IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

ISO 3297:2007 Certified ⁜ Impact Factor 8.066 ⁜ Peer-reviewed / Refereed journal ⁜ Vol. 10, Issue 7, July 2023

DOI: 10.17148/IARJSET.2023.107122

Numerical Analysis of The Effect of Pin Diameter on Stress Distribution in Active Punch-Type Multi-Point Forming

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Abstract: One of the flexible sheet metal forming methods is multi-point forming (MPF). MPF is mostly utilized in automotive and aerospace prototypes to cut down on time and costs. To comprehend the impacts of forming orientation on multi-point formation, two alternative forming orientations have been explored in this work. Deform 3D, a finite element program, was used to model and analyse multi-point forming (MPF) orientations. The V-type shape was created using 0.5 mm thick sheet metal made of aluminium 1100. According to the necessary load of sheet metal in simulations, three different diameters, 10 mm, 12 mm, and 14 mm, were examined. The findings indicate that, in comparison conventional forming10 mm pin forming was a more suitable forming type for this shape.

Keywords: Finite element, Multi-point, Forming, Sheet metal

I. INTRODUCTION

The two industries that employ sheet metal components with three-dimensional geometries the most frequently are the automobile and aerospace sectors. The sheet metal forming technique is used to create these particular sheet metal shapes. However, a variety of die sets are needed during the design process, which drives up the cost of manufacture per unit. Due to its ability to change the shape of the die using movable pins, multi-point forming (MPF) lowers the cost of component design and prototype.

In their study of realistic finite element modelling approaches and the control of multi-point formation processes, Cai et al. [1] focused on three key challenges. The determination of the three-dimensional surface of the multi-point die, the forecasting of the initial blank sheet, and the design of the optimal forming path from the beginning blank to the desired shape were recognized as these problems. The problem was solved by designing an optimum path for formation using membrane finite elements. Examples using finite elements demonstrate how easy and quick it is to use the method.

Qian et al. [2] studied the impact of two distinct MPF techniques, MSF and SF, on the development of the dish head. The formation principles and aspects of various methodologies were examined with regard to stress distribution and strain. Both numerical calculations and experimental studies were carried out. Multi-step forming was able to enhance forming quality, get rid of wrinkles and dimples, and optimize the deformation path as a result. Results from numerical simulations were consistent with those from experiments.

Cai et al. [3] completed thorough finite element simulations of the processes for stretching three types of parts using dynamic explicit finite element analysis. Results from multi-point die formation were compared to those from traditional die forming. The effect of the MPSD's design and the dimensions of the punch element on the accuracy of the produced components' shapes was examined. The conclusions could be useful in choosing MPSF specs and streamlining MPSF production processes.

Numerical analysis models for the flexible blank holder (FBH) and the absence of a blank holder (NBH) were created by Liu et al. [4]. The optimal FBH was then acquired by simulating spherical-shaped surface parts with different FBHs using finite element software. The results show that the FBH forming technique can successfully prevent wrinkling faults while also improving sheet metal movement homogeneity, spreading strain and stress more uniformly, and making the thickness distribution more bearable.

Liang et al. [5] used analytical methods, forming experiments, and finite element modelling to explore the multi-point cylindrical bend-forming process of the bi-directional trapezoidal sandwich panel. In the beginning, the regularity, forming faults, and deformation characteristics of the sandwich panel were examined. Then, the core layer's comparable elastic constants were determined by employing a semi-analytical method in combination with the finite element method (FEM). The dimple and straight plane effects are the forming faults that happen most frequently during the bending process.

The two main factors that have the most impact on forming issues are face sheet thickness and bending radius.

Zhu et al.'s [6] goal was to determine the physical causes of the elasto-plastic and springback characteristics' deformation during the multi-square punch forming (MSPF) process and to produce appropriate mathematical explanations. In order to examine the forming process and springback properties of the strip, theoretical equations are also created that take into account the follower load with varying boundary conditions. The validity of these equations using experimental data shows their precision.

In this study, the investigation of the effects of multi-point forming with active punches by using three different diameters of pins for the v-type sheet part was examined by using the finite element method. Effective stress distributions and required forming load-stroke graphs were investigated and compared with conventional forming to understand the effects of pin diameter.

II. FINITE ELEMENT MODELLING

The model and analysis were created using the DEFORM 3D finite element analysis program. The shape with the geometry illustrated in Fig. 1 was given multi-point forming.

