Energy Efficient Heat Treatment Process to Remove the Failure of Tool Steel in Industrial Component

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Abstract

The major components in forming process of operations are dies and punches. The combination of die and punch together make a one unit which is called as die set. As per the requirement basic material to manufacture die and punch is cold work tool steel. To perform maximum work then wear resistance as well as strength of die is required. Generally working surface of die is made with stellite or cemented carbide material. For the present work, the investigators have visited to automobile industry where industry is presently facing the problem of failures in inner lower control arm which is a part of suspension system. The surface of component can display typical ductile fracture on inner and outer surface of inner lower control arm. The experimental work had been carried out with energy efficient heat treatment process for tool steel such as OHNS, D-2, D-3, and EN-31 as per industrial requirement on the basis of tensile test and chemical Compositions.

Keywords. Cold work tool steel, Failure Mode Effect Analysis (FMEA), Rework priority number (RPN), Draw bed restraining Forces, Percentage indices process capable.

1. INTRODUCTION

In automobile industry sheet metal parts perform an important role also it will increase competition in global markets. Different parts of four wheeler system, body parts of vehicle, and door parts are manufactured in sheet metal industry. In manufacturing industry we can observed that for each and every process there are some defects [1]. In manufacturing engineering process design for sheet metal forming is also important aspect, which can calculate cost and evaluate quality of product. On the basis of trial and error method conventional process design is efficiently implemented [2]. So to reduce cost, remove defects, improve product quality and productivity decide whether the industry can maintain their leading edge and competitiveness in all over market places [3].

Recently, the industry has to set group for the forming simulation which are as follows [4].

I. Reduce the time:
   a. Early checking of work pieces
   b. Reduce the time for development
   c. Reduce the trial times
   d. Check modification wishes with minimum time

II. Reduce the Cost:
   a. Manufactured product with minimum cost
   b. Reduce the cost of die

c. Press down sizing
d. Reliability of part increases

III. Improve the product quality:

a. Selection of quality work piece material
b. Complicated parts with Quality
c. Accumulation for new materials
d. Process repeatability

1.1. Origin of the Research Problem

This project focused on industrial component which are used in automobile suspension system which is attached to chassis. Now demand of industry is to avoid component failure as well as no fracture or no rework. The tools are loaded in complex manner, understanding these loading conditions are important for efficient jigs and fixture design. The components must be durable enough to tolerate significant loads and harsh environmental effects. From design point of view, data for defective components is shown below.

1.2. Failure of tool steel as well as burr on edge of component

Figure 1.1 Failure of Punches as well as burr on edges of component

Inside this industrial requirement base and graphical as well as experimental failure analysis it is observed that, material selection is more important for tool steels with appropriate grades also. In this project work select tool steels are D-2, D-3, OHNS and EN-31material grade. The main purpose for the selection of above tool steel are availability and cost of tool steel material as well as demand if industry. During the punching and piercing operation failure of tool steel as well as burr on edge seen on component to which rejection of part take place.

1.3. Justification for Problem Selection

During manufacturing and forming process defects are burr, wrinkles, spring back, punch failure, taper cutting and cracking etc. seen on the components. All the defects are study under product and process failure mode effect analysis (FMEA) and check their severity, occurrences and detections calculate rework priority number (RPN) for each and every defect. From this defects punch failure and Fracture on edges of component is a major problem with maximum RPN number, on the nose of punch cracks are visible. Now the present work has to focus on above define defects are to be visible on inner lower control arm component.

Table 1.1 List of operations with defects and actions

Stages of Operations	**Type of Defect**	**Type of Issue**	**Remarks /Action required**
Shearing	Burr on edges	No Effect	Grinding
Blanking	Burr on edges	No Effect	Rework / Grinding
Drawing	Wrinkles	Quality	Rework for quality
Forming	Spring back	Die design	Rework on die design
	Fracture on Edges	Production Loss	Part rejected
Pocket on left side	Burr on edges	Quality	Grinding
		Rework	
Pocket on Right side	Burr on edges	Quality Issue	Grinding
		Rework	
First Notching	Taper Cutting	Loss of production	Part rejected
Second Notching	Taper Cutting	Loss of production	Part rejected
Punching of Four Holes	Failure of Punch	Maintenance Issue	Change Punch
		Repairing	

