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Experimental Analysis for the Premature Failure of Deep Drawing Punch and Optimization for Production of CuZn30 Brass Tube

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Abstract

In this study, deep drawing process in a specific press machine has been analyzed for the premature failure of punches. There are various parameters that affect the output of the deep drawing procedure. Among which the inconsistent hardness, different punch materials are analyzed for the optimum production which concluded that 100Cr6 steel is best material for optimum production and long life of the punch. The research was Performed in 30-ton horizontal cranking press machine to test and carry out experimental activities. The important parameters that affect the deep drawing procedure are punch geometry, punch and die materials, working material, blank holder, Speed, stroke length. However, keeping other parameters constant, the effect of punch tip radius, hardness of the punch, Punch material, work material and coolant condition are experimentally analyzed in this study. Among the various parameters of deep drawing procedure, the optimum punch tip radius for the uniform wall thickness distribution is found to be 0.8 mm, the optimum Coolant condition is found when the jaifa soap solution and for the working material composition the best result was obtained at the 70-percentage copper but if it has to deviate the result should not contain excess of zinc percentage. The reviewed heat treatment SOP for manufacturing the punches has also been suggested as a conclusion of the study.

Keywords

Deep Drawing, Punch, Die, Material, Coolant, Brass

1. Background

Deep drawing is a common process in industry for manufacturing products from sheet metals. Very complex parts can be achieved using deep drawing. The process is widely used for producing different products such as automotive parts, defense products, cans, sinks and housing, and the application areas are getting larger every day. In the deep drawing process, the sheet metal is radially drawn into the die cavity by the mechanical action of a punch. In deep drawing the punch acts as a force transfer media for drawing action and is subjected to different kinds of stresses such as bending stresses and compressive stresses. The life of the punch plays major role in mass production industry. The premature failure of the punch disturbs the production processes and also results in more cost in production tooling's. The word 'premature failure' in this report refers to a condition of the punch at which it is unable to give an output from a machine to the specified quality standard when it is installed in the machine. The failure of punch may be breaking, bending, corroding etc. of the punch before it produces a certain specified quantity of products. Common types of punch failure are explained in following points. To reduce premature failure of punch it's necessary to understand the nature and cause of failure. The reasons for the premature failure may be numerous including the material of punch, Geometry of punch, speed, alignment of punch, handling, quality of working materials and their characteristics, coolants and lubricants used in drawing process etc. The initiative has been taken to experimentally investigate and identify the failure of the deep drawing punch through hit and trial method in the production line. This study is basically focused to a drawing machine used in one of the factories in Nepal where a brass cup is drawn into a dome shaped one end open tube. Punch has been extensively used and is a one of the major forming tools for deep drawing process. In the tube producing machine the premature failure of the punch disturbs the production process and also results in more cost of tooling's. The operators of the machine are wondering that the replacement of the punches is very non-uniform. This is to say that when they replace a punch which produced sixty thousand pieces tubes for a certain time, the next punch should have to be replaced when it produces just thirty thousand pieces or the other times it might be just five thousand or ten. this also results in low quality of the product so this is necessary to investigate and identify the types, cause and nature of pre-mature failure of deep drawing punches and accordingly to take the corrective measures. This study is particularly focused to the optimization of resources in one of the factories, where the machines were imported a long ago but the technological know-how has not been perfectly transferred to the new comers as a result there is always dilemma in deciding the best option for parameters for optimum Production. In this study the initiative has been taken to experimentally investigate and find the optimum solutions for few of the parameters for the brass tube production machine.

2. Literature Review

Liwen Tian, Changfeng Men, Qiang Yu in Optimization of process parameters in deep drawing process based on orthogonal experiment method used LS-DYNA software for finite element simulation of box parts. In the process of cold stamping, they were based on the orthogonal experiment method. The thickness of the thinnest place was considered to represent the quality of finished parts and found the optimal process parameters of blank-holder force, die entrance radius and combined with punch radius 5mm, as well as punch velocity. [1]

According to authors factors affecting the deep drawing process are .

a Punch fillet subjected to biaxial tensile stress. It make result in the thickness changing is serious.

b Most important factor which affects the thickness of minimum is bland holder force, second being concave die entrance radius, the influence of punch velocity and the radius is nominal. If the blank holding force is too big it will make the sheet ripping, if it is too small; it may make sheet wrinkling.

