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EFFECTS OF VARYING PUNCH-DIE CLEARANCES DURING HOLE PIERCING IN CHAIN COMPONENTS – A SIMULATED EXPERIMENTAL STUDY

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ABSTRACT

The punch die clearance in metal stamping tool is an important factor which decides the produced component's quality. It affects the size and quality of the profile produced by the blanking or piercing operation. An attempt is taken in this study to analyses the effects of varying punch-die clearances during hole piercing operation in an industrial chain component using DEFORM 3D software. Simulations were conducted with insufficient, optimum and Excessive clearance values and their results are discussed. The simulation experiments are conducted on AISI 1060 steel component used for industrial chain as inner plate, and the results of the simulations are discussed.

Keywords: *DEFORM 3D, Piercing and Metal Stamping*

1. Introduction

Metal Stamping is the process of mass production of components from sheet metal. It uses a press where a press tool comprising punch tool and die surface forms the metal into the required shape and size. These tools make the components from either coil stock or unit stock sheet metal. Blanking and piercing are the basic sheet metal cutting operations. Operation wise they look alike. But they differ in application wise. While performing blanking and piercing operation some amount of material cutout from the stock material. If the cutout material is the required product the process is called as blanking and if the cutout portion is the scrap the process is called piercing.

In blanking and piercing operations, the stock material is forced into the die opening by the punch to make the cut. Hence a clearance is given between the punch and die in the stamping tool. This clearance will decide the size of the blank or the hole produced. In blanking operation, the die shape and size are maintained as per the required blank size and the clearance is given on the punch (i.e punch size = die size - total clearance). In piercing operation, the hole size is maintained as punch size and the clearance is given on the die (i.e die size = punch size + total clearance). The punch-die clearance is an important factor which decides the required size of the component. Excessive clearance and insufficient clearance will lead to defective parts. Hence, we have to select an optimum punch-die clearance. Selecting a suitable clearance is an important task in blanking and piercing operations. The properties of the material to be cut will affect the clearance to be selected.

The Finite element method (FEM) is becoming popular and effective tool in simulating metal forming processes. FEM is a matured tool for applied into metal forming. It helps in analyzing material flow, analyzing defects and estimating die stresses and loads. But for blanking and piercing operations FEM is less mature.

The FEM simulation conducted by varying punch and die clearances and the results were in excellent correlation with the actual experiments [1]. Using FEM simulations, the critical locations in the die prone to wear are identified and die inserts are suggested in these places [2]. FE simulations are used to find the optimum punch-die clearance for different part radii to obtain more uniform punch wear using DEFORM 2D/3D [3].

Various authors conducted FEM simulations for metal stamping process. However, there is lot of scope for research in metal stamping processes. The present work aimed at simulating the hole piercing operation in manufacturing industrial chain plates and to analyze the effects of varying clearances. This work would be beneficial in choosing the correct clearance and to reduce the defects in the components.

This paper consists 6 sections. First section is the introduction about metal stamping operation and previous works are discussed. The second section deal with the methodology being followed. Third section

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discusses the simulation experiments conducted on the hole piercing operation. The results of the simulation experiments were discussed in the fourth section. Fifth section describes the conclusions and sixth section lists the references used for the current work.

2. Methodology

This experiment begins with the 3D modeling of the blank, punch and die and then import them in STL format in DEFORM 3D software.

