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Review on Sheet Metal Forming Process

[1]Roopesh Sharma, M. Tech Student, Department of Mechanical Engineering, Jaipur Engineering College, Kukas, Jaipur

[2]Jitendra Rai, Assistant Professor, Department of Mechanical Engineering, Jaipur Engineering College, Kukas, Jaipur

Abstract

The sheet metal forming technique is widely used in automotive industry for manufacturing of various components. Several different processing methods have been implemented in the industries to achive its repeatability and productivity. The current research reviews existing work conducted in sheet metal forming process using numerical and experimental techniques. The study on effect of operational parameters, material type and optimization process has been presented.

Keywords: Sheet metal forming analysis, FEM, forming limit diagram, sheet metal forming process

Introduction

Sheet metal forming (SMF) techniques are widely used in many industries to produce final-shaped components from a workpiece. In an SMF process, a thin piece of metal sheet is stretched into a desired shape by a tool without wrinkling or excessive thinning. In the past decade, methods for forming high-strength material with low plasticity and difficult-to-form metals have been developed for cold, warm and hot forming conditions [1,2]

Literature Review

According to Makinouchi et al. [3] numerical formulations of SMF can be classified into three main categories, which are, static explicit, static implicit and dynamic explicit. Numerical modeling of the forming of new metallic materials, i.e., multiphase steels, requires full-field models.

In 2020 Han et al. [4] proposed a microstructure-based multiscale modeling of large strain plastic deformation by coupling a full-field crystal plasticity-spectral solver with an implicit finite element solver. The model which was developed takes both dislocation density and phenomenological hardening law into account and is suitable for modeling materials with complex microstructural characteristics (e.g., grain morphology, multiple phases and textures).

Ma et al. [5] employed the plastic strain criterion depending on the triaxial nature of stress in the prediction of fracture in stamping parts using the simple tensile test. They also applied the digital image grid method (DIGM) to measure the strain localization behaviour and local strain distribution. Based on DIGM, a new method for the identification of the ductile damage limit of steel sheets was proposed with the aid of the historical path of nonlinear local strain and local fracture strain that had been measured. The commonly used Cockroft damage criterion, in which the plastic strain and the maximum principal stress are integrated, is an effective method to predict fracture under various loading conditions

Ma et al. [6] combined the measured transient displacement field with the FEM and a measurement-based FEM (M-FEM) was developed for the computation of the distribution of the local stress and strains, and the accumulation of ductile damage in a tensile test piece.

In the case of thin metal sheets, the uneven pressure will promote the onset of localized necking instability which will lead to fracture. Therefore, Shen et al. [7] proposed a mechanism for a rubber-induced smoothing effect on the confined laser shock in order to smooth the laser shock wave. It has been suggested that the smoothing effect is mainly due to the radial expansion of the plasma cloud on the rubber surface.

Kayan and Kaftanoglu [8] proposed non-isothermal deep drawing which is applied to DP600 HSLA and IF steels in elevated temperature conditions. They found that the process increases the LDR and there is no significant change in the microstructure of the material due to warm forming. The application strategy that was developed can solve the problems encountered in applications at ambient conditions, such as dimensional instabilities due to spring back and high residual stresses.

Xu et al. [9] studied electrically assisted incremental sheet forming with a combination of an electricity-assisted method with double sided incremental forming (E-DSIF) (Figure 1) and the newly designed slave tool force control device used to ensure stable tool–sheet contact. E-DSIF reduced the spring back of finished parts during the unclamping and trimming stages.

