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ScienceDirect
Trans. Nonferrous Met. Soc. China 26(2016) 2442−2448
Transactions of Nonferrous Metals Society of China
www.tnmsc.cn

Effect of gap generator blank thickness on formability in multilayer stamp forming process

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Received 7 September 2015; accepted 22 March 2016

Abstract: Experimental and numerical analyses for the effect of the thickness of gap generator blank (GGB) on the formability of the outer blanks were investigated. The thickness of the GGB has the greatest impact on the thinning of the lowest blank. In addition, the friction at different regions and the additional interlayer contacts can also affect the thinning of different regions as well as increase the punch force. This work will enhance the understanding of simultaneous multi-layered blanks forming and will help the composite design engineers to tailor requirement-specific hybrid parts such as fiber metal laminates (FMLs) and functionally graded structures (FGSs) for hi-tech applications.

Key words: gap generator blanks (GGB); thinning; friction; punch force; hybrid part

1 Introduction

Fiber metal laminates (FMLs) have been widely used in aerospace structures and infrastructure due to their light weight and high specific strength. There are two common techniques being used to make FMLs. The first method is used to make huge FML structures which are comparatively simple in design by autoclave, such as wings and aircraft's skins [1−3]. The second method is applied to the stamp forming (die/punch etc.) to fabricate relatively small, deep drawn, complex profiled parts using thermoplastic resins such as polypropylene-based short fiber metal laminates [4−8]. ZAFAR et al [9−12] recently proposed and demonstrated the concept of simultaneous forming method (the 3A method) for multilayer metallic blanks, which ultimately facilitates the manufacturing of tailor-made FMLs and functionally gradient structures (FGSs). In contrast with the existing methods used to make FML parts, this new approach eliminates the prerequisite of heating/solidification/reheating of the blank assembly/tooling and the requirements to strictly control the stamp forming parameters such as the punch and the binder forces. The 3A method can only be used for forming products which have a uniform gap as shown in Fig. 1(a). One of the major drawbacks of applying the "3A Method" is the absence of gap between the simultaneously formed layers when vertical features are formed such as in deep drawn cylindrical parts, as shown in Fig. 1(b). In order to solve this problem, an "improved 3A method" based on the provision of extra "gap generator" blank between the inter layers has been devised and implemented in this research. The concepts of the 3A and the improved 3A methods (GGB strategy) are reproduced in Fig. 2 for easy comprehension in this work. After simultaneous forming of the metallic blanks assembly, GGB can be separated by mechanical/thermal means and the required composite materials (weavings/unidirectional/chopped/self-reinforced polymers, etc.) can be placed at any desired areas with a freedom to use the thermosetting (TS) or thermoplastic (TP) resins. While the existing methods can only employ short/chopped fibers with TP resins because the woven fabric/long fibers can easily be ruptured using existing methods. Furthermore, the needs to make a different set of tooling (punch/die) for each layer of the multi-structural part are also eradicated. A detailed literature survey and discussion about the advantages of the simultaneous forming method (the 3A method), the limitations of the existing methods and the motivation to conduct the present study were described in Refs. [13−18].

Foundation item: Project (2010DFA52030) supported by the International Scientific Cooperation, China; Project (51175024) supported by the National Natural Science Foundation of China
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DOI: 10.1016/S1003-6326(16)64364-9

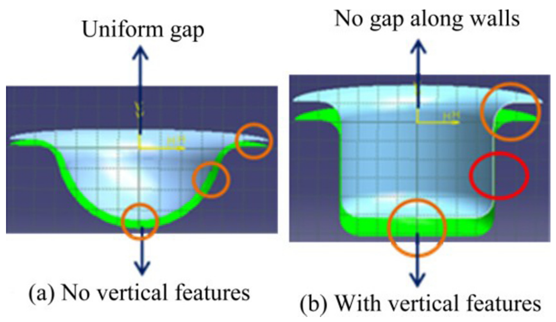

Fig. 1 Gap variations with shape change: (a) Part without any vertical feature; (b) Part having vertical features

