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Influence of different punch shear on punch life During piercing process

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Abstract: Punching or piercing is among the oldest and most frequently used sheet metal forming process. The main objective of this study is to increase the punch life. In this study effect of different punch shear on punch life is evaluated experimentally on 30 tones Mechanical power press. In this study piercing process of ø20mm hole on 6 mm thick flat strip of Low carbon steel AISI 1020 is carried out on 30 tones mechanical power press with flat bottom punch. The main problem in this operation is punch broken frequently when using flat bottom (without shear) punch. Which results in lower punch life and productivity. Hence there is need of designing a new punches with single shear, double shear, and combined flat & double shear which gives higher punch life and productivity. Also the reason for the breakdown has been analyzed and inspected by the method of Fish bone diagram

Keywords- Piercing process, availability, fish bon diagram, root cause analysis, punch shear, tool wear, and clearance.

1. INTRODUCTION

Punching and blanking are similar sheet metal cutting operations that involve cutting the sheet metal along a closed outline. If the part that is cut out is the desired product, the operation is called blanking and the product is called blank. If the remaining stock is the desired part, the operation is called punching. For piercing process, there are several mold factors that affect punch wear. The factors are: the clearance between the punch and die; the sharpness of the cutting edges; the angle of shear on the punch and die; the percentage penetration. Much work on tooling optimization has been done in the past. But the vast majority of work was done on cold forging dies and others. Limited work has been done on effect of different punch shear.

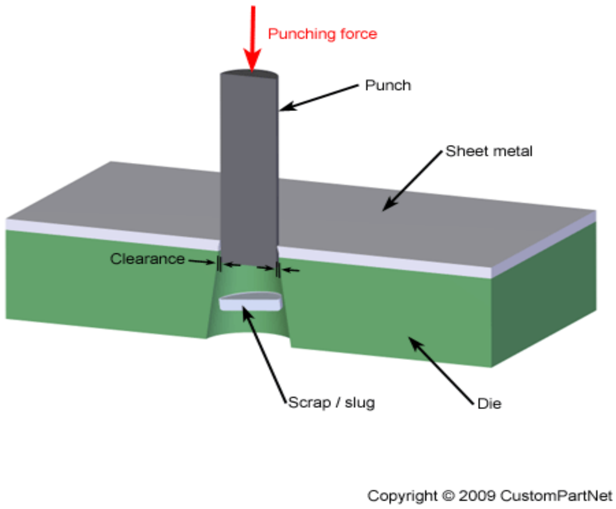

Fig. 1. Punching process.

Punching process can be considered to include series of phases in which sheet metal undergoes deformation and separation as seen in fig 2

- Impact of punch

The punch first touches the fixed sheet .at impact a compressive stress rapidly builds on the punch and sends a shock wave through it.

- Penetration

The punch penetrates into the sheet .first causing an elastic and then plastic deformation

- Fracture

When the stresses increase shearing occurs followed by fracture .fracture begins from both the punch end and die end of the sheet they usually meet and complete fracture of the material takes place

- Stripping

The punch move down to the bottom dead center and ejects the part. At the bottom dead center direction of the punch motion is reversed. Due to the friction between the stock and the surface of the punch, the surface pressure intensifies. A stripper or blank holder strips the blank from punch.

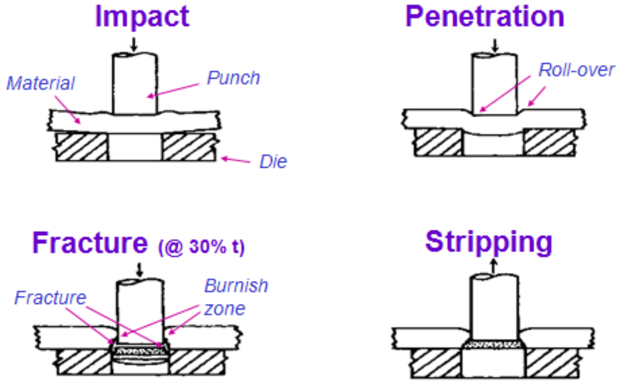

Fig.2 punching cycle.

2. LITERATURE SURVEY

Pravin kumar, Rudramurthy[1] (2013) In this literature reason for the breakdown has been analyzed and inspected by using Fish bon diagram by this analysis root causes of breakdown were identified. After root cause analysis availability, Mean time between failures increased 4.16%, 13.66% and Mean time to repair (MTTR) decrease 46.42%.