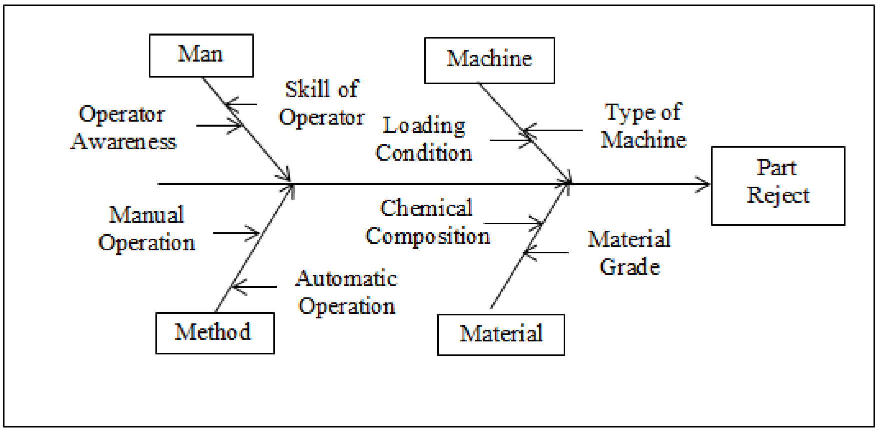

Figure 1.2 Causes and Effect Diagram

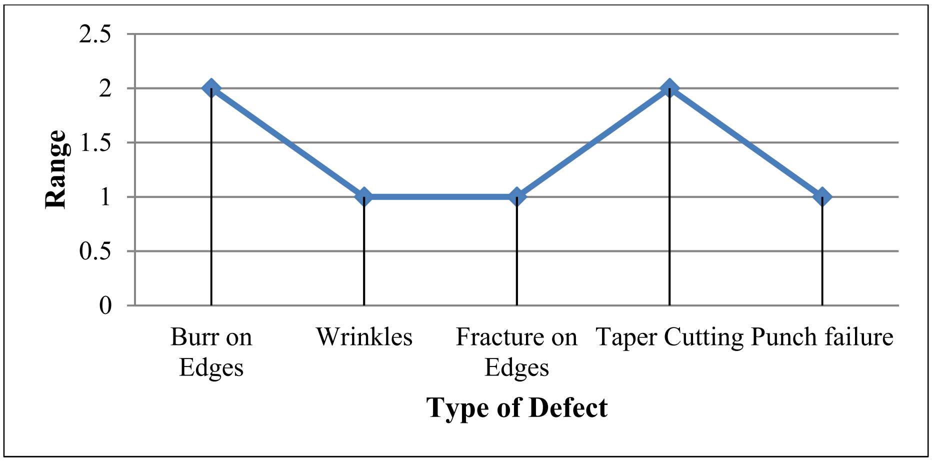

Figure 1.3 Graphical representations of Range and Type of defect

Graphical representation shows that, the failure range of each defect with respected to type of defect in Shearing, Blanking, Drawing, Forming, Punching and Notching process of operation. To identify different defects of components select 2000 samples. The maximum failure rate of punch failure is very high on the basis of maintenance time and cost of component. From this chart we focus on Burr on edges of components as well as failure of punch. For this identification and selection of problem referred product FMEA and Process FMEA with reference to Rework priority number also.

2. EXPERIMENTAL METHOD & MATERIAL SELECTION

Figure 2.1 Unfinished test samples before experimental work

In sheet metal production different operation are carried out to manufacture product are blanking, forming, bending, notching, piercing, punching as per requirements of components and their materials, from which they are manufactured. In punching operation elasticity, fatigue and stress-strain are never found to maintain burr free operations of without punch failure will never avoid. In above operations major problems are seen on punch failure and it is observed that it will create other issues on industrial components.

Step 1: Industrial survey for preparation of objective function and selection of tool steels.

Generally many number of tool steels are used in sheet metal processing industry as per their need, from the available material with best suitable heat treatment process selection of tool steel again very important. To maintain object function of project work it is important to perform overall analysis.