Saani Shakil, Mostafa Hameed and Abdessalem Chamekh in Single stage sheet cup deep drawing analysis using finite element simulation found that design and control of deep drawing process depends upon geometry and materials of the tools like blank holder, punch, die, etc., as well as the work piece material and the interaction between them. The value of blank holder force, die fillet radius and friction coefficient are modified and their effect on the punch reaction force, cup thickness and equivalent plastic strain has been analyzed. This study has found that blank holder force does not have a great impact on the drawing process. However, it can't be eliminated from the essential design variable of forming process. Die fillet radius is responsible for variation in the thickness of finished product and punch reaction forces. Therefore, die fillet radius is important variable. The friction coefficient is responsible for remarkable variation in punch reaction forces and PEEQ values and less variation in finished product thickness. [2]

Adnan I.O. Zaid and Fadhil A. Hashim in **Effect of punch and die profile radii on deep drawing of galvanized sheet** (in International journal of scientific & Eng. Research, Vol. 8, Issue 1, Jan-2017 ISSN 2229-5518) have grouped the various parameters that affect the deep drawing process into four groups, they are:

i Parameters related to the forming machine which include mechanical hydraulic or servomotor process.

ii Parameters related to the die set, (Punch and Die) which include their design, mechanical behavior radial clearance percentage, punch and die profile radii, surface roughness and out of roundness.

iii Parameters related to the blank; its material type, dimensions, geometry, chemical composition, mechanical and physical properties.

iv Parameters related to the process: dry or lubricated; lubricant type, lubrication system, holding down pressure, friction, punch force, total consumed word, drawing ratio and limiting drawing ratio. (Geometrical as well as mechanical parameters) The authors of this article concluded that maximum drawing force is greatly influenced by the radial clearance between the punch and the die, the maximum drawing force decreases with increase of the die profile radius whereas it's liability for wrinkling increases. Total consumed work in drawing the galvanized cups was also influenced by radial clearance percentage whereas the authors have found that maximum drawing force was less affected by the punch profile radius as compared to die profile radius. [3]

Ionela Iordan, Consrantin DOGARIO and Cristina Mohora in **Finite element analysis for deep drawing process and part shape optimization.** Dept. Machine and production systems, University Politechnica of Bucharest, Romania presented some aspects regarding the sheet metal deep drawing process and shape optimization by using finite element analysis in LS Dyna by evaluating the amount of strain and stress each forming process contributed to the final products. The research they performed brought out with optimal design in order to reduce deformations and help to obtain accurate parts. They also prepared two prototype molds based on these simulations. [4]

A. Pourkamali Anaraki, M. Shahabizadesh and B. Babace in**Finite element simulation of Multi-stage deep drawing processes & comparison with experimental results** Published in World academy of Science, Engineering and Technology. 6-1-2012 Stated that the experimental techniques of determining the punch force, blank holder forces and the thickness distribution of the sheet metal is quite expensive method. So they used software under axisymmetric condition to simulate the entire production steps with additional operations such as intermediate annealing and spring back on. [5]

They extracted the simulation results such as thickness distribution, punch force and residual stresses at any stages and the result was compared with the experimental results. [5]

According to authors, the multistage drawing process are usually applied to forming parts that have geometrical complexity or formability problems and can not be formed by 1-step drawing. A number of difficulties have been encountered because of strong non-linearity and the element re-meshing technique is required to eliminate severe element distortions. [5]

3. Production Process of Brass Tube in the Machine

Brass cups are procured from the supplier. These Brass cups are then annealed and fed into the machine with punch and die set up as shown in fig 1 below. Final Output of the machine is shown by the label in the figure 1 below. This process is a complex process where the geometry of the punch, coolant types used, raw materials quality and properties, hardness of the punch plays an important role in the quality of the produced tubes as well as durability of the drawing punch and die.

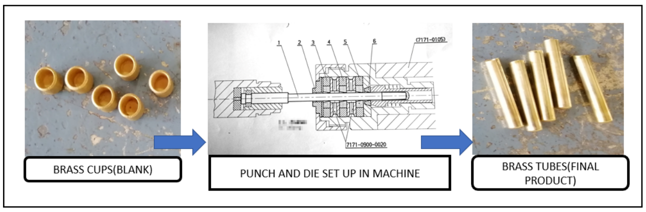

Figure 1: Production Process of brass tubes

3.1 Machines and equipment's used for Research

This cranking press machine is originally manufactured by the German Fritz Werner company Ltd. This is powered by a 8 KW, 3-Phase electric motor and mechanical Power conversion consists of a crank shaft which converter rotary motion into linear motion.