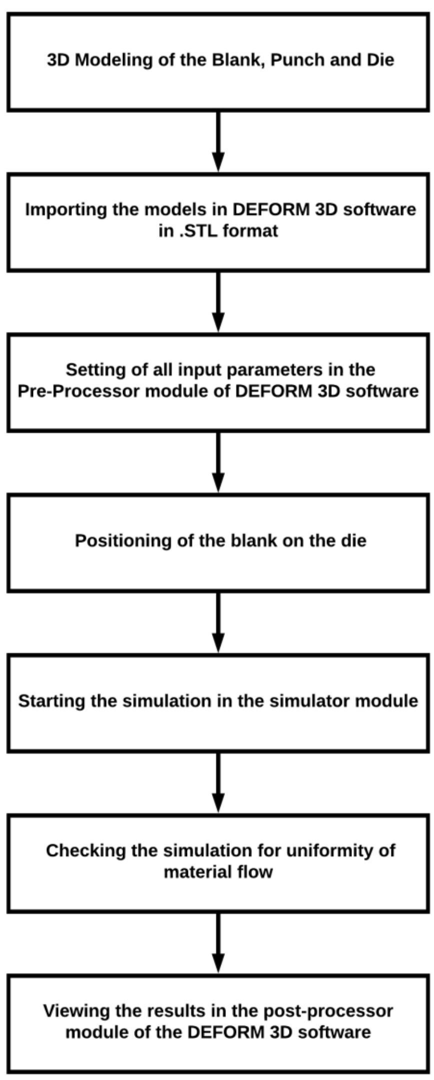


Fig 1. Methodology

The pre-processor module of the DEFORM 3D software performs three important tasks. In the input module of the software the models and the process conditions are introduced. The automatic mesh generation program of the software creates a mesh taking various parameters into consideration. The software also consists of an interpolation module for interpolating the deformation history of the old distorted mesh into the newly generated mesh. These three tasks, called automatic remeshing, make it possible to perform continuous simulation without user intervention. The simulation is started in the simulator module after inputting all necessary parameters in the pre-processor module. The simulation can be paused in between to facilitate checking correctness of the process. The post processor module is used to view the results of the simulation.

Figure 1 describes the methodology followed in this work. DEORM 3D [4] software is a latest and well-tested industrial simulation engine which also gives an option for fast solution processing.

3. Modeling and Simulation

3.1 Modeling for Hole Piercing process

The component material chosen is AISI 1060 which is having equivalent properties of the actual material used in the industry for the production of chain inner plate. Figure 2 shows the dimensions of the component modeled for the simulation experiments.

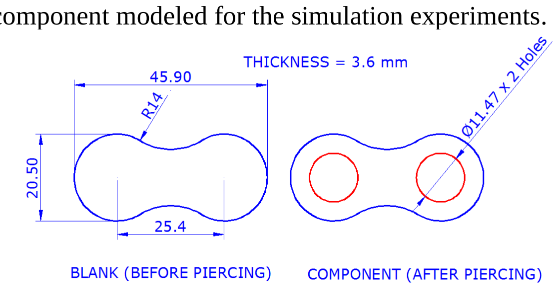


Fig 2. Dimension of the component modeled for simulation experiments

The size of the die opening modeled for this study is 11.65 mm. Industries using 4 to 8% of sheet thickness as clearance for precision blanking and piercing operations in hard steels. Figure 3 shows the dimensions of the piercing punch modeled for the simulation study. Three different punch diameters shown in Table 1 were used in the modeling of the punches used in the simulation experiment to analyze the effect of varied punch-die clearance.

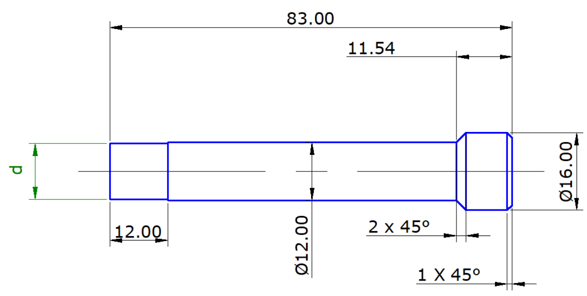


Fig 3. Dimensions of the Piercing Punch

Table 1: Punch Sizes used for the Simulation Experiment

Clearance applied in % of sheet thickness	Punch diameter (d) in 'mm'
1% (In-sufficient clearance)	11.614
5% (Optimum Clearance)	11.470
10% (Excessive Clearance)	11.290

Figure 4 shows the assembly of the models for the simulation of the piercing process. The Component blank, Die, Blank holder and Punches are modeled in 3D and imported as STL format to DEFORM 3D.

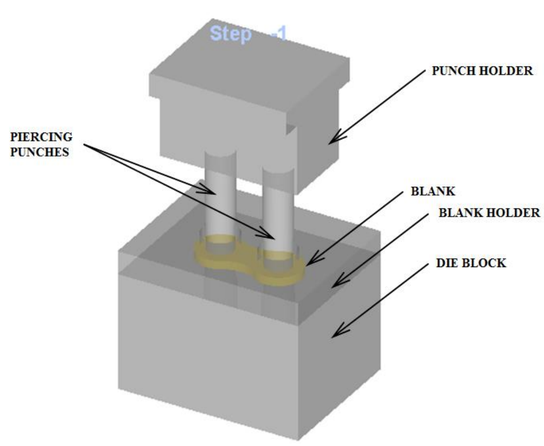


Fig 4. Models used for the Simulation of the process

3.2 Simulation of Chain Inner Plate Hole Piercing process

In the DEFORM 3D Software package, the Simulations are done in the COLD FORMING option. The parameters shown in Table 2 are used for simulating the process:

