An experimental study on factors affecting Cold Extrusion of steels

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Abstract - *Sheet Metal forming is a phenomenon used in various products to facilitate manufacturing of various complicated 3D parts. But enough know how of the process is not available. Sheet Metal extrusion also called as Pip formation being one of them, is now widely used in many Electrical products in order to simplify the entire product design. This paper aims at studying the material flow of 513D steel under various pre-defined conditions and establishes relation and correlation between various factors. The study consisted of experimenting with various combinations of punch diameter, punch depth for various material thickness using statistical tools i.e. DOE and establishing relation between the parameters. The experimental results were analyzed and concluded which can be used as theoretical fundamental for design of sheet metal extrusion (pip formation) process.*

Key Words: Cold extrusion, pip formation

1.INTRODUCTION

The requirements of strong, high-performance, and accurately finished functional 3D parts of engineering industry, make sheet bulk metal forming process widely developed currently so as to facilitate the manufacturing of these complicated 3D parts. As one of the typical sheet bulk metal forming processes, the sheet metal extrusion process is often used as a prior forming process that is combined with stamping to produce components with protruded part or the blind cavity as the positioning element. The sheet metal extrusion process is a combined process in which punch penetration and extrusion take place at the same time and a large deformation happens during the whole process. Therefore, the traditional analytical method is not qualified to analyze the deformation mechanism, and there is still not enough know-how available about this process. The process design is often based on trial and error tests, which is a time-consuming procedure.

The entire paper aims at establishing a relation or finding out the factors which influence dimension of extrusion like material flow behavior, rate of strain, diameter of punch, depth of penetration etc.

The following method or flow was followed in experimentation.

A trial tool was designed based on theoretical evaluation for pip formation.

1) This tool was tried out in 40T Hensel press and results compared.

2) Analysis using Design of Experiments (DOE) for pip formation.

3) Trial taken according to the DOE in **5T hand press** and results collated.

4) Trial taken according to the DOE in **40T Hensel** and results collated.

5) Trial taken according to the DOE in **30T Hydraulic** and results collated.

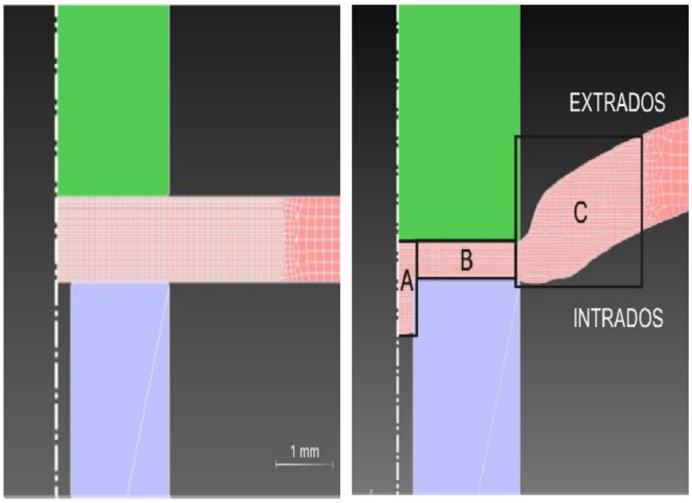
Based on these, the metal flow behavior and influence of various diameters and depth of punch was analyzed.

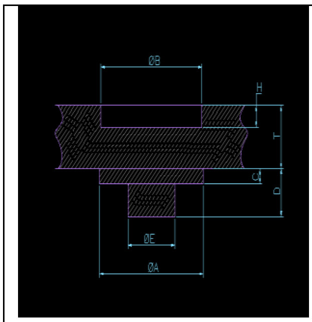
Finally some conclusions were drawn based on the results.

1.1 Sheet metal extrusion:

During sheet metal extrusion process, the sheet is held between the stripper and die. The punch then penetrates into the sheet metal and extrudes it towards the extrusion outlet of the die. The final workpiece is not the only deformed material. Three different forming areas can be distinguished: the metal filling the die cavity (A), the compressed strip between upper and lower punch (B) and the deformed strip around the punches (C). (1).

Ideally the process should collect as much material as possible and favor the filling of the die cavity, but when the volume between the punches is reduced the material also flows outwards. The amount of material outside the punches should be reduced as much as possible, because it is detracted from the workpiece and furthermore the deformation of the strip adjacent to the tool edges is higher. (1). Analyzing various components, which were contained Pip featured, we have concluded that approximately 50-60% material is flow in to cavity i.e. region A; whereas remaining material flow into region C. Based on this understanding, following formula is formulated.





