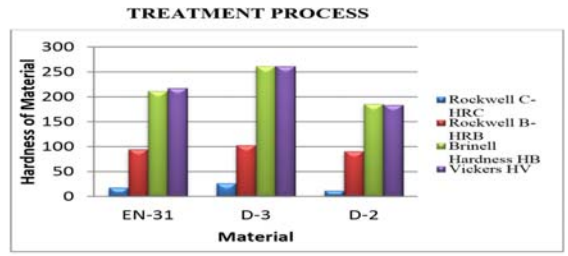

Fig. 7 Graphical representation of Hardness of Tool Steel after Annealing

A. ***After Annealing* :-** If we consider annealing heat treatment process Brinell Hardness- Grade of material D-3, D-2 and EN-31 grade material shows the 212HB, 262HB and 186HB. After annealing heat treatment process Brinell hardness of D-3 grade tool steel material is higher as compared to D-2 and EN31. It means that the D-3 grade tool steel material is harder than the remaining tool steel material. Generally its hardness is increase or decrees after the hardening and tempering process. If we again consider the Vickers hardness test result the hardness of D-3 grade material is 262 HV which is higher as compared to D-2 and EN-31 tool steel material.

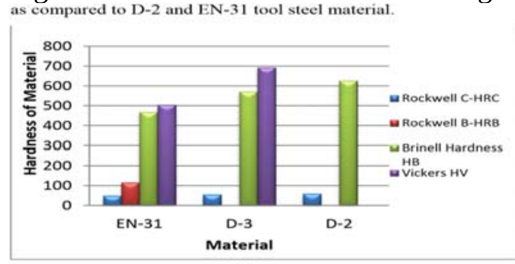

Fig. 8 Graphical representation of Hardness of Tool Steel after Hardening and Tempering

B. ***After Hardening and Tempering*: -** After hardening and tempering heat treatment process Brinell hardness HB of D-3 and D-2 material is 572 HB and 627HB. D-2 material shows the maximum Brinell hardness as compared to EN-31 and D-3 Also in Vickers hardness HV for D-3 material is 694 HV means Vickers hardness of D-3 material is maximum as compared to EN-31 and D-2.

C. ***Comparison*:** After annealing specimen becomes harder than 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.

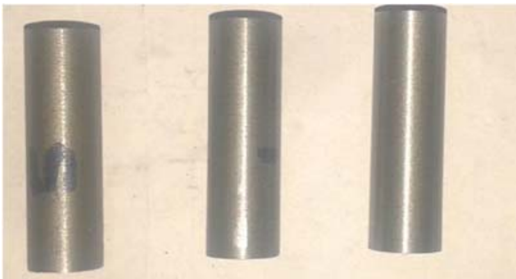

Fig. 9 Overview of the test sample used for heat treatment process

VI. CONCLUSION

In this work different methods are studied for increasing the mechanical properties and Heat treatment method is used to find the mechanical properties of EN31, D2, and D3 materials. And also know the effect of heat treatment on the mechanical properties of EN31, D2, and D3 materials. 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, D2, and D3 after heat treatment processes such as annealing, normalizing, and hardening & tempering. A future aspect of this study to carry out further is very wide. Selecting of different tool steel material and compare them the effects on their mechanical properties. Using Different analytical approaches is also making an effective outcome which is also recommended.

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