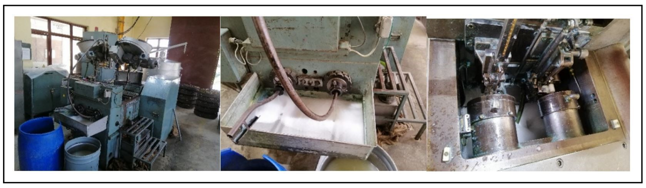

Figure 2: Horizontal Crank Press Machine

3.2 Heat Treatment System for Hardening and Tempering

The heat treatment system consists of two heating furnaces which have the maximum capacity of 1200 degree Celsius and a quenching tank used as the container of quenching oil for quenching steels for hardening and tempering purposes. This heat treatment system is employed to quench punches to set the hardness of latter to desired value.

Figure 3: Heat Treatment System

4. Methodology

Quantitative research technique is used to complete this study. The data and result are verified hit and trial method. Following flowchart illustrates the complete methodology that is followed for the completion of the thesis.

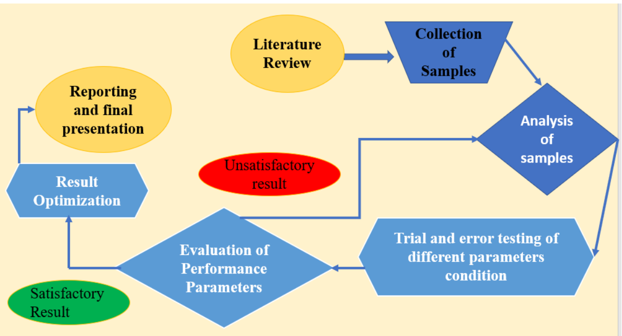

Figure 4: Research methodology

Convenience sampling technique is employed for the determination of sample size for this research. There were altogether 21 failed punches found. So, in the population size of 21 following formula was used at the error value of 5 percentage:

$$S = \frac{N}{1 + N_e} \tag{1}$$

Where, S = Sample Size, N is the population and e is the error.

For the purpose to analyze the premature failure of punches, twenty samples of the failed punches were collected. The different samples of the punches collected had different types of failure. Most of the punches were found to be chipping, stripping and head failure. Though few of them were ringing and compressive failure.

Based on the defects observed by physical and chemical analysis, new punches were manufactured by changing the punch materials, tip radius and the heat treatment SOP. New produced punches were then used in hit and trial basis to get the optimum result. Hit and trial production were carried out in following conditions to optimize the result.

a Punch Produced by using different Heat Treatment SOP

b Punch manufactured with sharp edge tip, tip radius 0.5,0.8 and 1 mm

c Hit and trial production in different lots of Brass cups procured

d Punch manufactured with three different materials

5. Result and Discussion

5.1 Hardness and Chemical Composition

The collected samples were taken to the lab and hardness for each of the sample were taken using the Innova-test Universal hardness testing machine. Setting to the Rockwell hardness tester. Most of the hardness value for failed items were found to be between 62-66 HRC. Also, the chemical composition of the sample was also measured using the Foundry Master spectrometer. The table below shows the hardness value, type of failure and chemical composition of few samples of the pre-maturely failed punches. The samples were named as S1, S2, S3 and likewise up to S20 for the purpose to use in the laboratory.

