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Comparison of Multi-Point Progressive Forming and Conventional Forming for Wavy Shaped Part by Using Finite Element Analysis

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Abstract: Multi-point forming (MPF) is one of the flexible sheet metal forming processes. The prototyping of the automotive and aerospace, MPF is mainly used to reduce cost and time consuming. In this study, multi-point progressive forming (MPPF) type was modelled and analysed in finite element software Deform 3D. Sheet metal part of aluminium 1100 was used to form the desired shape. MPPF and conventional forming were compared according to tearing of sheet metal in simulations. The results show that MPPF was more appropriate forming type for this shape comparing the conventional forming. Tearing was also observed in conventional forming process.

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

I. INTRODUCTION

The automotive and aerospace industries are the most common users of sheet metal components with three-dimensional geometries. These types of sheet metal geometries are manufactured via the sheet metal forming method. Nonetheless, throughout the design process, a range of die sets are required which raises the unit cost of production. Multi-point forming (MPF) reduces the cost of component design and prototype since it can modify the geometry of the die using adjustable pins.

MPF is a relatively new and sophisticated forming technology, and researchers are interested in it due to the benefits it offers. Li et al. [1] studied the fundamental characteristics of MPF and concluded that this method can be used to form pieces that are significantly larger than the dimensions of the die. They also added that due to its flexible nature, MPP reduces time and part costs while maintaining high precision and quality.

Cai and Li [2], provided an initial attempt to create a framework for modelling the MPF process using simulation. They employed an updated version of Lagrangian formulation and developed an implicit elasto-plastic finite element code to model the process. They also proposed a new algorithm to evaluate elastic-plasticity with time increment. To validate the formulations offered in the study, hydrostatic bulging of rectangular sheets and two-dimensional stretching with a hemispherical punch are examined. They asserted that there was a significant correlation between the numerical results and the experimental data as well as the data that had been published.

Liu et al. [3], discussed the multi-point die forming (MPDF) and multi-point press forming (MPPF) and the guidelines for determining the size of the element were provided. They developed a MPDF apparatus with a computer control system and other required mechanical components. Then they investigated several specialized MPDF techniques such as large size sheet forming, usage of blankholder for thin materials, obtaining high precision with using a close loop MPDF and reverse engineering of MPDF. They stated that MPF is a quick, computerized, and economical shaping method that has a big potential to be used in sheet metal forming areas.

Abaas et al. [4] presented a multipoint forming die with a novel design that can regulate the displacement and force delivered to each punch. They mentioned that by using this design, it is possible to maximize the flexibility of the forming process and decrease the needed adjusting time. After conducting experiments, they determined that adjustment time was decreased by 90% compared to conventional forming procedures; nonetheless, the finished product developed dimples that required attention.

Yang et al. [5] studied on the forming of small, thin metal components by combining MPF and deep drawing with the intention of expanding the advantages of MPF. They concluded that MPF has several benefits in terms of tool flexibility.

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However, product quality must be maintained as the deformation process is becoming more sophisticated. They got better results on aluminium sheets than steel sheets since lower drawing forces are required for each pin to draw aluminium material. In addition, they noted that cushioning and lubrication are essential components for the MPF process.

MPF offers several benefits over conventional forming procedures, particularly for non-traditional forms. Investigation of various sheet metal shapes is vital, and finite element analysis is the most efficient method for performing this process. In this study, the comparison of damage factors was made between multi point progressive forming and conventional forming of a wavy shaped aluminium part.

II. FINITE ELEMENT MODELLING

In finite element analysis, DEFORM™ 3D software was used to construct the model and analysis. Multi-point die and conventional type forming was created for the shape that has a geometry as shown in Fig. 1.