Pawan Kumar Rai, Dr.AasMohammad,[2] (2013) In this research study also clears that what practices can increase the tool life and how long we produce burr free parts. They were studied the different causes of defects (burr) in sheet metal such as clearance, improper material selection, punch& die alignment, die set design, punch geometry etc.

J arun, S pravin kumar, M. Venkatesh [3] (2013) focused their study on Failure Mode and Effect Analysis (FMEA) of piercing process. A series of punching operation is done on various work pieces and the defects are found. Based on the evidence found, the ratings are given and risk priority number (RPN) is given. It is observed that the punch chipping and point breakage due to the high impact or compressive force has the highest risk priority number **-** 336. Based on the RPN, the preventive measures are given for each failure. Some of the failures in the piercing process are like Punch tip breakage, head breakage, Slug jamming, Galling etc. They found that FMEA is a proactive approach in solving potential failure modes.

K. Nagendran ,S. Sathish, J. David [4] (2014) In this literature the analysis of tool parameters like load, stress and life of the tool are the main causes of tool wear and their model generations are created through ANSYS software. Life (In terms of travel length in m.) HcHCr punch= Max:0.0034808, Tungsten carbide punch = Max:0.0073189.

Sachin Kashid, Shailendra Kumar[5] (2014) In this literature the parameters affecting life of punches of compound die such as size and material of punches are investigated through Finite Element (FE) analysis. They can be produced with these punches before their failure.

S.Y. Luo [6] (1996) In this research the worn conditions of the punch cutting edges in punching holes on a larger thickness AISI 52100 steel plate using punches of different convex shear angles. A relatively longer punch life is obtained when convex double shear angle of 200.

Ch.Mastanam, K.Prasada Ra Dr. M.Venkateswar Rao [7] (2012) This literature gives various design calculation and FEA simulation of punch and die such as stress , deflection , length of punch, etc.

Sutasn Thipprakmasa, Siriporn Rojananb, Pravitr Paramaputic [8] (2008) In this research the authors focused on the theoretical explanation of the piercing process using step taper shaped punch (STSP) by using the finite element method (FEM) and also verified these FEM simulation results with experiments. The suitable taper angle of approximately 6◦ obtained in this study.

Yuan Yongfu, Liu Cunping [9] (2013) presented experimental research on simulating piercing of a Q235-A sheet. Simulation used the FEM program ANSYS, and conclude that the clearance was the most influential factor of the mold parameters in piercing process.

.2.1Conclusion derived from Literature Review

From review of above literature we can conclude the following points:

- ✓ For piercing process following are the important parameters such as Clearance, Tool wear, Sheet material and Thickness, Punch geometry, punch shear, Hardness value which are effect the punch life.
- ✓ Various technique such as Failure Mode and effect analysis(FMEA) , Root cause analysis , Artificial neural network (ANN) , Finite element analysis (FEA) are very use full to predict the different failure and its causes.
- ✓ Life of punches mainly depends upon the area to be blank or pierced and material of punch.
- ✓ Life of the punch can be increased by providing different types of coatings on punch.

3. PROBLEM DEFINATION

Piercing operation consist of simple hole punching. It differs from blanking in that punching (material cut from stock) is the scrap and the strip is the work piece. In this study piercing process of ø20mm hole in Low carbon steel AISI 1020, 6mm thick flat strip is carried out on 30 Tones mechanical power press. The main problem during this operation is punch broken frequently when using flat bottom (without shear) punch. Which results in lower punch life and productivity. Hence there is need of designing a new punches with different shear, which gives higher punch life and productivity.