Step 2: Specimen preparation with turning operations

Figure No.2.2 Specimen preparation with turning operations

In experimental work always require sample with their specimen preparation. For this testing purpose select four sample materials as per the requirement of industrial expert, availability of sample material and cost of material. Prepare a two sample for each material for two heat treatment process like annealing, hardening and tempering. For the sample preparation material cutting is the initial step which is carried out using Hydraulic or Power Hack saw machine. Sample sizes are 16 mm diameters with 250mm to 100mm length are prepared using required lathe operations on turret lathe.

Step 3 : Testing of tool steel materials before heat treatment for EN-31, D-3, D-2 AND OHNS

To check the performance of tool steel it is important to check their chemical composition. In chemical composition it easily checks the alloy elements and their impact on performance of tool steels just like shearing. If we consider the physical properties and mechanical properties of tool steel like stiffness, corrosion resistance, strength, ductility, plasticity, elasticity then it is important to check their alloying elements. Each and every alloying elements like chromium, molybdenum, tungsten, vanadium having a specific role to determine above properties. Test for each sample is done 2-4 times from smooth surface of sample on different point. So this overall procedure is performed for OHNS, D-3, D-2 and EN-31tool steel samples.

3. RESULTS AND DISCUSSION

Table 3.1 Tool steel material Chemical Composition

Material	**EN- 31**	**D-3**	**D-2**	**OHNS**
Si%	0.29	0.43	0.58	0.58

Material	EN- 31	D-3	D-2	OHNS
C%	0.92	2.34	1.58	1.28
Mn%	0.34	0.28	0.3	1
Ni%	--	--	--	0.17
W%	-	0.02	--	1.5
Mo%	--	--	1.04	--
V%	-	0.10	1.02	--
S%	0.007	0.005	0.005	0.02
P%	0.02	0.026	0.02	0.027
Cr%	1.42	12.2	11.01	0.44

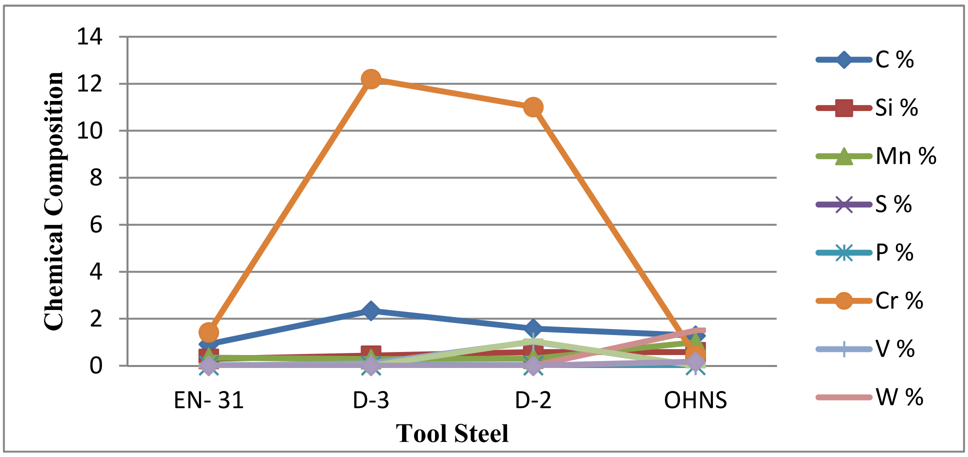

Figure 3.1 Tool steel material Chemical Composition

From the above graphical study it is observed that for D-3 and D-2 materials chromium content is maximum for these two materials. Chromium is a steely-grey, lustrous, hard, and brittle transition metal. Chromium is the main additive D-3 and D-2 materials, to which it adds anti-corrosive properties. If higher is the Melting point (1907 °C) of chromium will increase the melting point of D-3 and D-2 tool steels.

Table 3.1 Physical Properties of Sample Materials

Materials	Dia. (mm)	Area (mm^2)	Gauge Length (mm)	Final GL (mm)	Yield load (KN)	Ultimate Load (KN)	Yield Stress (MPa)	UTS (MPa)	% E
OHNS	15.25	182.65	80	96.1	85.9	157.98	441.85	816.6	20.1

Materials	Dia. (mm)	Area (mm^2)	Gauge Length (mm)	Final GL (mm)	Yield load (KN)	Ultimate Load (KN)	Yield Stress (MPa)	UTS (MPa)	% E
EN-31	15.1	179.08	82	100.1	111.02	158.9	491.23	703.1	22.1
D-2	15.05	177.89	85.1	95.05	87.12	153.05	413.77	724.1	11.7
D-3	15.12	179.55	84.9	86.65	97.2	204.56	451.11	949.4	2.06