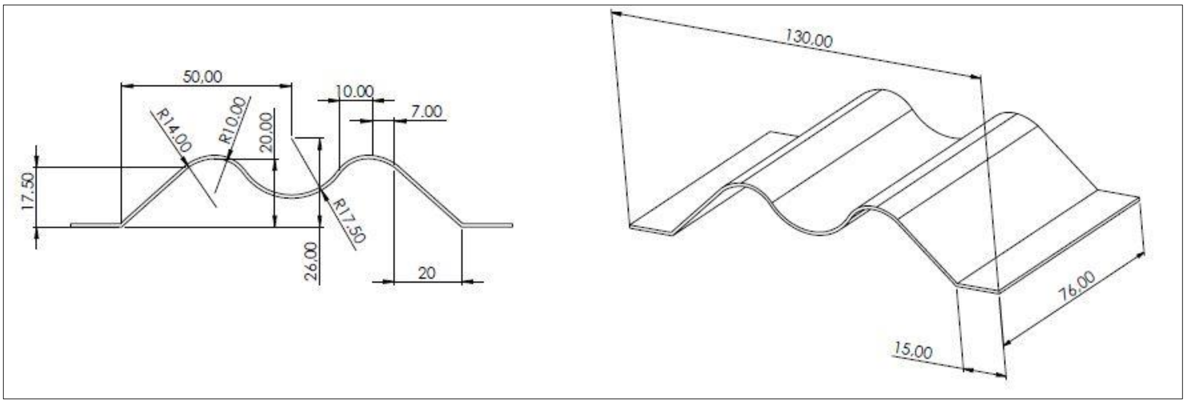

Fig. 1 Technical Drawing of Sheet Part

In conventional forming, top and bottom die was modelled as solid die. In modelling section of multi-point forming, the top die was created with 11 pin packages consisting of 7 pins of 10 mm each and bottom die was created as like conventional forming type. In modelling section for both type, elasto-plastic type material was defined as workpiece material and rigid type was modelled as dies material. For specimen material, 0.5 mm thickness of Al 1100 was defined as workpiece material and was added to workpiece from Deform 3D database. The frictions blank-die interface was added to keep Coulomb's model. The friction coefficient at this interface were considered as 0.1 [6]. Element and node numbers was added to material as 13373 and 4613, respectively. Normalized C&L was selected as fracture criteria and damage factor for Al 1100 was defined as 0.34. If it was added, this means that the material will start to tear once the defined value is reached [7]. Additionally, stroke rate for forming operations was defined as 1 mm/min. Schematic representations of both type forming were given in Fig. 2 and Fig. 3.