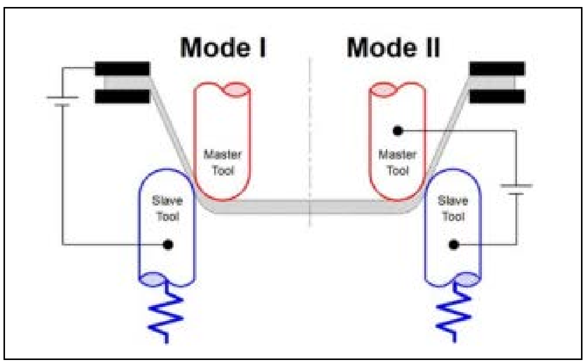

Figure 1: Schematic diagram of the circuit connection in E-DSIF

Al-Obaidi et al. [10] designed a fixture for hot single-point incremental forming of glass-fiber-reinforced polymer (GFRP) supported by hot air. The GFRP sheet was sandwiched between combinations of two poly tetra fluoro ethylene (PTFE; commonly known as Teflon) layers and metal sheets (Figure 2). The Teflon layer was used to reduce the flow of the melted matrix polymer out of the woven fiber. The aim of the work was to develop a way to shorten the production process for medical implants which will dramatically reduce the cost of their manufacture. In general, the relationship between the depth of the formed part and the heat initiated was found to make the overall work piece temperature homogeneous.

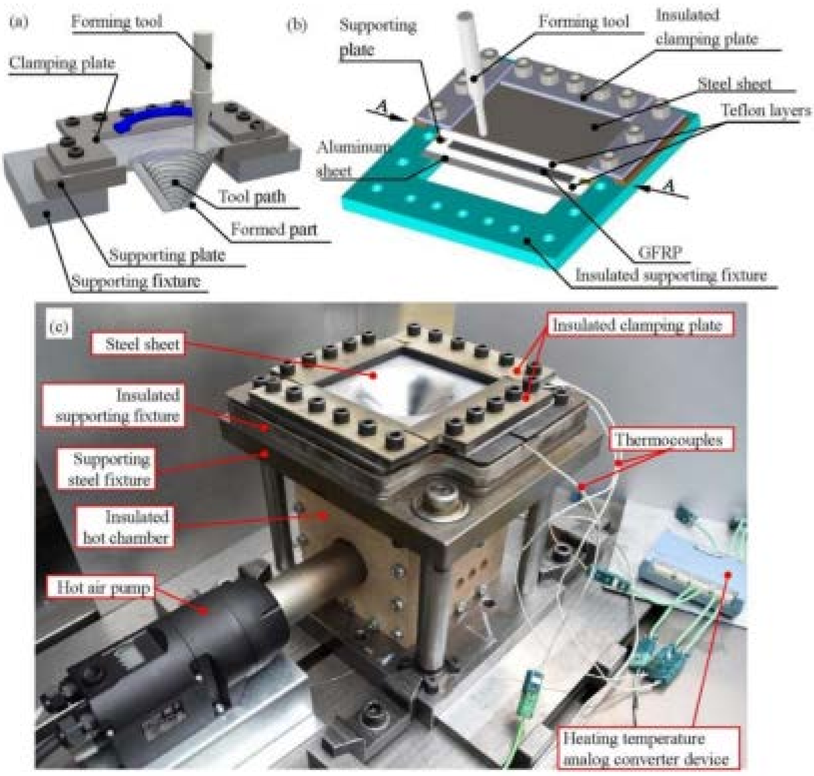

Figure 2: Principle of SPIF, work piece combination

Belhassen et al. [11] introduced FEM to analyze the RPF process in AA6061-T4 sheet metal. An elastic-plastic constitutive model with a J2 yield criterion and mixed nonlinear isotropic/kinematic hardening coupled with Lemaitre's ductile damage has been adopted during forming.

Irthiea et al. [12] report the results of FE simulation and experimental research on micro deep drawing processes of 304 stainless steel sheets using a flexible die. Two novel approaches were considered with regard to the positive and negative initial gap between an adjustment ring and a workpiece and a blank holder (Figure 3). Initial gaps affect the final cup profiles, in particular at the shoulder corner radius (Figure 4). The numerical predictions conducted in Abaqus/Standard software reveal the capability of the proposed technique to produce micro metallic cups with high quality and a large aspect ratio.