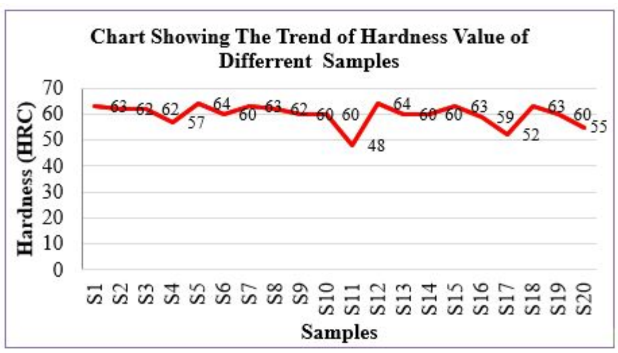

Figure 5: Chart showing the hardness trend of samples punch

Table 1: Hardness and chemical composition of samples

Sample	Type of failure	Hardness(HRC)	Type of steel
S1	Stripping	63	90MnCrV8
S2	Head failure	62	100Cr6
S3	Stripping	62	90MnCrV8
S4	Galling	57	100Cr6
S5	Chipping	64	100Cr6
S6	Galling	60	100Cr6
S7	Stripping	63	90MnCrV8
S8	Stripping	62	100Cr6
S9	chipping	60	100Cr6
S10	Chipping	60	100Cr6
S11	Bending	48	100Cr2
S12	Head failure	64	100Cr6
S13	Galling	60	90MnCrV8
S14	Stripping	60	100Cr6
S15	Stripping	63	100Cr6
S16	Ringing	59	100Cr6
S17	Galling and ringing	52	100Cr2
S18	Head failure	63	100Cr6
S19	Stripping	60	100Cr6
S20	Bending	55	100Cr6

5.2 Causes of Failure:

5.2.1 Inconsistence Hardness

Hardness is one of the most characteristic properties of materials(Zhang, Li & Zhang, 2011) the table above showing the achieved hardness is more than the stated in specification sheet (60-62) HRC Heat Treatment processes are followed after all manufacturing process are done. The sole purpose of heat treatment is to limit the hardness to a specified value which is 60-62 HRC. The list of failed parts, type of failure observed and the hardness values is as shown in the Table 1 and figure 5 above.

The hardness values of the above punches are found the more than specified value. Reasons for the unconformity might be the process parameter of heat treatment process. Several Hit-and-trial experiments found that the following heat treatment SOP shown by table 2 brought the best result.

5.3 Different steel types for punch material

The chemical composition of different 20 samples of failed punches were tested by using the spectrophotometer of Oxford Instruments. The tested

Table 2: Reviewed Heat treatment SOP

S.N.	Process Parameter	Remarks
1	Preheating Temperature	550
2	Holding Time	20 Minute
3	Heating temperature	850
4	Holding time	3 min
5	Quenching Duration	Up to 200 degrees (about 3 min)
4	Quenchant	Oil bath
5	Quenchant Temperature	Room Temperature (20 degrees)

samples were found to be made from three types of material 100Cr6 Steel,90MnCrV8 steel and 100Cr2.

The experiment shows that the punches prepared from 100Cr6 steel are more durable when they are treated according to the heat treatment SOP specified in table 2 above. This SOP is found out on the basis of several Hit and trial methods and obtaining the optimum result.

5.4 Effect of Punch Tip Radius, Work Material and Different Coolant Condition

5.4.1 Punch tip Radius

To check the influence of tip radius of punch, the drawing punch with various tip radius as shown in table below were used. Basically, the four types of tip radius were used like without radius, with radius 0.5 mm, with radius 0.8 and with radius 1 mm. The performance of these tip radius was then recorded as shown by the table 3 below.

Table 3: Effect of punch tip radius on wall thickness and length

Punch tip radius	Wall thickness of drawn case				Variation	Average	length of case
Degree	0	90	180	270			
Without Radius	0.16	0.2	0.22	0.18	0.06	0.19	57.7
Radius R-0.5 mm	0.24	0.28	0.26	0.16	0.12	0.235	60.64
Radius R-0.8mm	0.24	0.25	0.25	0.25	0.01	0.25	55.52
Radius R-1mm	0.32	0.2	0.2	0.22	0.12	0.212	58.52

According to this table, the wall thickness was found uniform when the tip radius of 0.8 mm was used. Though the wall thickness variation when the punch with sharp tipped (without radius) is also found uniform, however the required thickness value is 0.24 to 0.27 mm and the length of tube required is 54 to 57 mm. The output with radius 0.8 mm is found optimum.

5.4.2 Effect of Different Coolants

20 Punches were manufactured using 100Cr6 material with a hardness of 60 to 62 HRC. Then 5 samples each were used for 4 different coolant conditions. After the experiment was performed with all four coolant conditions the best result obtained with jaifa soap solution as shown in the table below.

