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Numerical and Experimental Investigation ofEffective Parameters on Formability of Al-St Two-Layer Sheet Metals

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ABSTRACT: Recently, the use of laminated sheet metals has been spread in various industries, such as aerospace and automotive industries due to the improvement of formability of low-formable lightweight sheets and making compound properties such as corrosion resistance. Forming these sheets is faced with some limitations, such as wrinkling and separation of the layers. To overcome these limitations, hydroforming process has been introduced. In this paper, hydrodynamic deep drawing assisted by radial pressure and also hydromechanical deep drawing processes of Al-St two-layer sheet metals have been investigated experimentally. In order to perform a detailed investigation, finite element simulation was also carried out by ABAQUS software. It was shown that formability of the aluminum sheet can be improved by laminating with the steel sheet. Moreover, the results illustrated that in hydrodynamic deep drawing assisted by radial pressure, wrinkling is decreased and thinning is increased by reducing the gap between blank holder and die. When the gap becomes zero (hydro-mechanical deep drawing without radial pressure), wrinkling is reduced considerably and also drawing ratio is decreased. Additionally, it was identified that the arrangement of the layers with respect to the punch has a great effect on formability of the two-layer sheet.

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Drawing ratio

1- Introduction

Multi-layer sheet metals, which are a combination of two or more dissimilar sheet metals, usually with a different thickness of layers, have wide applications in various industries. The most important feature of these sheets is the high strength to weight ratio that causes them to become suitable to use in the automotive and aerospace industries. Formability and deformation properties are the main considerations of multi-layer sheet metals that depend on the thickness of layers, the arrangement of layers relative to tool surface, tool shape, etc. [1]. Among the forming methods, the hydroforming process, due to accessing higher drawing ratio, producing complex parts and high quality of produced parts has widely been considered [2].

Bagherzade et al. studied hydroforming process of Al-St two-layer sheets. They found that by increasing drawing ratio, the critical fluid pressure is decreased. Also, by increasing thickness of the higher-strength sheet, the pressure range of the working fluid is increased. It was demonstrated that when Al sheet is in contact with a punch, compared with the case in which St sheet is toward the punch, the working area of the fluid pressure is increased and higher pressures can be used. In both cases, maximum thinning occurred on the external layer [3].

In this research, in the beginning, Al-St two-layer sheet was formed by a hydrodynamic deep drawing process and the effect of different parameters such as the distance between blank holder and die, and process pressure were investigated. It was observed in this process that, wrinkling of sheets is high. To eliminate wrinkling, hydro-mechanical deep drawing process was used and the parameters such as the arrangement of layers and process pressure were examined. Finally, the two processes were compared and also a comparison between formability of two-layer sheet and one-layer sheet was made. Finite element simulation also was carried out by ABAQUS software. In this paper, by using two different hydroforming processes, it was tried to form two-layer sheets with no defect such as wrinkling or thinning.

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2- Two-layer Sheet

In this research, a low carbon steel sheet (St 13) and an aluminum sheet (Al 1050) were used to make a two-layer sheet. The sheet properties are shown in Table 1.

Table 1. The properties of the sheets

subject	Al 1050	St 13
Thickness, mm	1.02	1
Density, kg/m	2300	7800
Yield strength, MPa	131	158
Elastic module, GPa	70	210
Poisson ratio	0.33	0.3
Strain hardening exponent, n	0.13	0.33
Hardening coeff., K MPa	214	600

3- Finite Element Simulation

In this research, finite element software, ABAQUS 6.10, was used for simulation. Due to symmetry, one quarter of the die set was modeled. In order to investigate wrinkling and applying radial pressure to edges of the sheet, 3D model was used. The die set was modeled discrete rigid using R3D4 element and the sheets were modeled deformable using C3D8R element.

4- Results and Discussion

Firstly, in order to validate the simulation results, simulation and experimental results were compared. Then, the process parameters were investigated.

4- 1- Effect of fluid pressure

Fig. 1 shows the thickness distribution at different maximum pressures in the hydrodynamic deep drawing process. According to Fig. 1, by increasing pressure, maximum thinning is decreased.

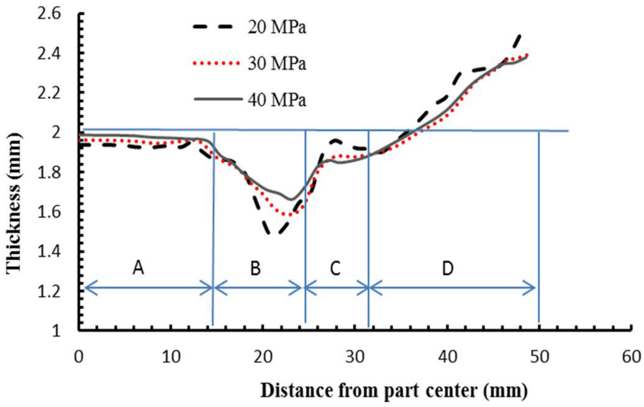


Fig. 1. Thickness distribution curve at different maximum pressures in the hydrodynamic deep drawing process