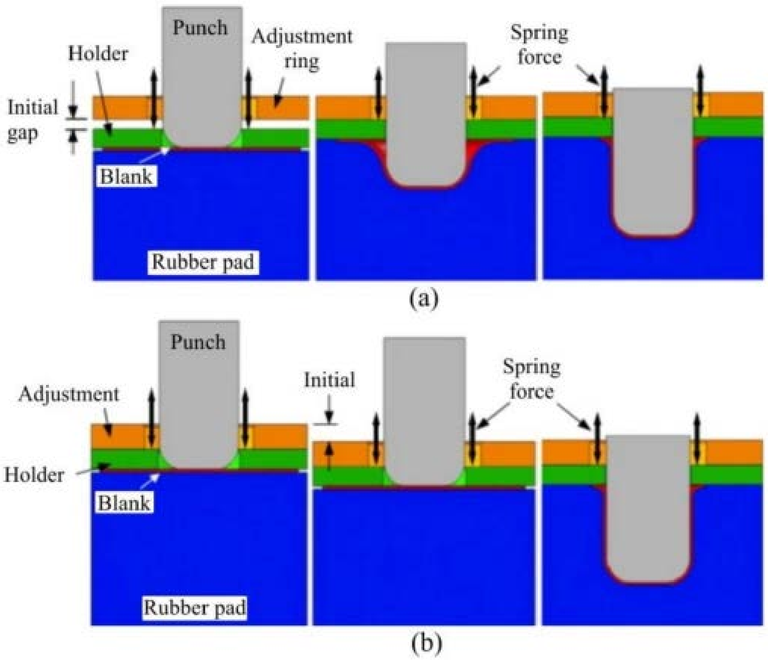

Figure 3: Flexible forming technology with (a) positive and (b) negative initial gap [12];

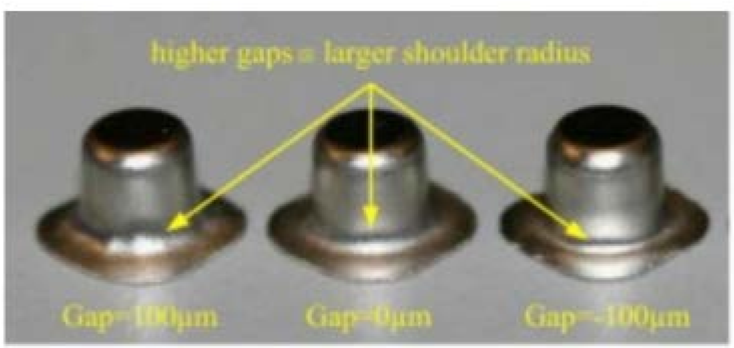

Figure 4: Cups formed with different initial gaps [12]

Prashant P. Khandare [13]. Metal forming is a process in which the desired shape and size are obtained through plastic deformation of a material without any loss of material. Bending is a metal forming process in which straight length is transformed into a curved length. Roller forming process is a continuous bending operation in which a long strip of metal is passed through typical roller adjustments, until the desired curvature shape is obtained. The bending changes according to material and according to the loading condition and thickness of sheet

Panthi, S.K. et al. (2007) [14] used analyzed elastic recovery in sheet metal bending with the help of finite element simulation. This study examined the effect of load on spring b back with varying thickness and die radius.

Bahloul R.et al. [15] used finite element simulation for the prediction of punch load and stress distribution during the wiping-die bending process. Here numerical simulation was modelled using elastic plastic theory coupled with Lemaitre's damage approach. They used ABAQUS for finite element simulation. The punch load and stress distribution was be predicted in view of optimization using response surface methodology (RSM) based on design of experiments.

Patil and Satao (2014) M.K.N., Patil, B.T. and Satao, M.S. (2014) [16] provided detail literature review about optimization aspects of deep drawing as well as use of finite element simulation in this area. This comprehensive review article clearly reveals importance of finite element simulation in sheet metal forming simulations.