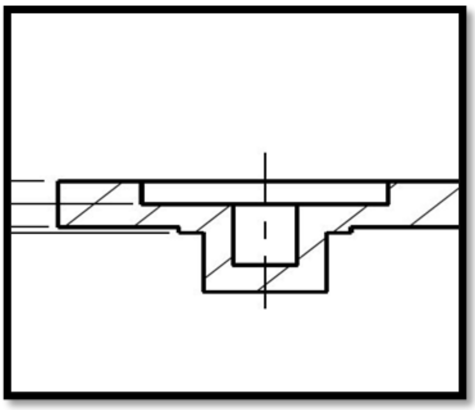
Volume of Output/ Volume of Input = 0.55

Vol. of Input = $Vi = \frac{\pi}{4} B^2 H$

Vol. of Output:

$$Vo = \frac{\pi}{4} E^2 (D - C) + \frac{\pi}{4} (A - E)^2 C$$

Based on the above phenomenon a trial tool was designed and released for manufacturing. Then tool trial was conducted on the 40T Hensel Machine. The intention of this trial was to establish relation between the theoretical values and practical values of pip with varied punch diameter and penetration.



1.2 Design of Experiment (DOE)

It was decided to develop experiments with controlled external environment and following a particular pattern. It was decided to go ahead with **DESIGN OF EXPERIMENTS BY TAGUCHI METHOD.**

Design of Experiments (DOE) is a powerful statistical technique introduced by R. A. Fisher in England in the 1920's to study the effect of multiple variables simultaneously.

Taguchi has envisaged a new method of conducting the design of experiments which are based on well-defined guidelines. This method uses a special set of arrays called orthogonal arrays. These standard arrays stipulate the way of conducting the minimal number of experiments which could give the full information of all the factors that affect the performance parameter. The crux of the orthogonal arrays method lies in choosing the level combinations of the input design variables for each experiment.

A typical orthogonal array:

While there are many standard orthogonal arrays available, each of the arrays is meant for a specific number of independent design variables and levels . For example, if one wants to conduct an experiment to understand the influence of 4 different independent variables with each variable having 3 set values (level values), then an L9 orthogonal array might be the right choice. The L9 orthogonal array is meant for understanding the effect of 4 independent factors each having 3 factor level values. This array assumes that there is no interaction between any two factor. While in many cases, no interaction model assumption is valid, there are some cases where there is a clear evidence of interaction. In our case we have considered L9 orthogonal array with 3 influential factors and 3 levels

Table -1: FOR 3 FACTOR WITH 3 LEVEL USE L9 array

	1	**2**	**3**	**4**
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	3	3
5	2	2	2	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	1	2	1

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For 513D material

	1	2	3
1	5.05	0.80	1.2
2	5.05	0.90	1.5
3	5.05	1	1.6
4	5.64	0.80	1.5
5	5.64	0.90	1.6
6	5.64	1	1.2
7	6	0.80	1.6
8	6	0.90	1.2
9	6	1	1.5

Factors considered:

A- Punch diameter (Ø5.05, Ø5.64, and Ø6.00

B- Punch Depth (0.80, 0.90 and 1.00)

C- Material Thickness (1.2, 1.5 and 1.6)

Experimental Conditions:

1) First trial with DOE was conducted in 5T Hand Press and the results are shown.
2) Second trial was conducted in 40 T Hensel Mechanical Press
3) Third trial was conducted in 30T Hydraulic Press

ANALYSIS REPORT FOR 513D MATERIAL (5T Hand Press)

Punch diameter (A)	Punch depth (B)	Material thickness (C)	Res-1	Res-2	Res-3	MEAN1	SNRA2
5.05	0.8	1.2	2.2	3.29	2.5	2.663333	8.153105
5.05	0.9	1.5	3.72	1.76	1.93	2.47	6.552431
5.05	1	1.6	2.66	2.6	2.6	2.62	8.364523
5.64	0.8	1.5	3.81	3.2	3.53	3.513333	10.84783
5.64	0.9	1.6	2.68	1.87	2.74	2.43	7.301796
5.64	1	1.2	2.9	1.92	2.87	2.563333	7.682091
6	0.8	1.6	2.43	2.97	2.37	2.59	8.136539
6	0.9	1.2	3.55	3.1	3.18	3.276667	10.26416
6	1	1.5	3.55	3.9	4.3	3.916667	11.77878

