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A Hybrid Flexible Sheet Forming Approach Towards Uniform Thickness Distribution

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Abstract

This paper presents a newly developed flexible sheet forming approach with better sheet thickness distribution and reduced processing time comparing to the conventional incremental sheet forming. In the approach, a two-step forming process has been proposed: multi-point forming as preforming is employed to achieve an initial shape and designed thickness distribution; After the preforming, incremental sheet forming process is then applied to finalize part geometry with desired thickness distribution. In the work, a numerical model for predicting the thickness distribution of the final part is developed by integrating finite element simulation and analytical prediction of ISF process. To achieve the uniformity of final thickness distribution, the preformed shape is optimized based on the developed thickness prediction model. Additionally, a real industrial case problem of forming an aerospace cowling is used to validate the proposed hybrid flexible sheet forming approach. Satisfactory results are obtained, which demonstrates the feasibility and effectiveness of the developed forming process.

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Keywords: Hybird forming; Incremental sheet forming; Thickness distribution

1. Introduction

Sheet metal forming has been widely used in automotive, aerospace, medical, and recently in renewable energy. The conventional sheet metal forming processes such as stamping and deep drawing are more suitable for mass production. For manufacturing of high value-added, small batch and customized products, the employment of conventional process would results high tooling costs, long lead time and high-energy consumption. To overcome these limitations, the flexible sheet forming concept, aiming to reduce the lead time, incurred cost and energy consumption, has attracted significant research attentions in recent years, incremental sheet forming (ISF) [1] and multi-point forming (MPF) [2] are two typical flexible sheet forming approaches.

Incremental sheet forming, with its unique technical advantages in dieless forming and enhanced formability, has attracted ever increasing interests in both academic and industrial communities after the popularity of NC technology in 1990s [3]. In the ISF process, a hemispherical tool moves along the pre-designed toolpath and deforms the clamped sheet layer by layer. With the inherent feature of localized deformation, ISF could achieve higher strains comparing to the traditional stamping process [4]. However, ISF also has some limitations including long processing time, low geometrical accuracy and coarse surface finish. In order to overcome these limitations, effort has been made to explore a number of variations of the ISF process：Iseki et al [1] developed the modern ISF process using a simple tool and a path of the contour line and a non-symmetrical parts has been made using a manually operated X-Y table. Matsubara [5] developed the two-point incremental forming (TPIF) process, in which the tool is drawing contours from the inside outwards while the blank holder is gradually moving downwards on to a male die. Bambach et al [6] employed a multi-pass strategies to formed a four–sided pyramid with a nearly right angle. Malhotra et al.[7] employed mixed in-out and out-in tool paths achieve a smoother component. Malhotra et al. [8] also developed a double side

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incremental forming (DSIF) process with two moving tools. In the DSIF process, the sheet is squeezed by two tools and uniform thickness distribution can be obtained. In the above ISF processes, the control of sheet thinning is difficult as the blank will not flow into the die cavity during the deformation as that in conventional stamping process. To overcome this problem, Araghi et al. [9] proposed a hybrid process in which the stretch forming and non-symmetric incremental sheet forming are combined together. Using this hybrid process, better sheet thickness distribution can be obtained with reduced forming time. However, the potential problem of the existing hybrid forming technology is that a specific supporting die is required, which reduced the process flexibility and efficiency. At present, there is limited report on this hybrid technology. Further development are necessary based on the existing ISF technology to improve this process.

Multi-point forming (MPF) is another flexible forming technology. In the multi-point forming process, matrices of punches are employed to replace the traditional dies [10]. In the multi-point forming, 3D freeform surface can be obtained by adjusting the position of the punches. However, in the MPF process, a particular defect is the dimples left by the punches, which is inevitable even by placing elastic rubber sheet on the die surface [11]. In addition, the shape complexity may be limited by the punches' size in MPF process. Due to above shortcomings, multi-point forming is more suitable for forming parts with small curvatures other than those with complex geometries.

In order to overcome the problems in the existing flexible forming processes, a hybrid flexible sheet forming approach has been proposed in this work by combining the MPF and ISF technology. In the approach, sheet is preformed to designed shape by employing the multi-point forming method. After the preforming, incremental sheet forming process is utilized to form the part from the concave side of sheet. In this way, the designed part geometry could be achieved with improved thickness distribution.

2. Flexible hybrid forming

2.1. Introduction to the flexible hybrid forming process

To facilitate the proposed flexible forming approach, a hybrid forming setup has been designed and developed as shown in Fig. 1. As can be seen in the figure, a forming platform with rotatable blank holder and reconfigurable die has been designed. By clamping the sheet in the blank holder, a preform operation can be implemented by moving the platform downwards. After the preforming process, the blank holder can be unclamped from the platform and rotate to the vertical position with the preformed part in it. Using an industrial robot, ISF process can be implemented from the concave side of the part. By using this process, the part could be finalized to the designed shape. The actual developed flexible hybrid forming equipment is shown in Fig 2.

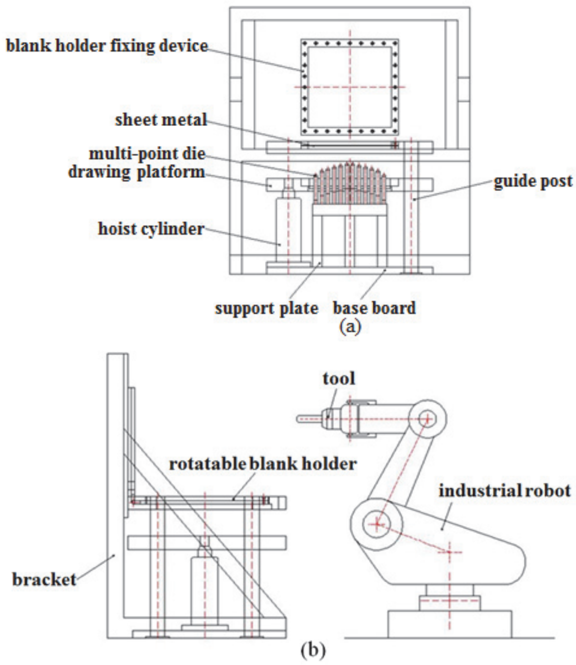

Fig. 1. Hybrid forming equipment: (a) Multi-point forming structure; (b) Incremental sheet forming structure

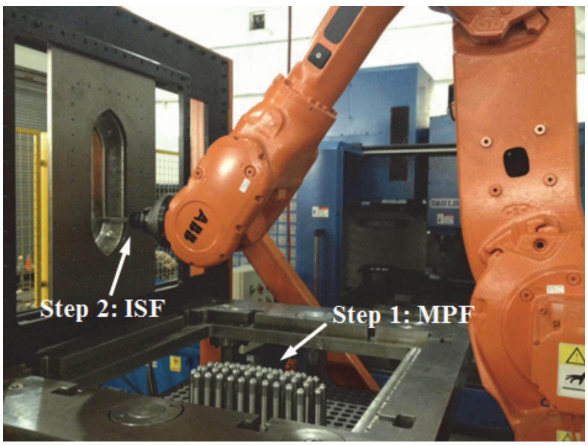

Fig. 2. Two-step hybrid flexible sheet forming equipment

In this two-step forming process, the challenge comes from the determination of preform shape to achieve a more uniform thickness. As preform shape is a major factor that affect the final part thickness, a proper preform shape become virtually important in the process design of the developed hybrid forming process. In order to predict the final thickness distribution, a numerical approach has been employed in the analysis. Based on