Patil, B.T. and Joshi, K.N. (2016) [17] optimized various aspects of tube hydro forming process (without axial feed) using finite element simulations. Essentially tube hydro forming is the process of manufacturing light weight parts by passing pressurized fluid through tube. Modelling hydro forming process is complicated but essential for accurately producing parts. The author has also developed 3-dimensional finite element model for tube hydro forming using Creo Parametric 2.0. They used Hyper Mesh for pre-processing and used LS-DYNA explicit solver.

Joshi, Patil and Satao (2014) [18] studied optimization of variation in wall thickness of deep drawn cup using combined methodology of design of experiments and finite element methodology. They called this methodology as virtual design of experiment. Their investigation involved the effect of die radius, sheet metal thickness and blank holder force on wall thickness variation in cup drawing using finite element simulation.

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Ma et al. [22] combined the measured transient displacement field with the FEM and a measurement-based FEM (M-FEM) was developed for the computation of the distribution of the local stress and strains, and the accumulation of ductile damage in a tensile test piece.

Su et al. [23] proposed a new two-step electromagnetic forming process which combines EMF with electromagnetic calibration for local features of large-size sheet metal parts. During this process, the work piece is first electromagnetically formed by a flat spiral coil and then electromagnetically calibrated by a helical coil with a similar shape to the final profile of the work piece.

Su et al. [24] studied the uneven deformation behaviour of a 2219 aluminium alloy work piece formed by electromagnetic flanging. The authors established a numerical model in LS-DYNA 8.0 software to study the effect of different axial angles between the flanging direction and the normal direction of the sheet. They concluded that uneven deformation behaviour is essentially due to the uneven deformation requirement.

Conclusion

The sheet metal forming process is being analyzed by various researchers using FEM and experimental techniques. The feasibility of different techniques of fault detection i.e. digital image grid method (DIGM), double sided incremental forming (E-DSIF) is determined. Various tests are conducted using LS-DYNA technique and critical regions of high stresses and deformation are identified.

References

1. Hagenah, H.; Schulte, R.; Vogel, M.; Hermann, J.; Scharrer, H.; Lechner, M.; Merklein, M. 4.0 in metal forming - questions and challenges. Procedia CIRP 2019, 79, 649–654. [CrossRef]
2. Gronostajski, Z.; Pater, Z.; Madej, L.; Gontarz, A.; Lisiecki, L.; Lukaszek-Solek, A.; Luksza, J.; Mróz, S.; Muskalski, Z.; Muzykiewicz, W.; et al. Recent development trends in metal forming. Arch. Civ. Mech. Eng. 2019, 19, 898–941. [CrossRef]
3. Liu, X.; Sun, W.K.; Liew, K.M. Multiscale modeling of crystal plastic deformation of polycrystalline titanium at high temperatures. Comput. Methods Appl. Mech. Eng. 2018, 340, 932–955.
4. Trzepieci ´nski, T.; Lemu, H.G. Effect of computational parameters on springback prediction by numerical simulation. Metals 2017,7, 380.
5. Ma, N.; Takada, K.; Sato, K. Measurement of local strain path and identification of ductile damage limit based on simple tensile test. Procedia Eng. 2014, 81, 1402–1407.
6. Ma, N.; Sato, K.; Takada, K. Analysis of local fracture strain and damage limit of advanced high strength steels using measured displacement fields and FEM. Comput. Mater. Contin. 2015, 46, 195–219.
7. Shen, Z.; Wang, X.; Liu, H.; Wang, Y.; Wang, C. Rubber-induced uniform laser shock wave pressure for thin metal sheets microforming. Appl. Surf. Sci. 2015, 327, 307–312.
8. Kayhan, E.; Kaftanoglu, B. Experimental investigation of non-isothermal deep drawing of DP600 steel. Int. J. Adv. Manuf. Technol. 2018, 99, 695–706.
9. Xu, D.K.; Lu, B.; Cao, T.T.; Zhang, H.; Chen, J.; Hong, H.; Cao, J. Enhancement of process capabilities in electrically-assisted double sided incremental forming. Mater. Des. 2016, 92, 268–280
10. Al-Obaidai, A.; Kunke, A.; Kräusel, V. Hot single-point incremental forming of glass-fiber-reinforced polymer(PA6GF47) supported by hot air. J. Manuf. Process. 2019, 43, 17–25.
11. Belhassen, L.; Koubaa, S.; Wali, M.; Dammak, F. Numerical prediction of springback and ductile damage in rubber-padforming process of aluminum sheet metal. Int. J. Mech. Sci. 2016, 117, 218–226.
12. Irthiea, I.; Green, G.; Hashim, S.; Kriama, A. Experimental and numerical investigation on micro deep drawing process of stainless steel 304 foil using flexible tools. Int. J. Mach. Tools Manuf. 2014, 76, 21–33.
13. Prashant P. Khandare, Dhiral N. Patel, Mayur K. Aher, Ravi S. Parbat and Prof. Swapnil S. Patil, “Study of Portable 3 Roller Pipe Bending Machine”, International Conference on Emerging Trends in Engineering and Management Research, ISBN 978-81- 932074-7-5, 23 March 2016, 624-630.