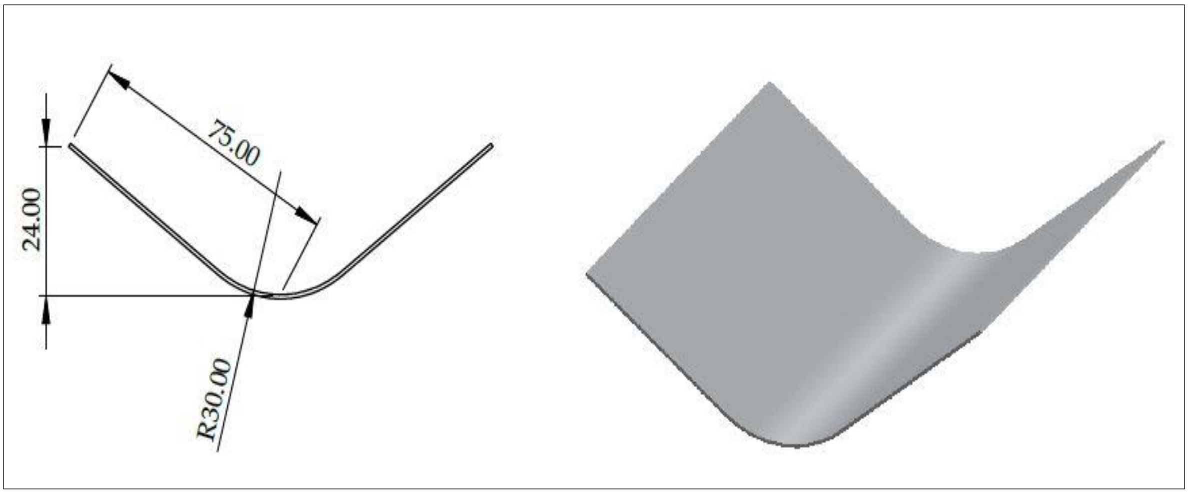
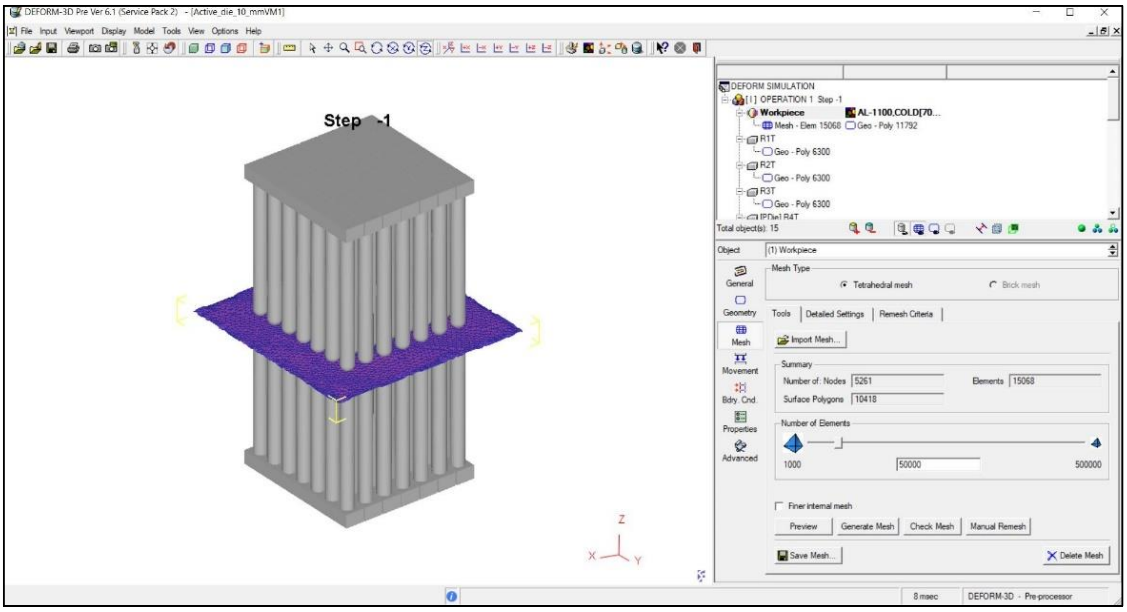


Fig. 1 Technical Drawing of V-Type Sheet Part

A numerical study led to the development of three different diameters of pins, 10 mm, 12 mm, and 14 mm, forming types. 11 packages of 7 pins were used to build the dies for the multi-point forming modelling part. For both kinds, the rigid type was represented as die material, and elasto-plastic type was described as workpiece material in the modelling section. Al 1100 with a 0.5 mm thickness was added to the workpiece from the Deform 3D database as the specimen material. In order to preserve Coulomb's model, the friction blank-die interface was included.

