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A Numerical and Experimental Study on Bending of Glass Fiber Metal Laminate Composite for Reducing Resultant Defects

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ABSTRACT

Nowadays, fiber-metal laminate composites are highly used by designers due to their good mechanical properties and low weight particularly in aerospace industry. The Fiber Metal Laminate shows improvement over the properties of both aluminum alloys and composite materials. In this study, bending properties of these composites are investigated both numerically and experimentally. Since these multi-layers have a very limited formability and deformation of fibers is pure elastic, the fibers cause some kind of springback that is known as a defect. In the current study, six types of specimens are prepared with variable fiber angles and thickness of layers for bending test. In addition, the bending test is optimized through the Taguchi design experimental method, until the results become independent of die and press parameters. The effects of design and fabrication parameters of fiber- metal composite on the springback are investigated in detail. The results show that the springback increases linearly with increasing punch radius and with decreasing pressure forming due to the reduction of the plastic deformation. On the other hand, by increasing the punch speed, the springback increases slightly because forming by the high-rate punch speed increases the amount of elastic recovery in aluminum sheet and induces larger springback. Moreover, when the fibers are parallel to the bending axis and the thickness of outer layers increase, the bend radius and springback decrease. The obtained results are compared partially with the FE numerical results.

KEYWORDS:

Fiber metal laminate, bending, springback, finite element, Taguchi method.

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1- Introduction

One of the advanced composite materials is FML that consists of layers of fiber and thin metal. Today, this type of material is a proper alternative for metal structures, particularly in aerospace application because of its good fatigue strength and fracture stress. This material has both good qualities of metals and fibers. For example, it can have good ductility, impact resistance and damage strength. One of the most common FML that is widely used is ARALL made of aramid fiber and the other is GLARE that is base of the glass fiber [1]. The major advantage of the glass fiber compared to the aramid fiber is its better resistanance to fracture [2]. Moreover, in the later one, the adhesive layer of the material used (for gluing the layers) is a barrier against corrosion. The other advantages of the multi-layers are their resistance against fire, good damping and isolation properties. Crack growth rates in a multi-layer composite fiber-metal are very low. Another feature of multi-lyres is the cracks cause by the fatigue in metal part do not affect on the fibers. Some researches about the glass reinforced aluminum laminates has already been performed [3]. The springback phenomenon is one of the main drawbacks of the process formation that causes many costs to industry and many studies have been done in order to reduce it. Some studies on the glass fiber-aluminum show that decreasing the bending radius can reduce the amount of springback [4]. In the current study, the optimization of the bending process in order to reduce the springback is investigated in detail and the optimum bending process to reduce springback using the Taguchi experimental design is studied.

2- Methodology

The effects of design and fabrication parameters of fiber- metal composite on the springback are investigated. For this purpose, six sets of samples with different angles and thicknesses are considered. The sheets consist of two aluminum layers with the thicknesses of 0.8 and 0.4 millimeters and one composite layer with the angles of 0, 45 and 90 degrees, which are made manually. To investigate the process more precisely, a finite element simulation is also conducted and the obtained results are compared to each other. Some parameters such as die radius, punch speed and pressure of the punch are investigated and their effects on the springback are examined. Furthermore, the effects of the fiber angle and increasing the thickness of outer layer on the amount of springback have been investigated.

3- Experimental Study

In order to find the properties of the materials required for the bending test the specimens are made based on the ASTM standard and uni-axial tests with the Zwick machine are achieved, as shown in Figures 1 and 2.