GGB thickness is one of the most important material design parameters, which needs to be considered during the FML or FGS parts design planning stage. This gap determines the thickness/quantity/volume of the composite sheets (woven fabric/sheets/resin) or the weight/volume of the fibers (short/chopped fibers/resin) which could be placed in that space after forming and disassembly of the blank layers. After disassembling the formed metallic layers, the GGB is removed. The mechanical/thermal/chemical properties of the laminated part are ultimately designed and controlled by the gap produced by the GGB. Since, during a plastic deformation process like the deep drawing, the stresses in the flange, walls and the bottom of a cylindrical part are different and hence the strain states are also different. Especially, when multiple metallic layers are formed using the same punch and force, the forming behavior of layers with different thicknesses may not be similar. This study will investigate the effect of the different thicknesses of GGB and the forming behavior of the thinner blanks around it. In order to get a clear evaluation, most of the parameters such as material, diameter, target forming depth, punch speed, coefficients of friction and formed diameters of the multilayer parts are kept similar. However, the layup configurations and the thicknesses of the GGB are changed to draw a three-layer structure. It is important to emphasize that using the GGB strategy (the improved 3A method) to form the multilayer metallic structure as a framework to make complex hybrid parts is the latest methodology and rare literature is available in this regard.

2 Numerical simulation and experimental setup

Aluminum alloys Al2024-O having a diameter of 140 mm were used to the three-layer forming simulations. Thickness combinations and the tensile properties of the alloy are given in Table 1. The tensile test was performed according to ASTM E8 at room temperature using

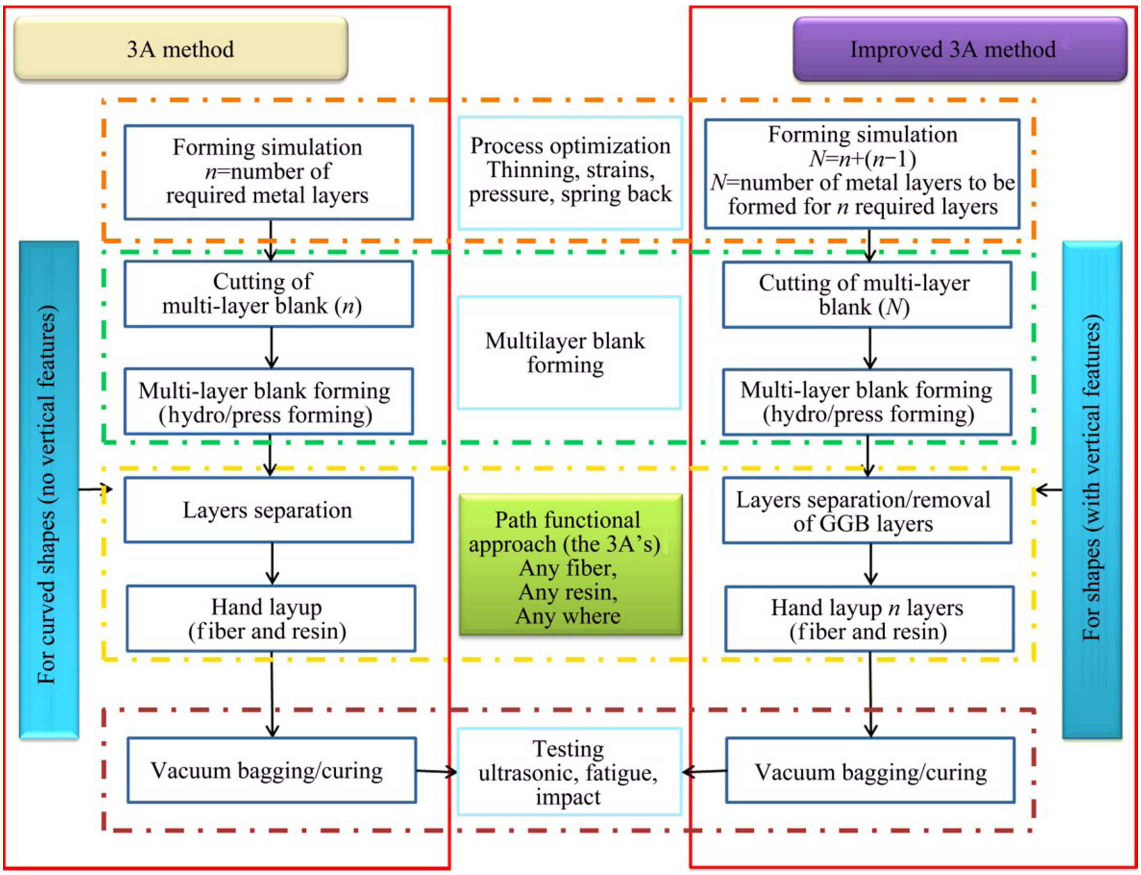

Fig. 2 3A and improved 3A methods (GGB strategy)