It was determined that this interface's friction coefficient was 0.1 [7]. Numbers for the elements and nodes were added to the material as 17683 and 6037, respectively. The damage factor for Al 1100 was set at 0.34 and normalized C&L was used as the fracture criterion. In the event that it was inserted, this indicates that the material will begin to tear once the stated value is reached [8]. Additionally, 1 mm/min was established as the stroke rate for forming operations. Fig. 2 provided schematic illustrations of multi-point forming die.



DEFORM-3D Pre Ver 6.1 (Service Pack 2) - [Active_die_10_mmVM1]

DEFORM SIMULATION
- [1] OPERATION 1 Step -1
  - Workpiece — AL-1100,COLD[70...
    - Mesh - Elem 15068 — Geo - Poly 11792
  - R1T
    - Geo - Poly 6300
  - R2T
    - Geo - Poly 6300
  - R3T
    - Geo - Poly 6300

Total object(s): 15

Object: (1) Workpiece

Mesh Type: ● Tetrahedral mesh ○ Brick mesh

Summary
Number of: Nodes 5261
Elements 15068
Surface Polygons 10418

Number of Elements: 1000 — 50000 — 500000

☐ Finer internal mesh

8 msec — DEFORM-3D - Pre-processor

Fig. 2 First Forming Orientation

Conventional forming of this shape is shown in Fig. 3.

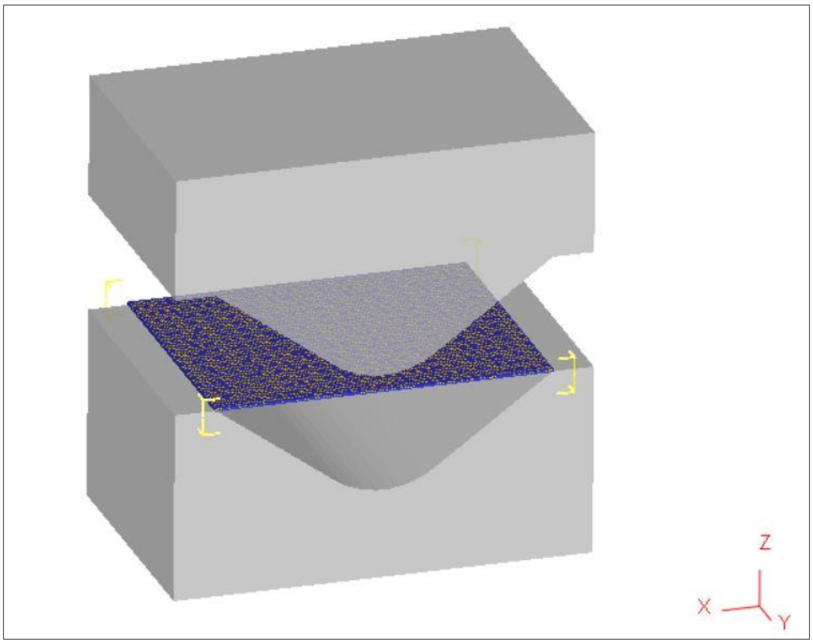


Fig. 3 Conventional Forming of V-type part

III. RESULTS AND DISCUSSION

Fig.3 shows the row numbers of both the top and bottom dies. In forming process. In forming process, a row of top and bottom dies are moved downward and sheet metal takes the form of desired shape. Row 1 pressed the sheet metal first during multi-point forming (MPF). Second, rows 2 and 3 created the sheet metal, followed by rows 4 and 5, and rows 8 and 9 finally pressed the sheet metal.