14. Panthi, S.K., Ramakrishnan, N., Pathak, K.K. and Chouhan, J.S., 2007. An analysis of springback in sheet metal bending using finite element method (FEM). Journal of Materials Processing Technology, 186(1), pp.120-124.
15. Bahloul, R., Mkaddem, A., Dal Santo, P. and Potiron, A., 2006. Sheet metal bending optimisation using response surface method, numerical simulation and design of experiments. International journal of mechanical sciences, 48(9), pp.991-1003.
16. Joshi, M.K.N., Patil, B.T. and Satao, M.S. 2014 Review of Optimization Aspects for Metal Forming Process. An International Journal (ESTIJ),ISSN: 2250- 3498,Vol.4,no.2 pp 71-75
17. Shinde, R.A., Patil, B.T. and Joshi, K.N., 2016. Optimization of Tube Hydroforming Process (without Axial Feed) by Using FEA Simulations. Procedia Technology, 23, pp.398-405.
18. Joshi, M.K.N., Patil, B.T. and Satao, M.S., 2014. Optimization of Variation in Wall Thickness of a Deep Drawn Cup using Virtual Design of Experiments. Optimization, 4(5).
19. Trzepieci ´nski, T.; Lemu, H.G. Effect of computational parameters on spring back prediction by numerical simulation. Metals 2017, 7, 380.
20. Ma, N.; Takada, K.; Sato, K. Measurement of local strain path and identification of ductile damage limit based on simple tensile test. Procedia Eng. 2014, 81, 1402–1407.
21. Takuda, H.; Hama, T.; Nishida, K.; Yoshida, T.; Nitta, J. Prediction of forming limit in stretch flanging by finite element simulation combined with ductile fracture criterion. Comp. Meth. Mater. Sci. 2009, 9, 137–142.
22. Ma, N.; Sato, K.; Takada, K. Analysis of local fracture strain and damage limit of advanced high strength steels using measured displacement fields and FEM. Comput. Mater. Contin. 2015, 46, 195–219.
23. Su, H.; Huang, L.; Li, J.; Ma, F.; Huang, P.; Feng, F. Two-step electromagnetic forming: A new forming approach to local features of large-size sheet metal parts. Int. J. Mach. Tools Manuf. 2018, 124, 99–116.
24. Su, H.; Huang, L.; Li, J.; Ma, F.; Ma, H.; Huang, P.; Zhu, H.; Feng, F. Inhomogeneous deformation behaviors of oblique hole-flanging parts during electromagnetic forming. J. Manuf. Process. 2020, 52, 1–11.