4. RESEARCH METHODOLAGY

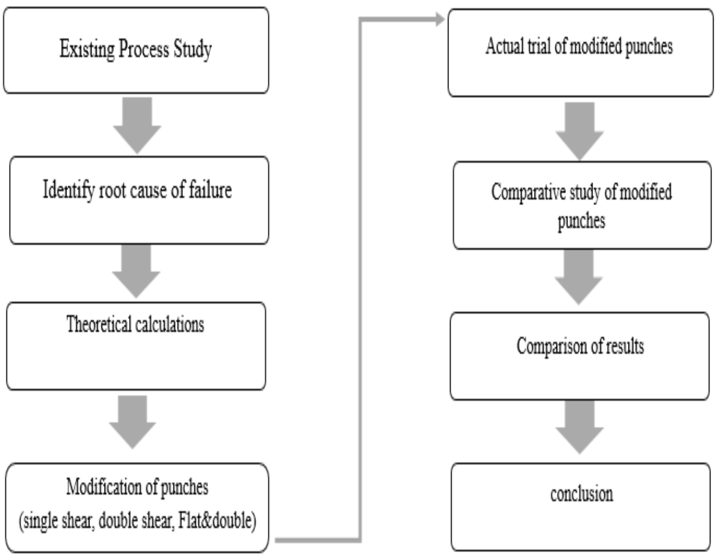

Fig. 3 research Methodology.

4.1 Theoretical calculations

1) cutting force required

Cutting force calculated by neglecting shear is given below,

$$Fc = Ls \times T \times Fs \quad \text{-----(1)}^{[2]}$$

Where,
Fc = cutting force, N
Ls = shear length, mm
T = thickness of material, mm
Fs = shear strength of material, N/mm^2

In this case we required to produce circular hole, hence for circular hole Ls= $\pi \times d$ and equation (1) can be written as,

$$Fc = \pi \times d \times T \times Fs \quad \text{-----(2)}^{[2]}$$

Where,
d= diameter of hole, mm
Now calculating cutting force by using equation (2)

In this case,

d= 20.00 mm
T= 6.00 mm
Sheet material: AISI 1020 hot rolled (annealed)
Fs= 30 kgf/mm^2 [3]
= 30*9.81 N
= 294.3 N
Now put all value in equation (2) we get,

$$Fc = 3.14 \times 20 \times 6 \times 294.3$$

Fc = 110892.24 N or 11.08 tones

- Cutting force calculated by considering value of shear is obtain by following equation

$$Fc = \left(\frac{T \times P}{S}\right) \pi \times d \times T \times Fs$$ ---(3)[2]

Where,

Fc = cutting force, N
T = thickness of material, mm
P = penetration factor, %
S= shear value, mm
d= diameter of hole, m
Fs = shear strength of material, N/mm^2

Note: to reduced cutting force value of $\left(\frac{T \times P}{S}\right)$ is < 1
Hence, T x P < S or S > T x P
Based on design data book 0.20% carbon content annealed (AISI1020) material penetration factor is 40% or 0.4.
In this case S= 3mm, T= 6 mm and penetration P= 40% or 0.4
There for we take penetration factor P = 40%, Now put all values in equation 3 we get,

$$Fc = \left(\frac{6 \times .40}{3}\right) \pi \times 20 \times 6 \times 294.3$$

= 88713.79 N

Here we can see that **2.21 tones** force can be reduced by applying shear on punch.

2) Stress developed in punch

$$\sigma = \frac{Fc}{A}$$ ---(5)[3]

Where,

σ = stress, N/mm^2 or MPa
Fc = cutting force, N
A = cross section area of punch, mm^2

$$A = \frac{\pi}{4} \times d^2$$

$$= \frac{\pi}{4} \times 20^2$$

= 0.785 x 20^2
= 314 mm^2

For flat bottom punch Fc = 110892.24 N for modified punch Fc= 88713.79 N

$$\sigma = \frac{110892.24}{314}$$

= 353.15 N/mm^2 or MPa--------------(flat bottom punch)

$$\sigma = \frac{88713.79}{314}$$

= 282.52 N /mm^2 or MPa-------------(for all modified shear punch)

3) Deformation of punch

Assuming that piercing punch is consider as one end fixed and compressive force is acting on other end ,force applied on punch is 80% of cutting force [3] , hence the deformation of the punch is obtain by following equation.

$$\delta = \frac{F_a \times L}{A \times E}$$ --(6)[3]