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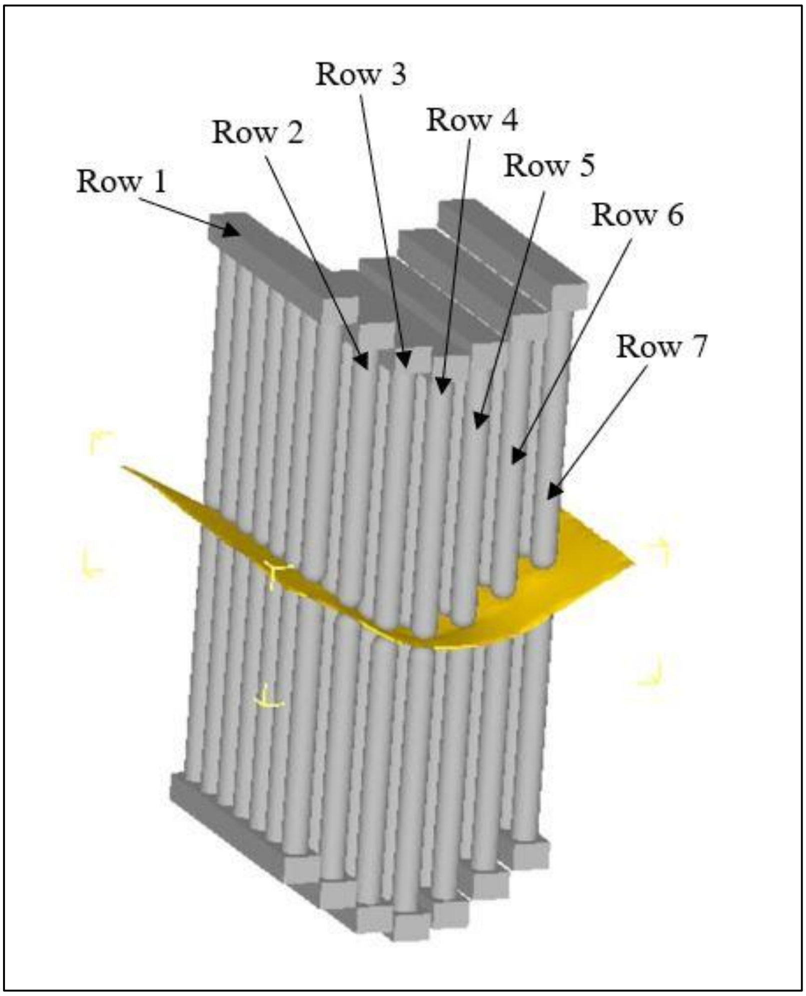
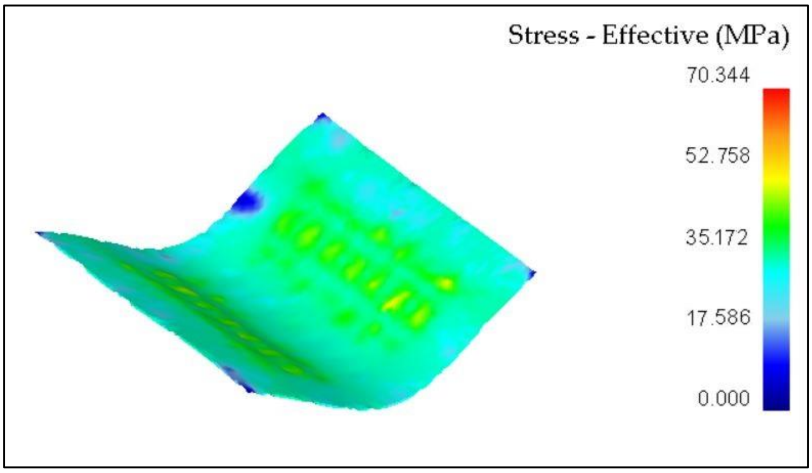
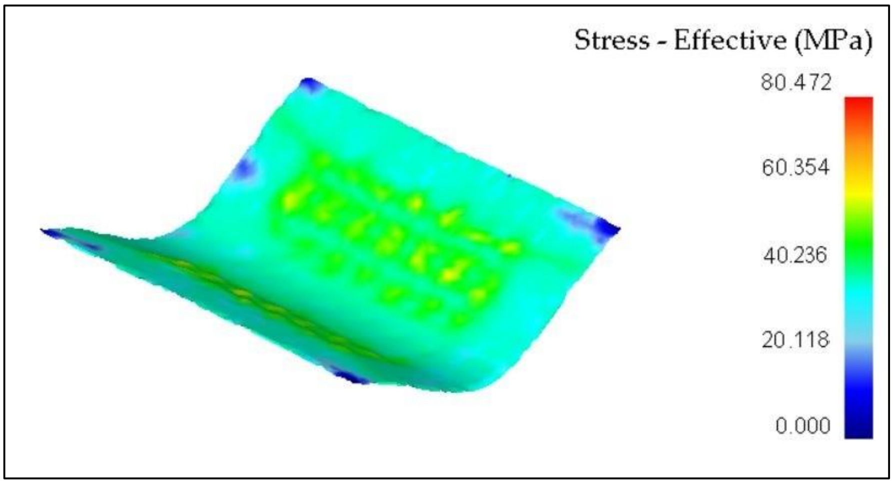


Fig. 3 The row numbers of both top and bottom dies.