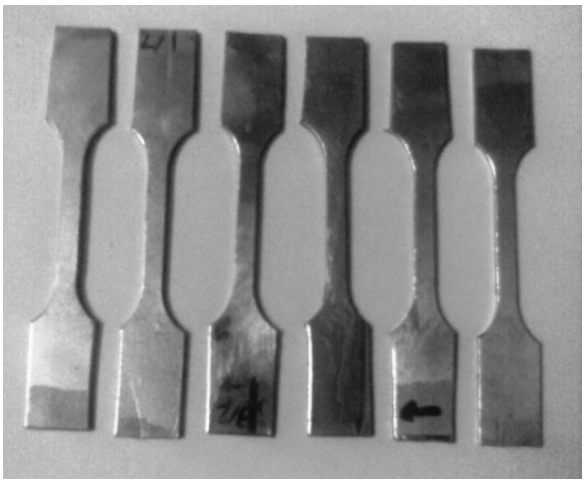

Figure 1. Standard specimens for uni-axial test

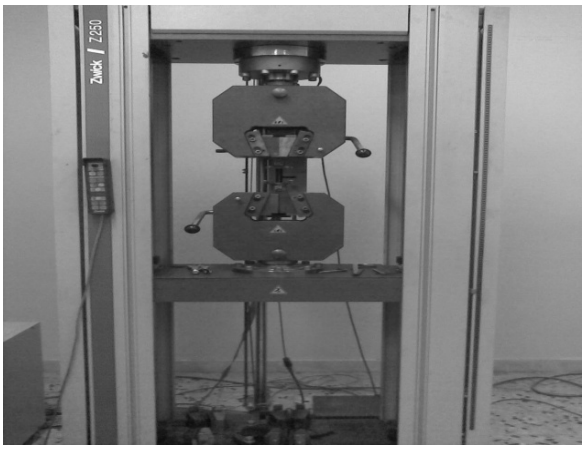

Figure 2. Zwick Universal Machine

In the bending test a V shape die with the bending angle of 100 degrees is used, as illustratde in Figure 3. The among of the springback for every specimen with two layers of Al and one layer of glass composite are determined three times and the average values are calculated.

4- Results and Discussions

In order to investigate the effect of the springback of multi-layers, the bending test is performed for the specimen with different thicknesses. As it may be seen from Figure 4, by increasing the thickness the amount of springback decreases which is because of

Figure 3. The die for bending test

development of plastic zone in the bending area.

5- Conclusions

In the current study, the V bending process of Fiber Metal Laminate Composite was investigated to optimize some process parameters by the Taguchi method. The effect of some parameters such as die radius, punch speed and the pressure applied on the specimen on the springback was studied. It is found

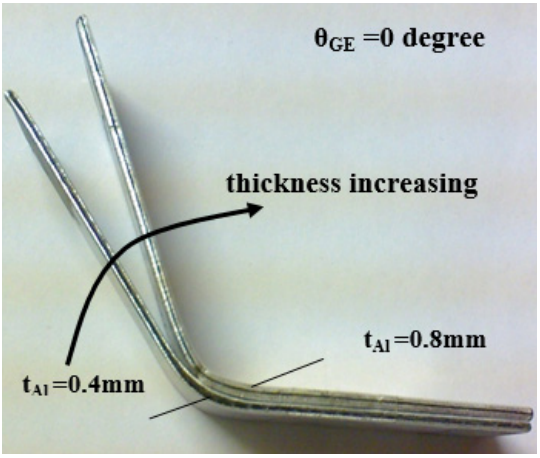

Figure 4. The effect of thickness on multilayer AL-Fiber Composite

that the influence of die radius was more important than other parameters in V bending forming and could have more effect on the springback. Moreover, when the punch radius decreases and the applied pressure increases, the springback decreases that is because of developing of more plastic deformation in bent area. On the other hand, increasing the punch speed could cause more springback. The effect of fiber angles and thickness of outer layer of Fiber Metal Laminate Composite was examined. To study this matter, six different groups with various fiber angles in the form of 2/1 and angles of 0, 45 and 90 and thicknesses of 0.8 and 0.4 mm were made and formed. The results demonstrated that the composite layers with the angle of 90 had less strength compared to other angles and therefore had less springback. Moreover, with increasing thickness of outer layer, the springback decreases significantly that could be attributed to developing of plastic zone in that area. The results showed that in different parameters of die, punch and material, the die radius and thickness of outer layer of Fiber Metal Laminate Composite had more influence on reducing the springback. The forming process was modeled by finite element software and the obtained results showed good agreement with the experimental data.

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