Table 4: Performance of a punch with jaifa saop solution as coolant

Punch Sample Number	Production	Rejection Rate
S1	60233	2.82
S2	57465	3.11
S3	53624	4.03
S4	57999	3.41
S5	56123	2.97
Mean Value	57088.8	3.268

For different coolant conditions, the best output production was obtained with minimum mean rejection rate of 3.268 percentage when jaifa soap was used as the coolant. The result was satisfactory with the blend of machining coolant and oil, however the Vectra-4 oil is far more expensive than jaifa soap so jaifa soap solution will be the best coolant. By the properties of jaifa soap, which can act as both coolant and lubricating agent due to its slippery characteristics.

5.4.3 Effect of work material

Effect of work-material for cups drawing machine is tested for CuZn30 brass however, the various lots of brass cups recieved has different composition of Cu and Zn percentages. The effect of various composition of CuZn30 brass sheet cups received was done using spectrophotometer and then the sheets/cups were tested in the production machine under several coolant conditions.

The test reports of different received lots of brass are nomenclature for the purpose of this research as lot A, lot B, lot C, lot D as shown in the table below. The values of various constituents including Copper (Cu) and Zinc (Zn) are listed in the Original copies of the test report are attached in annexure of this research paper.

The composition of copper and zinc in the different lots of brass was tested by using spectrophotometer and listed as below.

Table 5: Composition of Brass in different lots of procurement

Lot Name	Constituents (In %)							
	Cu	Zn	Pb	Sn	Mn	Ni	P	Fe
A	71.5	28.4	0.005	0.002	0.0071	0.002	0.0005	0.002
B	70.3	29.6	0.005	0.002	0.001	0.002	0.0005	0.002
C	70.6	29.3	0.005	0.002	0.0025	0.002	0.0005	0.002
D	69.2	30.3	0.0159	0.0108	0.0212	0.0487	0.0066	0.0056

The production was found maximum with minimum rejection rate when the copper and zinc percentage in the brass is exactly 70 and 30 percentage respectively. However, it is hard to get the exact percentage of copper and zinc in the specified ratio practically. Lot B above has the exact composition of copper and zinc, which gives the best result on an average of 57283 pcs per punch and minimum rejection rate of 3.33 percentage. In case the composition of copper and zinc differed, it is good when the percentage of zinc is less than the specified percentage. For example, for lot D above the zinc percentage is excess due to which the brass becomes brittle and hence the rejection rate is high. The Performance of Lot B working material is tabulated as below.

Table 6: Production Output (Pcs) with Lot B Composition

Punch Sample Number	Production	Rejection Rate
B1	55235	2.88
B2	55835	3.17
B3	60298	4.11
B4	57618	3.48
B5	57431	3.03
Average	57283.4	3.33

5.4.4 Effect of Tool Material

There are normally 3 type of tool material for the drawing punch 100Cr6, 90MnCrv8, and 100Cr2 Normally, the manufacturing of tools is done in tools production unit of same factory. so, the experiment was performed by testing 3 pcs of tools each made up of 100Cr6, 90MnCrV8 and 100Cr2 and the best working material obtained from the previous experiment.

Table 7: Performance of different tool materials

S.N.	Punch Material Used	Hardness Value	tool Life (pcs before break down)	% Rejection
1	100Cr6	60	60243	4.26
2	90MnCrV8	60	53145	5.12 %
3	100Cr2	62	48002	4.93

When the punch of three different materials were tested for the production output at the optimum condition of hardness value, coolant and working material obtained from result and discussion of above experiments. The best optimized output of the punches made from 100Cr6 steel was found to be the best.

6. Conclusion and Recommendation

The main reason for the premature failure of punches is found to be due to the inconsistent hardness. The cause of inconsistence hardness is the heat treatment process. Also, the properties of punch material have also the slight effect in the hardness of the punches. The manufacturing process and heat-treating process of punch has been slightly modified to get the better result.

The experiment was also performed to optimize the production of brass tubes by differing the tip radius of punch.it was found that the optimum production was met when the tip radius of punch is 0.8 mm. The production was also optimized for the various composition of CuZn30 brass according to the Lott of procurement. It was found that the lot size with more Zinc percentage has more rejection rate and ununiform wall thickness. The lot size with less zinc percentage has relatively less rejection percentage and more uniformly distributed wall thickness. Regarding the coolant type used in the drawing crank press machine, the Jaifa soap which acts as the coolant as well as lubricant in the crank press machine has best result in the production.

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