Table 2: Simulation Parameters used

FEM Simulation Conditions	
Object Type	Work piece : Plastic Punch/Die : Rigid Blank holder : Rigid
Work piece Material	AISI 1060 (3.6 mm thickness)
Shape complexity	Moderate
Accuracy Level	Accurate
Total Primary Die Travel	11.5 mm
Friction Co-efficient	0.08

The meshing of the blank is done by the software into 50,064 elements. The actual number of elements will set by the software after meshing.

Figure 5 shows the meshed model of the component used in the simulation experiments. The automatic mesh generation feature of the DEFORM 3D software generates the mesh.

Figure 6 shows the zones of the standard pierced hole which clearly indicates the various zones. Figure 7 shows the simulated pierced hole with optimum cutting clearance in the component.

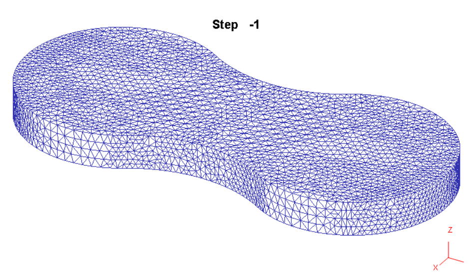


Fig 5. Meshing of the component

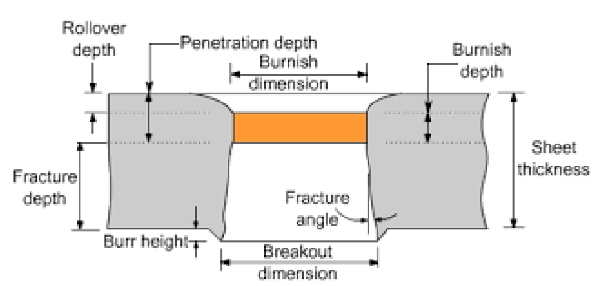


Fig 6. Zones of the Standard pierced hole

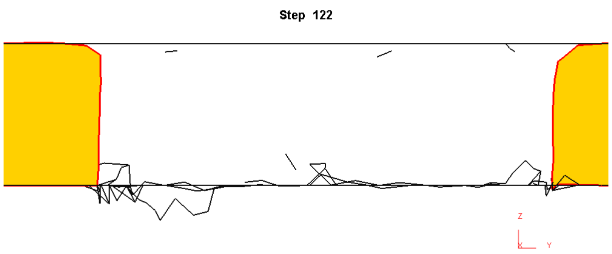


Fig 7. Pierced hole in the simulated component

Three different clearance values of 1%, 5% and 10% of blank thickness are used for the simulation experiments to ascertain the effects of varying punch-die clearances on the tonnage and component quality.

Figure 8 shows the simulated pierced component with 5% Clearance.

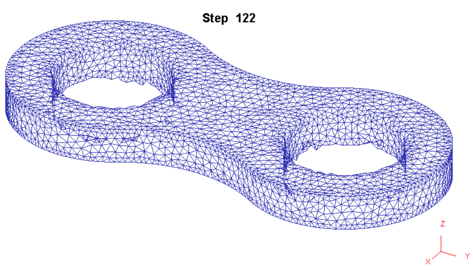


Fig 8. Simulated Component

4. Results and Discussion

4.1 Effect of varying clearances on Cutting force and Shear stress

The results of the simulation experiments conducted on hole piercing operation by applying varying punch-die clearances inferred that the punch load is decreasing as the percentage clearance is increasing. The reduction in punch load is in the increasing order of 1.4%, and 5% respectively for the 5% and 10% clearances applied when compared with 1% clearance. From Figure 9, it is evident that the maximum punch load is decreasing as the clearance applied is increasing.

For better understanding the simulation experiments were conducted with 1% to 5%, 7% and 10% punch-die clearances and the maximum punch load for each clearance value was found. Figure 10 shows the plot of maximum punch load for various clearances applied. The trend line exhibits that the maximum punch load is decreasing as the clearance applied is increasing.

