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ORIGINAL ARTICLE

Formability and failure analyses of Al/SUS bilayer sheet in single point incremental forming

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Abstract

The application of single point incremental forming (SPIF) on a composite sheet can combine the benefits from process and material to achieve high formability of parts. In this paper, the deformation behaviors of Al/stainless steel (SUS) bimetal sheets have been evaluated through the experimental and numerical works. The effects of layer arrangement, tool diameter, and step down on the formability and failure modes are analyzed. The finite element method (FEM) was carried out to simulate and increase the knowledge on the deformation behaviors of Al/SUS bilayer sheet. To validate the finite element analysis, the experimental tests were performed under the same conditions. The results show that to form the Al/SUS bimetal sheet, more efforts are required and the formability of bimetal sheets is limited by the percentage of tensile reduction of area of the outer layer. Therefore, lower formability of Al/SUS bimetal sheet corresponding to the higher thinning applied on the external layer of Al/SUS bimetal sheets and this leads to increase forming force induces during the incremental forming of this layer arrangement which promotes the earlier failure in the Al/SUS compared to SUS/Al bimetal sheets. Moreover, the fracture after necking is observed in case of Al/SUS and SUS/Al layer arrangements, especially for tools with a larger diameter. Furthermore, the occurrence of the delamination of the bimetal sheets is influenced by the layer arrangement of the fractured parts.

Keywords Incremental forming · Al/SUS bimetal sheet · Formability · Failure analysis · FEM

1 Introduction

Bonding dissimilar materials to produce the bimetal composite sheets can take the advantages of the parent materials, additional to the gained properties during the production process. Bonded metal sheets represent a suitable solution for the products with high characteristic performance. In this regard, to incorporate different mechanical and physical properties in one combined sheet, explosive welding, cold rolling, and hot rolling techniques can be adopted for developing such kind of sheets. Such a combination of different sheets can improve the formability, corrosion resistance, and electrical and thermal conductivities of the desirable parts. The composite sheets have wide applications in automotive, appliance, energy storage, and heat transfer sectors [1, 2].

In the last years, the formability of the bimetal sheets through the conventional forming processes has been gained much attention. Tseng et al. [3] predicted the formability and the fracture of Al/Cu bimetal sheet with different thickness ratios. The forming limit diagram (FLD) was investigated using the conventional forming test, and the fracture prediction was simulated using finite element method. The results revealed that the reduction in the formability was significant especially when the thickness of both layers is equivalent. In the plane stress condition, Yoshida and Hino [4] evaluated the formability of aluminum/stainless steel bimetal composite sheets in the stretch forming process. The analytical and experimental analyses of their study showed that the formability of composite sheets lies between their constituents. Based on the numerical analysis, Bagherzadeh et al. [5] studied the effect of layer arrangement and layers thickness upon the formability of hydro-mechanical deep drawing process of composite sheets. They proved that the maximum limit drawing ratio and minimum thinning could be attainable when lower

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