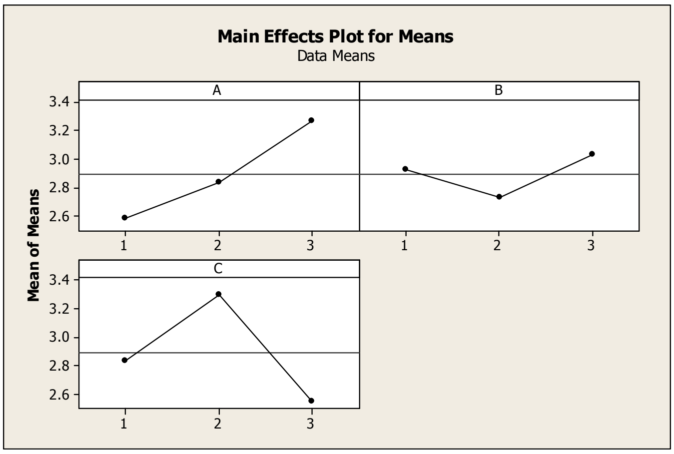
Taguchi Analysis: Res-1, res-2, res-3 versus A, B, C

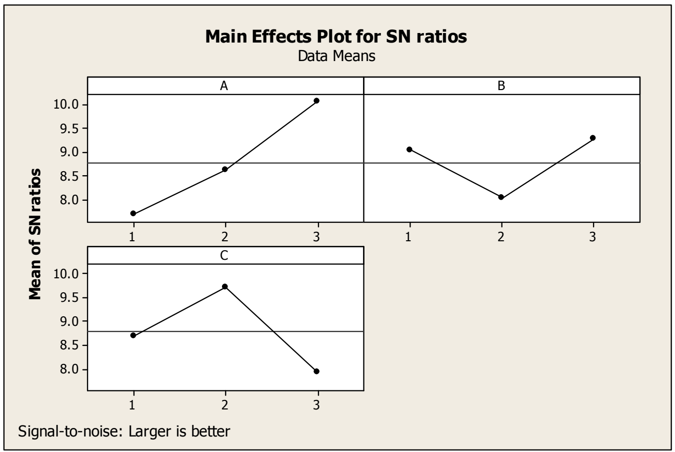
Response Table for Means

Level	A	B	C
1	2.584	2.922	2.834
2	2.836	2.726	3.300
3	3.261	3.033	2.547
Delta	0.677	0.308	0.753
Rank	2	3	1

Response Table for Signal to Noise Ratios
Larger is better

Level	A	B	C
1	7.690	9.046	8.700
2	8.611	8.039	9.726
3	10.060	9.275	7.934
Delta	2.370	1.236	1.792
Rank	1	3	2





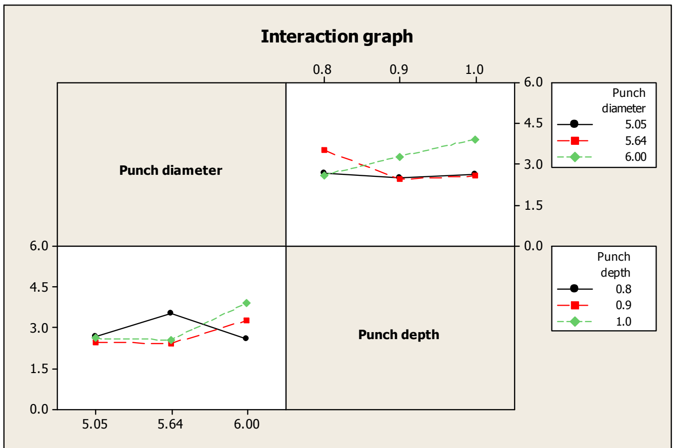
From the above two graphs it can be concluded that following condition is optimum:

A3 B3 C2 since larger is better.

Also when we calculate the Percent contribution of each of these factors we get the following table:

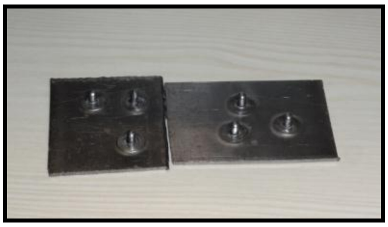
Factor	Percent Contribution on result (Pip height)
Punch Diameter	**32.83%**
Punch Depth	4.54%
Material thickness	35.29%
Error	27.33 %

This result shows that **Punch diameter** plays a vital role in determining the depth of pip than any other factor.



This interaction graph shows relation between Punch diameter and Punch depth.

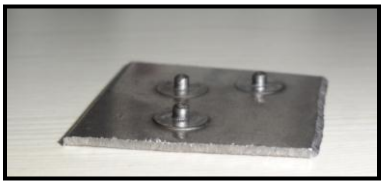
Experimental Conditions of T1, T2 and T3 with DOE:

T1 trial conditions	**Component Photo**
-Tool tried in 5T Hand Press -All the 9 experiments conducted and results recorded. -Tool speed was less since trial conducted in Hand press -Some samples with multiple strokes also taken for experimentation	 

Results of T1 trial recorded and analyzed as per DOE above.