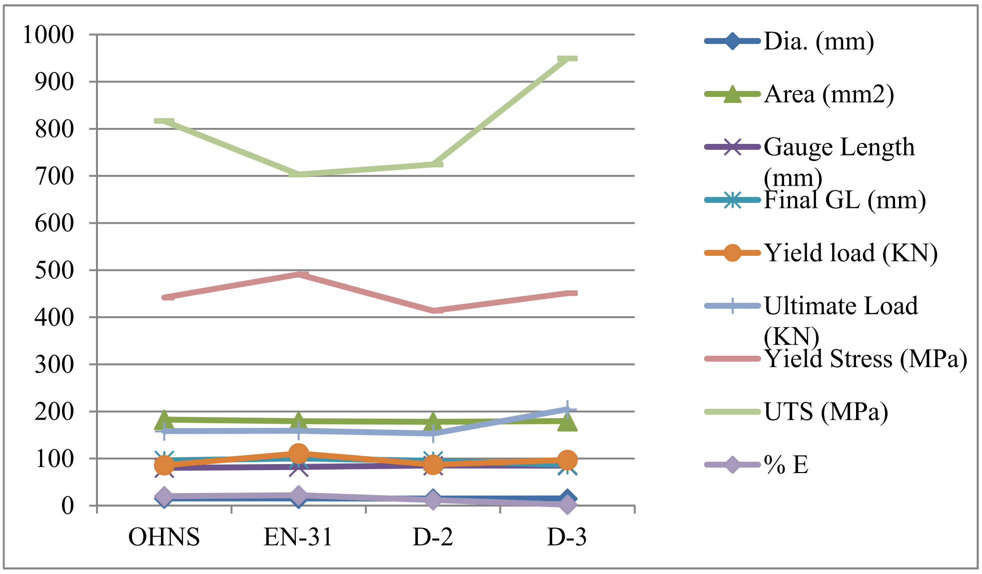

Figure 3.2 Graphical representation of Physical properties of Tool steels

Samples are to be selected for present work should be maintaining all the basic parameters to which entire experimentation done with same sequence of order. To check amount of plastic or elastic deformation of material will measured percentage of elongation. From the above measurement technique quantifies the ductility of materials. Also comparison between final length and original length determine ductility of material and percentage of elongation. From the above graphical study it is observed that percentage of elongation for D-3 and D-2 is more compared to EN-31 and OHNS.

3.1. Hardness and Heat treatment Process

Hardness is not a fundamental physical property of material it's a characteristic of a material. It is determined by measuring the permanent depth of the indentation and is defined as the resistance to indentation. By using 12 different test methods and area of indentation, indentation hardness value will be obtained easily. To check the hardness of four sample materials D-2,D-3 OHNS and EN-31used Vickers hardness tester, Brinell hardness tester and Rockwell hardness tester. From this testing methods calculate Rockwell hardness, Brinell Hardness and Vickers Hardness etc.

Testing of hardness for two general characterization

I. Material Characteristic

- Material Checking test
- Hardenability test
- Processes confirmation test
- Testing of tensile strength

II. Functionality

- Test to check function **as** per designed
- Wear resistance test
- Toughness of material
- Resistance to impact

Table 3.2 Heat Treatment of Tool steel

Test Material	**OHNS**		**EN-31**		**D-2**		**D-3**	
Heat Treatment	Annealing	Hardening & Tempering	Annealing	Hardening & Tempering	Annealing	Hardening & Tempering	Annealing	Hardening & Tempering
Rockwell C- HRC	25	65	20	55	20	75	30	60
Rockwell B- HRB	105	125	105	125	102	65	110	50
Brinell Hardness (HB)	195	470	230	470	195	590	285	560
Vickers (HV)	190	495	225	495	190	225	270	680

After Annealing Heat treatment :- From the above table and graphical representation it is observed that, Brinell hardness in annealing heat treatment process for OHNS, EN-31, D-2 and D-3 tool steel is 198HB, 230HB,195HB and 285HB. It means that, if we consider only Annealing Heat treatment process than it is observed that D-3 material is having higher hardness than OHNS, EN-31 and D-2 tool steel. Generally many times it is observed that, Hardness of tool steel material after hardening and tempering always increased or decreased. Parallel study again represents that, in Vickers hardness test D-3 tool steel having maximum (270HV) as compared to EN-31, OHNS and D-2 materials.