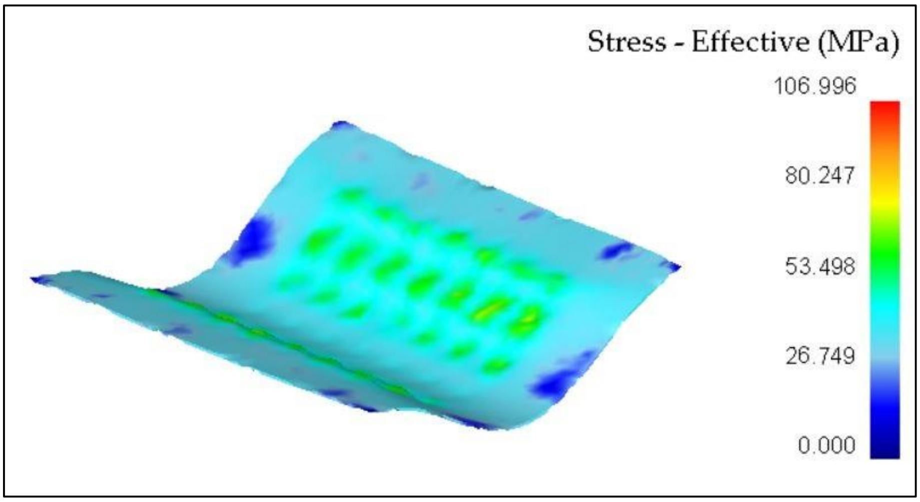
The effective stress distributions were found, as shown in Figs. 4 (a), (b), and (c) for 10 mm, 12 mm, and 14 mm, respectively. Fig. 5 depicts the effective stress distribution of sheet parts after conventional forming.



(a) 10 mm pin



(b) 12 mm pin



(c) 14 mm pin

Fig. 4 The effective stress distributions of MPF

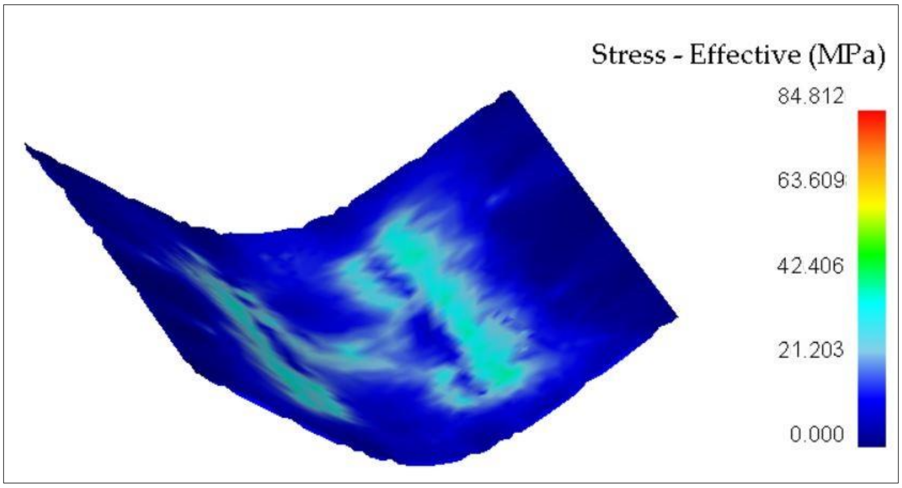


Fig. 5 The effective stress distribution of conventional forming

As seen in Fig.4, maximum effective stress distributions were obtained as nearly 71 MPa, 84 MPa, and 111 MPa for 10 mm pin, 12 mm pin, and 14 mm pin forming, respectively. In conventional farming, effective stress was acquired as nearly 85 MPa at maximum.

The highest effective stress was measured at 14 mm pin forming. Conventional forming and 12 mm pin forming in an active manner was nearly the same. However, minimum effective stress was obtained by applying the 10 mm active pin forming.

IV. CONCLUSION

In this study, aluminum V-type sheet parts were manufactured using two forming models. Utilizing the commercial program DEFORM 3D, finite element simulations were carried out to compare the effective stress distribution of sheet metal parts. Below is a summary of the study's major findings:

- Effect of pin diameter directly affects the forming of the V-type sheet metal part.
- Maximum effective stress was obtained by using the highest diameter of the pin.
- 10 mm pin forming is the proper selection between both conventional and active punch MPF.

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