The optimum condition found was with 6Ø punch, 1mm penetration in 1.5 mm thick 513D material. Also the percent contribution of punch diameter found more than depth of punch. The same needs to be validated in our existing tools. But the greatest factor contributing towards larger pip height is Machine speed or SPM. This experimentation was done in Hand press whose SPM is very low. As the SPM is low, the flow of material was more uniform and longer pip height could be achieved. **This clearly states that the height of pip depends on the rate of strain applied to the material. Slower the process, better the material flow.**

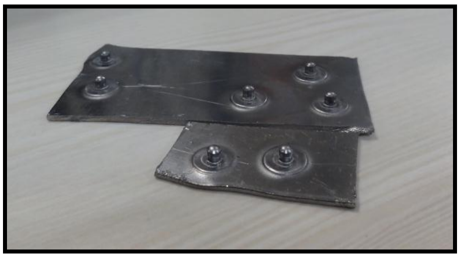
So it can be concluded that if component requirement is higher than component thickness, it is better to run the tool in Hydraulic press or slower press to get the results.

T2 trial conditions	Component Photo
-Tool tried in 40T Hensel Mechanical Press - All the 9 samples taken and results recorded -Tool speed was high - Some samples with multiple strokes also taken for experimentation	

Results of T2 trial as shown below:

Trial No	Punch Diameter (ØB)	Punch Depth (H)	Result (D)
1	6.00	0.75	2.1
2	6.00	0.75	2.2
3	6.00	0.75	2.4
4	6.00	0.75	2.3
5	6.00	0.75	2.3
6	6.00	0.75	2.5
7	6.00	0.85	2.62
8	6.00	0.85	2.70
9	6.00	0.85	2.72

From T2 trial results it is clear that with 6Ø punch and 0.85 mm penetration in 1.2 mm thick material, we can get a pip height of 2.5 – 2.7 mm maximum including dome height of around 0.5. This experiment again proves the fact the Type of Machine (Mechanical or Hydraulic) plays a vital role in determining the height of pip. In case of Hand press, since the SPM is low, the material could possibly flow in deeper space and around 3 times the material thickness height could be achieved. But same tool with similar conditions when tried in Mechanical press could not provide height more than 1.5 times material thickness. The intention of this trial was to establish the significance of Machine selection for this process.

T3 trial conditions	Component Photo
-Tool tried in 30T Hydraulic Press - 12 samples taken and results recorded -Tool speed was low	

Trial No	Punch Diameter (ØB)	Punch Depth (H)	Result (D)
1	6.00	0.85	3.15
2	6.00	0.85	3.20
3	6.00	0.85	3.38
4	6.00	0.85	3.00
5	6.00	0.85	3.10
6	6.00	0.85	3.20
7	6.00	0.85	3.40
8	6.00	0.85	2.60
9	6.00	0.85	3.10
10	6.00	0.85	3.10
11	6.00	0.85	3.30
12	6.00	0.85	3.30

This trial was conducted in Hydraulic press to establish correlation between the results of Hand press and Hydraulic press. It can be seen from the above table that the results are matching and the observations are similar to that of Hand press.

3. CONCLUSIONS

In this paper, the sheet metal extrusion (Pip formation) was simulated with various values of Punch diameter, Punch Penetration, Machine selection, Tool construction. The Statistical tool used to replicate this scenario was TAGUCHI Design of Experiment. Based on the experiments and the analysis, some factors influencing better material flow can be summarized as below:

1) As per our percent contribution matrix in DOE it was found **Diameter of punch** plays a vital role in determining the pip height. The punch depth plays only minimal role in increasing the height.

2) The next important factor that affects the material flow is **rate of strain that is applied on the material**. The slower the rate better is the material flow. Hence hydraulic machine are always preferred above Mechanical Presses.

3) The material flow also depends on the **polishing of the die and the die radius**. So optimum die radius is required for material to flow. Thus increasing the die radius improves material flow while increasing the punch radius restricts the flow.

4) **Tool construction** plays a very vital role in determining the extrusion height. The punch should be directly connected to Punch holder for better material flow.

REFERENCES

(1) Simulation of a Full Forward Extrusion Process from Metal Strip, Marion Merklein, Tommaso Stellin and Ulf Engel, Chair of Manufacturing Technology, University of Erlangen-Nuremberg, D-91058 Erlangen, Germany, Pg..494.

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