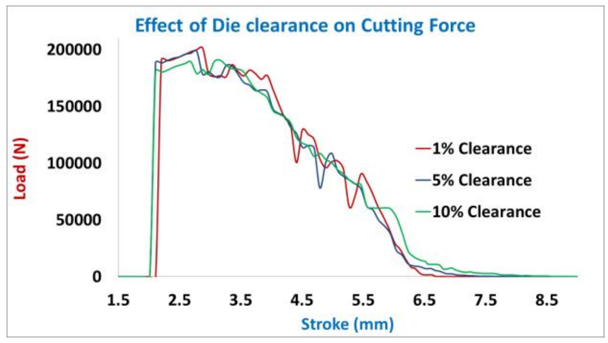


Fig 9. Force-Displacement Diagram for varying clearances

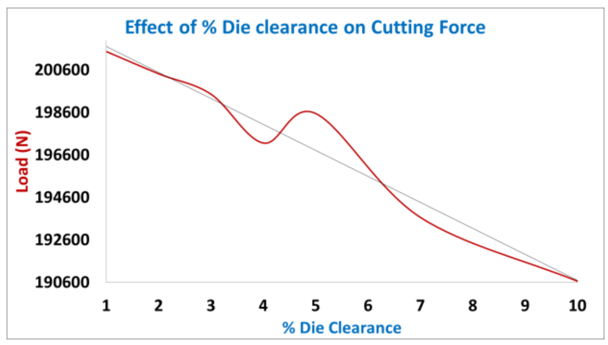


Fig 10. Effect of varying clearances on Punch Loading

The effective stress curve obtained (Figure 11) clearly indicates that the maximum shear stress is almost same irrespective of the percentage clearance applied. But the shear stress curve suggests that the increase in clearance value increased the separation time for the slug from the component. That indicates due to increased clearance the cutting elements started drawing the component initially in the clearance gap before started shearing. This could be the reason for increased separation time and will lead to increased burr size.

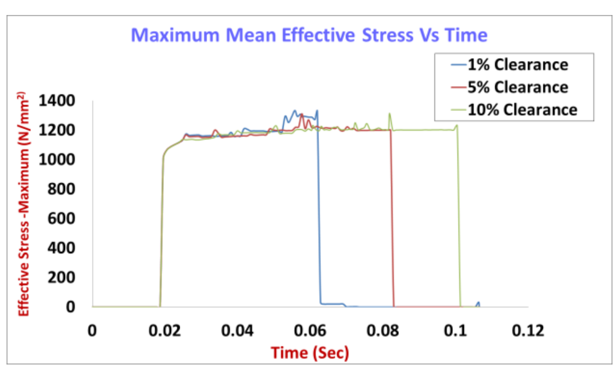


Fig 11. Effective Stress

4.2 Effect of varying clearances on Hole shape and burr formation

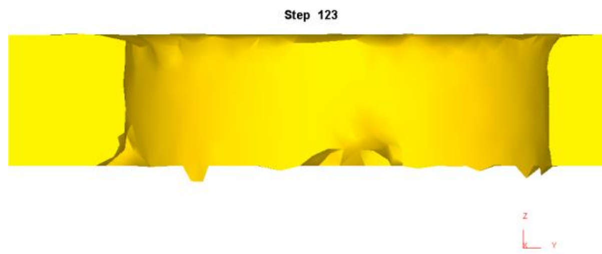
Simulation experiments were carried out with 3 different punch-die clearances (1%, 5% and 10% of sheet thickness) to investigate its effect on the quality of the pierced hole. Incorrect punch-die clearance will significantly affect the length of shear zone of the pierced hole. Figure 12 is the sectioned view of the simulated parts for the above mentioned clearances which shows the effect of varied punch-die clearance on the quality of the pierced hole. Figure 13 is the enlarged sectioned view of the holes pierced for better understanding. It can be seen from Figure 13 that punch-die clearance of 1% sheet thickness gives more burnish depth (cut band) on sheet thickness, and drops as punch-die clearance increases.