Where,

δ = deflection of punch, mm

F_a = Force applied on punch, N

L = length of punch, mm

A = cross section area of punch, mm^2

E = young's modules, N/mm^2

Here, Force applied on flat bottom punch = 0.8 * 110892.24 = 88713.79 N

Force applied on shear punch = 0.8*88713.79 = 70971.03 N

In this case,

F_a=88713.79 N & 70971.03 N, L= 100 mm, A= 314 mm^2 and E= 2.1 x 10^5 N/ mm^2

Now putting value of F_a, L, A and E in equation 6 we get,

$$\delta(\text{flat bottom punch}) = \frac{88713.79 \times 100}{314 \times 2.1 \times 10^5} = 0.1345 \text{ mm.}$$

$$\delta(\text{shear punch}) = \frac{70971.03 \times 100}{314 \times 2.1 \times 10^5} = 0.1076 \text{ mm.}$$

4) Maximum allowable Length of the punch

$$L\ max = \sqrt{\left[\frac{Ls}{8} \times \frac{E}{Fs} \times \frac{d}{T}\right]}$$ --(4)[2]

Where,

L max= Maximum allowable length, mm

Ls = shear length = π d (for circular shape only)

E = young's modulus of elasticity

= 2.1* 10^5 N/mm^2

D= diameter of hole, mm

T= material thickness, mm

Fs= shear strength of material, N/mm^2

$$Lmax = \sqrt{\left[\frac{3.14 \times 20}{8} \times \frac{2.1 \times 10^5}{294.3} \times \frac{20}{6}\right]}$$

= 136.6 mm (Maximum allowable length)

Here, existing length of punch is 100 mm.

4.2 Analysis and counter measures

Root Cause Analysis is a method that is used to address problem or non-conformance, in order to get to the root cause of the problem. Root Causes the factor that, when you fix it, the problem goes away and doesn't come back.

A Root Cause Analysis will disclose:

(a) Why the incident, failure or breakdown occurred

(b) How future failures can be eliminated by:

- Changes to procedures
- Changes to operation
- Training of staff
- **Design modifications**

Causes are usually grouped into major categories to identify these sources of variation. The categories typically Include:

- People: Anyone involved with the process.
- Methods: How the process is performed and the specific requirements for doing it, such as policies procedures, rules, regulations and laws.
- Machines: Any equipment, computers, tools, etc required to accomplish the job.
- Materials: Raw materials, parts, pens, paper, etc used to produce the final product.
- Measurements: Data generated from the process that are used to evaluate its quality.
- Environment: The conditions, such as location time, temperature, and culture in which the process operates.

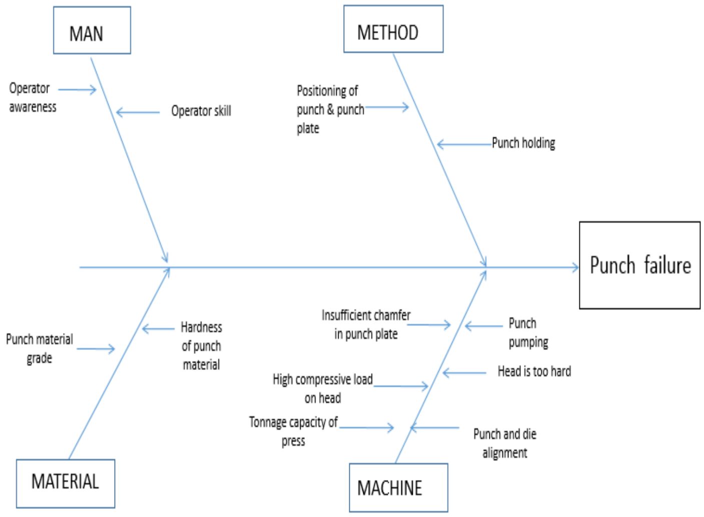

Fig: 4 fishbone diagram of punch failure

5. RESULTS AND DISCUSION

Here we calculate Availability, Mean time to repair (MTTR), Mean time between failures (MTBF) of all punches and compare its value with existing flat bottom punch.

Availability: Availability is the total time of utilization of a machine. Availability is the reciprocal of the difference between the total available hours and total breakdown hours to the total available hours.

- Availability

$$= \frac{\text{Total Available hours} - \text{Total Breakdown hours}}{\text{Total available hours}} \times 100$$

$$= \frac{250-30}{250} \times 100$$

$$= 88\%$$

Mean time to repair (MTTR): "Mean Time to Repair" is the average time that it takes to repair something after a failure.

- MTTR

$$= \frac{\text{Total breakdown hours}}{\text{Total no of breakdown}}$$

$$= \frac{30}{4}$$

$$= 7.5 \text{ hrs.}$$

Mean time between failures (MTBF): MTBF is the time between two failures. When failure rate is constant, the mean time between failures is the reciprocal of the constant failure rate or the ratio of the test time to the number of failures.