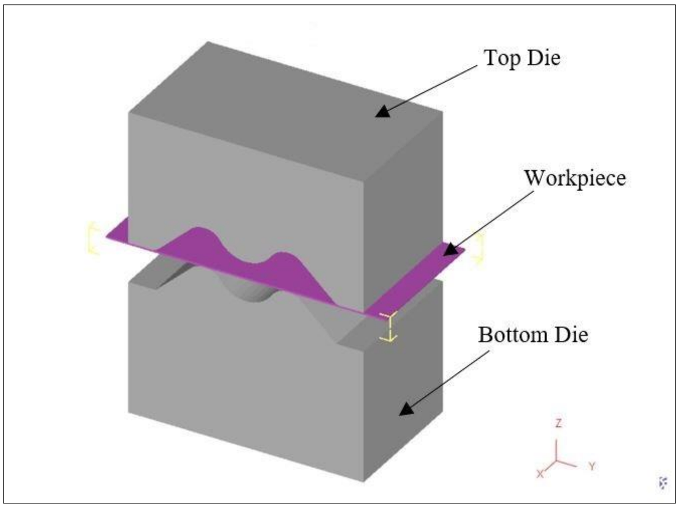

Fig. 2 Conventional Forming Die Set

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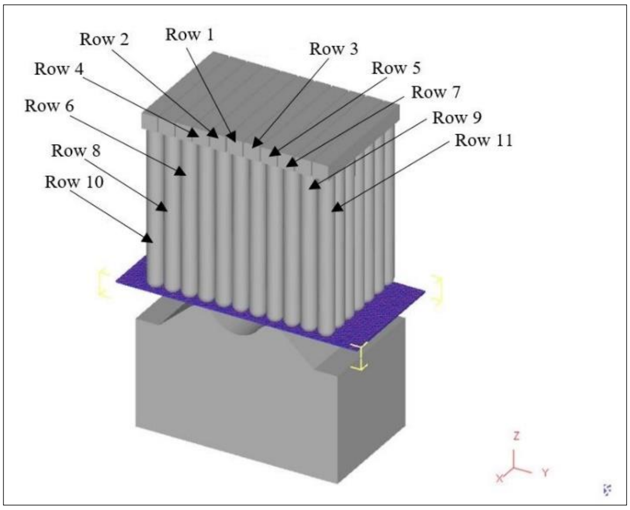
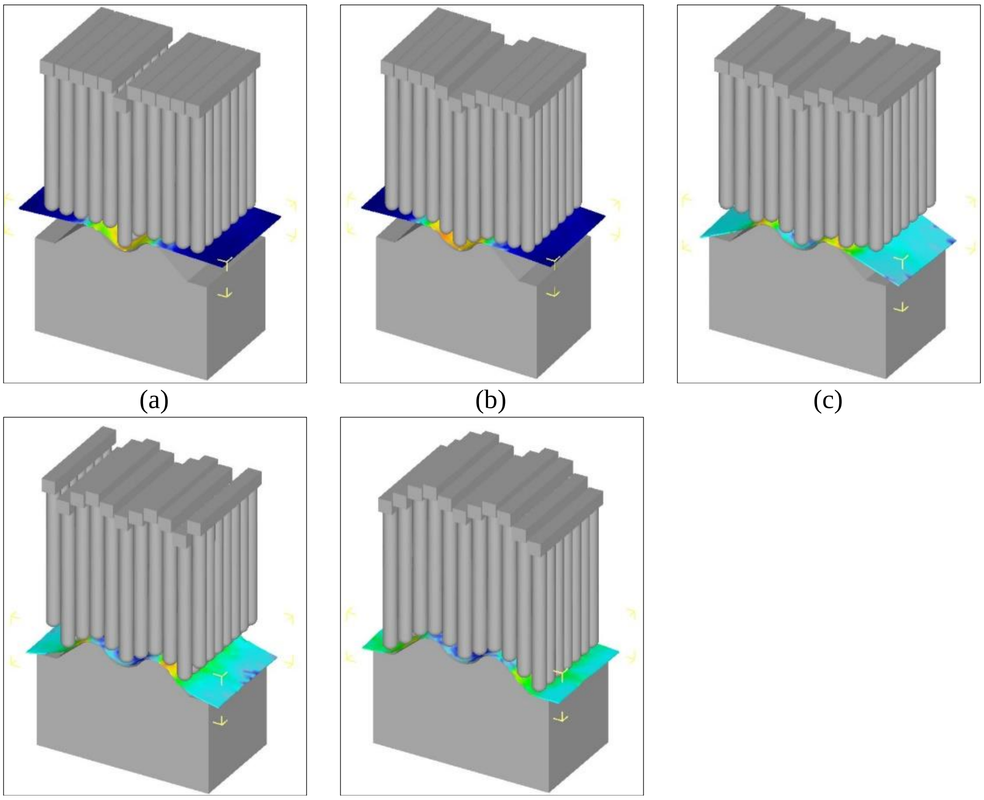


Fig. 3 MPF Die Set

III. RESULTS AND DISCUSSION

In multi-point progressive forming (MPPF), row 1 firstly pressed the sheet metal. Secondly, row 2 and 3 formed the sheet metal, then row 6 and 7 pressed, after that row 8 and 9 and finally, row 10 and 11 pressed the sheet metal. These steps were shown in Fig.4 (a), (b), (c), (d) and (e).



(a) (b) (c)

(d) (e)

Fig. 4 Multi-point Progressive Forming Steps (a) Row 1, (b) Row 2 and Row 3, (c) Row 6 and Row 7, (d) Row 8 and Row 9, and (e) Row 10 and Row 11

Damage factor distributions on the sheet metal part were shown in Fig. 5 (a), (b), (c), (d) and (e) after progressive multi-point forming. Highest value was obtained as 0.115. Therefore, tearing was not observed. But, in conventional forming

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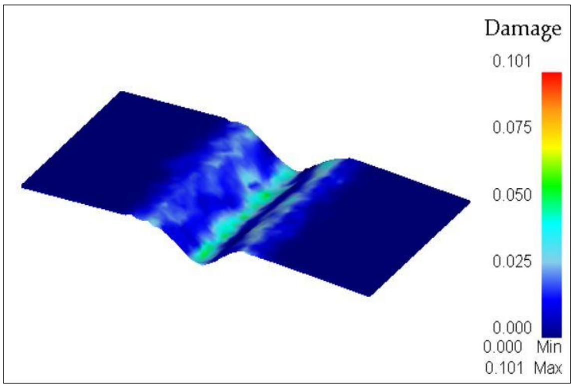
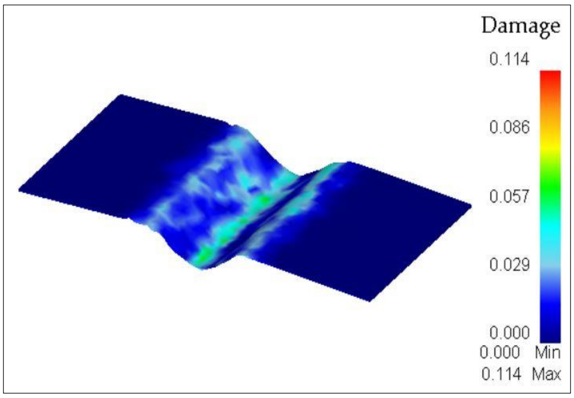
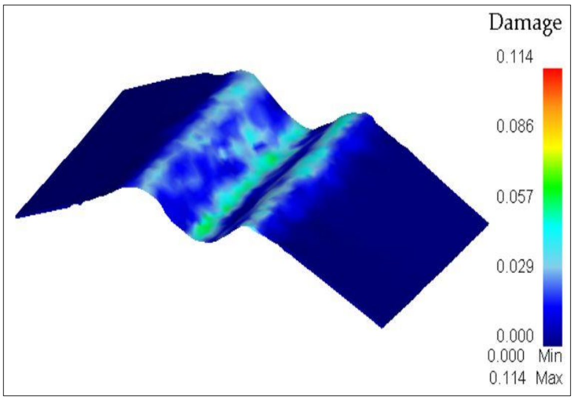
in Fig. 6, it was seen that the damage factor exceeds the defined value even before the forming process is completed. This causes the tearing of sheet metal part. In MPPF, sheet metal on die have the less contact area compared to conventional forming. Owing to this situation, material easily flows through on die shape.