(a) 1% Clearance

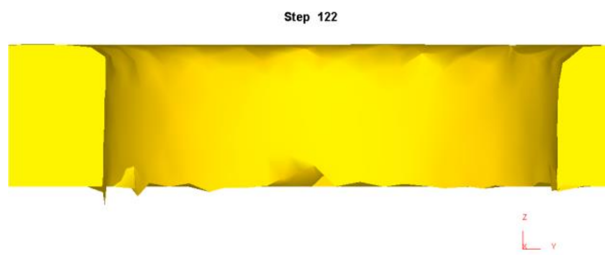
(b) 5% Clearance

(c) 10% Clearance

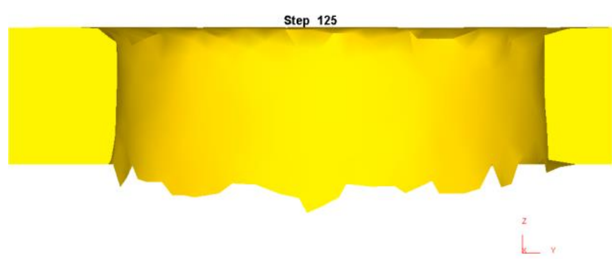
Fig 12. Simulated Component for different clearances



(a) 1% Clearance



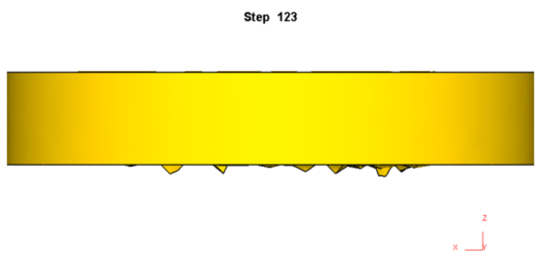
(b) 5% Clearance



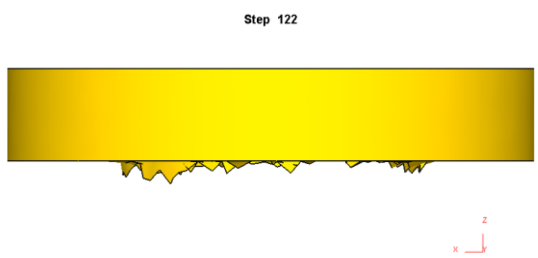
(c) 10% Clearance

Fig 13. Enlarged view of the simulated pierced hole for different clearances

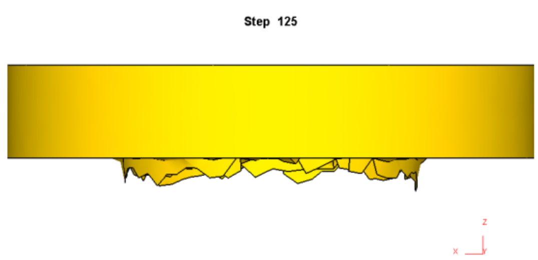
Also, it can be seen from the Figure 14 that increased punch-die clearance increases the burr size. Insufficient clearance causes higher tool wear and affects the part quality. Excessive clearance shows non uniform roll over, cut band, fracture and heavy burrs on the component. Optimum punch-die clearance and sharp edges of the cutting elements avoid burr formation. But for practical reasons burr is allowed to some extend (10% of sheet thickness when deburring not specified and 2% of sheet thickness if when deburring is specified such as “must be burr free”). Hence an optimum punch-die clearance should be chosen for better product quality and increased tool life.



(a) 1% Clearance



(b) 5% Clearance



(c) 10% Clearance

Fig 14. Side view of the simulated part which exhibit burr on the hole for different clearances

From Figure 12, Figure 13 and Figure 14 it is clearly evident that the pierced hole profile and burr size for 5% clearance is desirable.

5. Conclusion

Present work is a step forward in analyzing metal forming during piercing and similar operations. The piercing operation is simulated by providing different punch-die clearance values and established that increase in clearance decreases punch load and increasing burr size on the hole produced. Simulation experiments also established that insufficient clearance will affect the quality of the hole produced and optimum punch-die clearance will produce a better-quality part.

The combined effects of varying punch-die clearances, varying punch and die shear angles on the component size, quality and on press operating parameters are to be analyzed in the future work. The FEM package DEFORM 3D is used to study the metal forming process without building the necessary physical experimental setup. Number of simulations can be performed using DEFORM 3D to get optimum and accurate solution which can be validated by actual experiments. FEM packages reduce conduct of number of experiments in actual practice. The FEM experiments are generally producing accurate results compared to analytical models.

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