- MTBF

$$= \frac{\text{Total available hours} - \text{Total breakdown hours}}{\text{Total no of break down}}$$

$$= \frac{250 - 30}{4}$$

$$= 55 \text{ hrs.}$$

Punch type	Total available hours	Total breakdown hours	Total utilization hours	No of breakdown hours
Flat	250	30	220	4
Single shear	250	25	225	4
Double shear	250	21	229	4
Flat & double	250	12	238	3

Date	Punch shear(ends)			
	Flat bottom	Single shear	Double shear	Flat & double
1 to 7	17652(holes)	19856(holes)	22653(holes)	25351(holes)
8 to 14	18962(holes)	19325(holes)	23498(holes)	25030(holes)
15 to 21	18472(holes)	18987(holes)	23156(holes)	24156(holes)
22 to 28	16453(holes)	19563(holes)	18652(holes)	26894(holes)
Total	71539(holes)	77731(holes)	87959(holes)	101431(holes)
Broken punch	3	3	2	1
Punch life (holes/punch)	23846	25910	43979	101431
% increase life	-	9%	23%	42%

Table: 1 Readings of punch life.

Fig: 5 Testing of punch failure.

Punch type	Total available hours	Total breakdown hours	Total utilization hours	No of breakdown	Availability (%)	MTTR(hrs.)	MTBF(hrs.)	% Availability	% MTTR	%MTBF
Flat	250	30	220	4	88.0	7.5	55.00	-	-	-
Single shear	250	25	225	4	90.0	6.25	56.25	2.27	16.67	2.27
Double shear	250	21	229	4	91.6	5.25	57.25	4.09	30.00	4.09
Flat & double	250	12	238	3	95.2	4	79.33	8.18	46.67	44.24

Table: 2 Result comparison of before and after Appling shear on punch.

Sr no	Punch type	Availability	Target%	MTTR	Target hrs.	MTBF	Target hrs.
1	Flat	88.0	95	7.5	4-5	55.0	80
2	Single shear	90.0	95	6.25	4-5	56.25	80
3	Double shear	91.6	95	5.25	4-5	57.25	80
4	Flat & double	95.2	95	4	4-5	79.33	80

Table: 3 comparison of Availability, MTTR & MTBF.

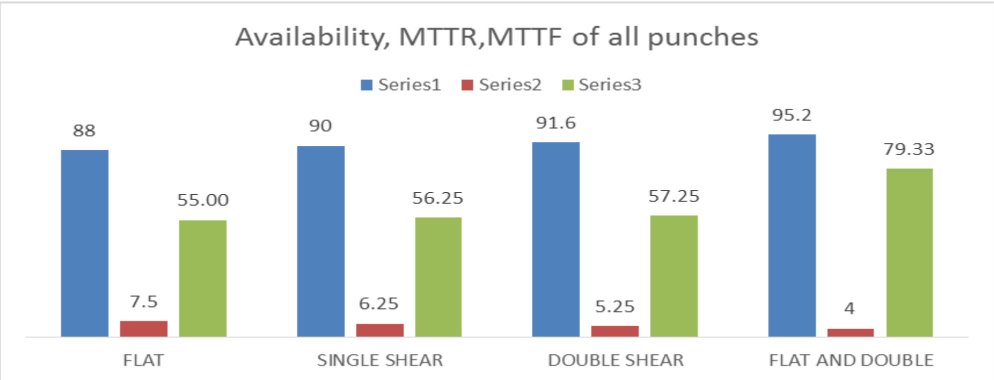

Figure: 6 Graph of Availability, MTTR, MTBF with different punch shear.

6. CONCLUSION

After analyzing all modified punches punch life, availability, MTBF, increased an MTTR will be decrease and targeted value was obtained.

Following objectives are achieved.

- ✓ Punch life increased 42% by using combined flat & double shear punch.
- ✓ MTTR reduced up to 46% by using combined flat & double shear punch.
- ✓ Availability and MTBF increased up to 8% and 44 % respectively % by using combined flat & double shear punch.
- ✓ Punch life, MTBF, MTTR and Availability reached at target value when using combined flat & double shear punch.

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