4- 2- Effect of the arrangement of layers

One of the important parameters in forming two-layer sheets is the arrangement of layers. In Fig.2, a comparison between thickness distribution of St-Al two-layer sheet, in which the steel sheet is in contact with a punch and the aluminum sheet is in contact with the die, and also Al-St two-layer sheet, in which the aluminum sheet is in contact with a punch, was made. As can be seen from Fig.2 (a), thinning in an aluminum layer of Al-St sheet is less. In two-layer sheets when a lower – formable layer (Al layer in Al-St two-layer sheet) is in contact with a punch, its formability is higher and its thinning is less. Based on Fig.2 (b) for higher-formable sheet, the difference is not so much considerable.

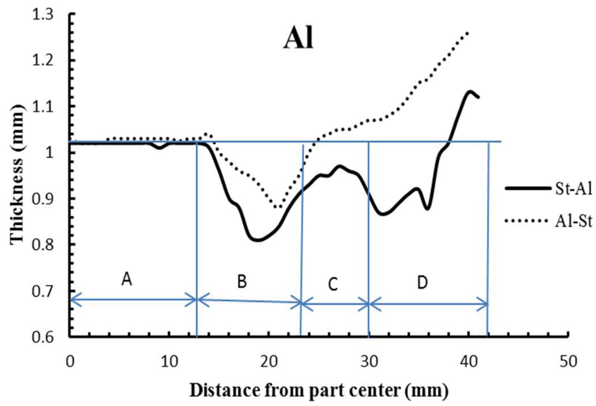
4- 3- Comparison between hydrodynamic and hydro-mechanical deep drawing processes

Fig. 3 shows the formed parts obtained from hydrodynamic deep drawing (HDDD) and hydro-mechanical deep drawing (HMDD) processes and their thickness distribution curves. It is observed that in HMDD, thinning is more and the amount of thickening on flange area and wrinkling of the two-layer sheet are less.

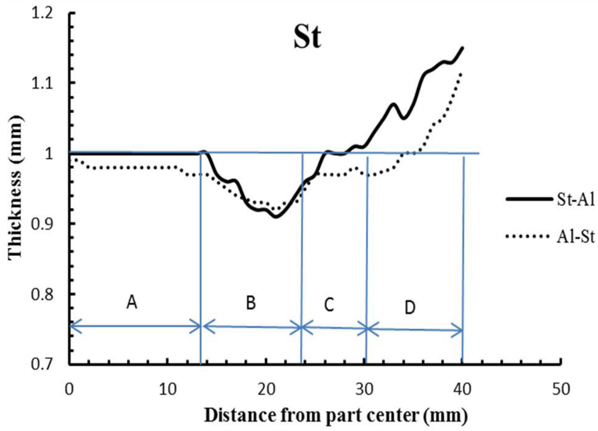
5- Conclusion

In hydrodynamic deep drawing process assisted by radial pressure, by decreasing the distance between blank holder and die, due to thickening of the sheet during the process and becoming harder of material flow, maximum thinning on punch corner area is increased and thickening on flange area and upper part of the wall is decreased.

In both HDDR and HMDD processes, by increasing fluid pressure, due to increasing the contact of the upper layer with a punch and, thus, increasing friction, the thickness is decreased. The amount of the decrease in thinning in



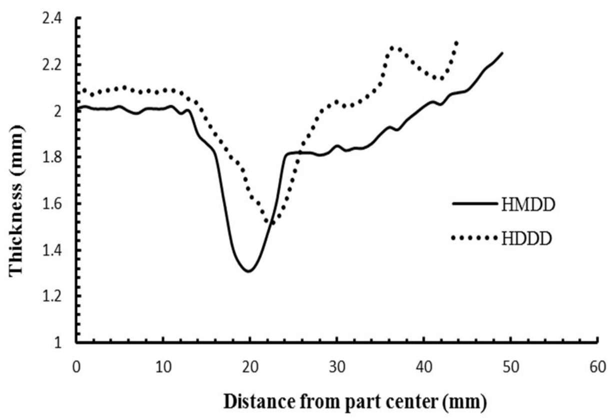
(a)



(b)

Fig. 2. Thickness distribution curve (a) Al layer (b) St layer, on two arrangements of the layers

(a)



(b)

Fig. 3. Al-St two-layer sheet (a) HMDD, (b) HDDD, (c) thickness distribution curve

hydrodynamic deep drawing process is more than that in hydro-mechanical deep drawing processes, because of the radial pressure in HDDR.

In general, for two-layer sheets, it can be recommended that the less formable layer be in contact with a punch to prevent the rupture and decrease the forming force.

By comparing HDDD and HMDD processes, it was observed that in HDDD due to the distance between the blank holder and die and also radial pressure, thinning is less but thickening and wrinkling are more. Moreover, in this process can be access to more drawing ratio.

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