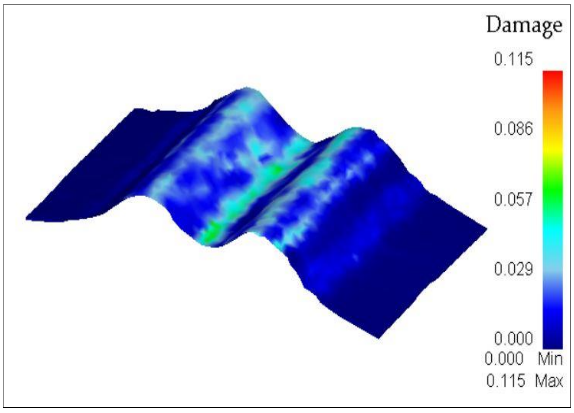
(a)



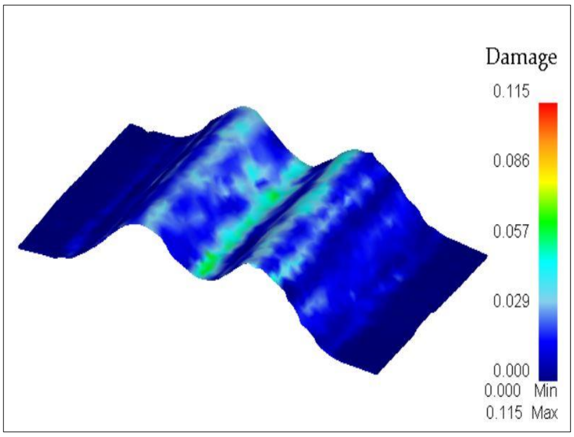
(b)



(c)



(d)



(e)

Fig. 5 Multi-point Progressive Forming Damage Factor Distributions after Pressing of
(a) Row 1, (b) Row 2 and Row 3, (c) Row 6 and Row 7, (d) Row 8 and Row 9, and (e) Row 10 and Row 11

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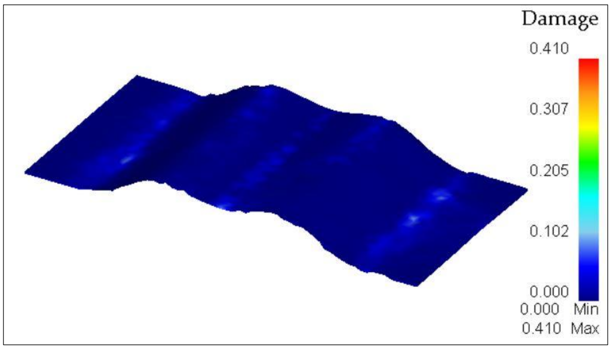

Fig. 6 Conventional Forming Stress Distribution

IV. CONCLUSION

In this paper, the multi-point progressive forming (MPPF) and conventional forming simulations were performed to form aluminum sheet parts. Finite element simulations were performed using commercial software DEFORM™ 3D to compare damage of sheet metal parts. The main conclusions of this study were summarized below:

- Conventional forming caused the tearing of sheet metal part comparing to MPPF.
- MPPF have the less contact area between sheet and pins. Thanks to this, the workpiece can be formed more easily.
- For this shape, MPPF is more applicable to obtain desired shape compared to conventional forming.

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