After Hardening and Tempering Heat treatment: - From the above table and graphical representation it is observed that, after hardening and tempering Brinell hardness of tool steels like OHNS and EN-31 is 470 HB and 470HB less than D-2 and D-3 tool steel. If we check Vickers hardness then it is observed that, Vickers hardness for OHNS is 495 HV, EN-31 is 495 HV, D-2 is 225 HV and D-3 is 680 HV etc.

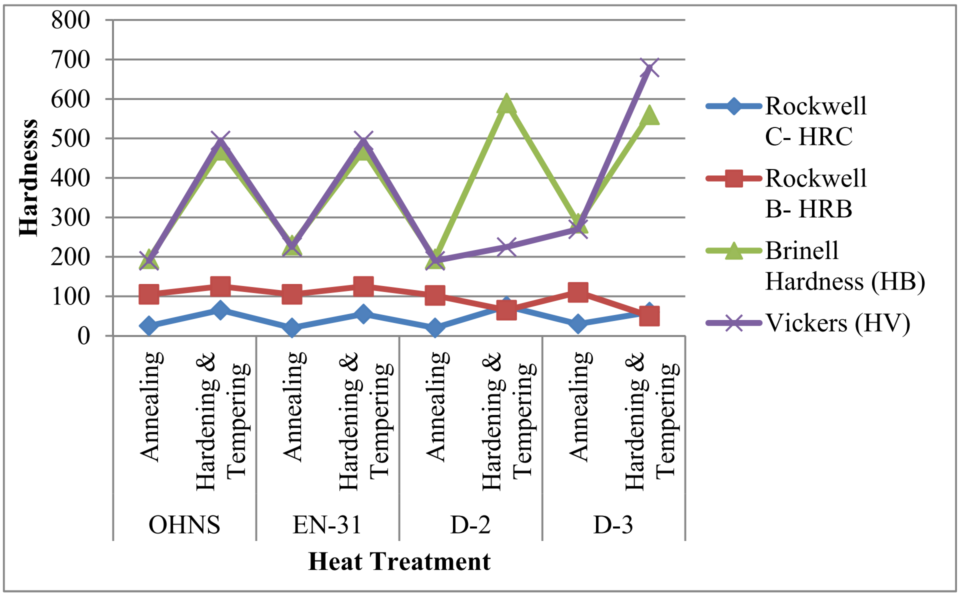

Figure.3.3 Graphical representation of Hardness and Heat Treatment Process

Comparison of Annealing and Hardening & Tempering After annealing heat treatment it is observed that, components will increase their hardness. In microstructure shows lack of grain boundaries and grain formation is not uniform. To improve this causes and effect of annealing heat treatment need to used hardening and tempering heat treatment process for good corrosion resistance, tensile strength and hardness of tool steel.

Figure 3.4 Trail on Pneumatic press machine

In industry all sheet metal processes are carried out on pneumatic press with different capacity of press are 250,400,600 tons to perform different operation like bending, drawing, blanking, piercing, Trimming, Notching etc.

4. CONCLUSION

This experimental study is very useful to avoid defects in industrial sheet metal components as well as improved energy efficiency of industries. In this paper used four samples are D-2, D-3, OHNS and EN-31 to performed energy efficient heat treatment process like Annealing, Hardening and tempering to calculate Rockwell hardness, Brinell Hardness and Vickers hardness etc. From the entire experimental study it is concluded that, D-3 tool steel give higher Vickers hardness (HV) 680 as compared to D-2, OHNS and EN-31. After experimental procedure, actual trial conducted on industrial pneumatic press machine to check the overall defects on industrial components and it is observed that defects are minimized up to 22% and it is calculated with total number of components rejected and accepted out of 2000 components. In this experimental study mostly focus on effect of heat treatment process like annealing and hardening & tempering for tool steels like OHNS, D-3, D-2 and EN-31.

5. REFERENCES

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Biographies

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