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ORIGINAL ARTICLE

Laser bending of tailor machined blanks: Effect of start point of scan path and irradiation direction relation to step of the blank

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Abstract Laser bending is a process of gradually adding plastic strain to a metal component to generate desired shape. In this paper, laser bending of tailor machined blanks has been investigated experimentally. For this purpose, effects of start point of scan path and also irradiation direction relation to step (position of variance in sheet thickness) of the tailor machined blank on the obtained bending angles are investigated. The results show that irradiation path from rim of thick section to rim of thin section of the tailor machined blank leads to more bending angles in comparison with irradiation path from thin section to thick section of tailor machined blank. Also, it is concluded from results that when the step of tailor machined blank is positioned in the opposite direction to the laser beam, more bending angles are obtained in the laser formed tailor machined blank in comparison with positioning of step of tailor machined blank toward the laser beam. The results indicate that the bending angle of tailor machined blank is increased with increasing the laser output power and decreasing the laser scanning speed.

1. Introduction

Laser bending is a flexible forming process that needs no hard tooling or external forces. It is used in some industrial applications such as shipbuilding, automobile, microelectronics and aerospace. In laser bending, a sheet is irradiated with a defocused laser beam. Thereby inducing rapid localized heating followed by cooling as the laser beam moves on to an adjacent area. In the heating stage, if the thermal strains in the irradiated zone exceed the elastic limit, then these strains are converted into plastic compressive strains. In the cooling stage, the sheet will undergo shrinkage and therefore a complex shape of the work-piece can be formed. For the first time in 1986, Namba [1] used laser beam as a tool for sheet metal forming. After Namba, many researchers have done a lot of works in the laser bending of sheet metals. In 1993, Geiger

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and Vollertsen [2] identified three key mechanisms called temperature gradient mechanism (TGM), buckling mechanism (BM) and upsetting mechanism (UM) to explain the thermo-mechanical behavior in laser bending based on geometrical and laser beam parameters. Also, in 2003, Steen [3] reported that for TGM to occur Fourier number i.e. kd/s^2v, (where k, d, s and v are the thermal diffusivity of material, beam diameter, sheet thickness and scan speed respectively) should be much lesser than unity whereas for BM and UM to occur it is the opposite. In 2001, Li and Yao [4] proposed a new scanning scheme with starting point from the middle of the workpiece and then they produced a convex shape plate. In 2006, Shen et al. [5] in a numerical work used two simultaneous laser beams along two parallel lines. They concluded that if the distance between two laser beams is not too large then plastic deformation generated in this state is larger than that generated by single sequential scans along the same lines. In 2006 and 2007, Shen et al. [6,7] investigated the effects of time intervals and overlapping on bending angles in laser bending using two simultaneous laser beams numerically. It is reported by some authors that geometric effects, especially due to thickness, play an important role in the laser forming. In 2005, Cheng et al. [8] proposed an analytical model to predict bending variation due to change of plate size (width and length). In all of the above references, a plate with uniform thickness was considered and studies cannot be applied to varying thickness plate. In recent years, a few researches have been done on the laser forming of varying thickness plates. In 2006, Cheng et al. [9] in a study using experimental, numerical and analytical methods investigated the effects of bending mechanism and process parameters on the deformation characteristics in the laser forming of varying thickness plates. They found a transition of the laser forming mechanism along the scanning path when the thickness varies. In their work, the effect of scanning speed, laser beam diameter and multiple scanning on the bending angle was investigated. Also, it was shown that proposed analytical model in their work can predict the bending angle and angle variations for laser forming of varying thickness plates. Also in 2006, Cheng et al. [10] using a strain-based strategy investigated the laser forming process for thin plates which varying thickness. Their proposed strategy was utilized in determining the scanning paths and the proper heating conditions. They showed that in the laser forming of varying thickness plates, both the in-plane and bending strains are needed to be accounted for in process design. Tailor-made blanks are sheet metal assemblies with different thicknesses and/or materials and/or surface coatings. These blanks can be made by welding or bonding or machining processes. A monolithic sheet can be machined to make the required thickness variations. The tailor made blanks that have been made by machining process are referred as tailor machined blanks. With tailor machined blanks, distribution of material within the structural parts used in the aircraft and automotive industries has been improved and therefore more cost effective, fuel effective and lighter vehicles can be made. Both laser bending and tailor machined blanks have been introduced recently and the aim of present work is studying the laser bending of tailor machined blank.

In a tailor machined blank, presence of two different thicknesses in one single assembly causes different forming behaviors such as different bending angles and curvatures in various sections of the blank. Due to thickness variations in tailor machined blanks, laser bending of these blanks is more difficult than laser bending of monolithic plates. However, bending angles in tailor machined blanks can be contrasted to the bending angle for constant thickness (monolithic) plates.

In this paper, laser bending of tailor machined blanks has been investigated experimentally. For this purpose, effects of start point of scan path and also irradiation direction relation to step (position of variance in sheet thickness) of the tailor machined blank on the obtained bending angles are investigated.

2. Experimental work

The dimensions of the tailor machined blank used in this paper and its irradiating path are shown in Fig. 1. The samples were made from mild steel with 200 mm (length) × 200 mm (width) × 4 mm (thickness). To prepare a tailor machined blank, firstly 1 mm of both sides of initial sheet were machined and a sheet with thickness of 2 mm was obtained. Then, half part of plate was machined to 1 mm by milling process. Milling process will produce residual stresses in the tailor machined blanks and therefore the specimens should be stress relieved. For this purpose, stress relieving heat treatment was performed and according to Ref. [11] the blanks were put in a furnace at a temperature of 500 °C for about one hour. After removing from the furnace, the specimens were air cooled in still air. Laser bending experiments were carried out with a continuous AMADA CO_2 laser with the maximum power of 2000 W. In the experiments, laser output power, laser scanning speed and laser beam diameter are adjusted as 1000 W, 30 mm/s and 6 mm, respectively. Also, laser focus location is adjusted at 4 mm above the surface of the sheet in thin section. However, in order to reduce the variation of laser beam diameter in thin and thick sections of the tailor machined blank, a lens with large focal length (190 mm) is used. During laser bending process, temperatures of various points are recorded with an infrared laser thermometer (Model: IRTEK IR190G). For this purpose, the infrared thermometer is placed at a distance of

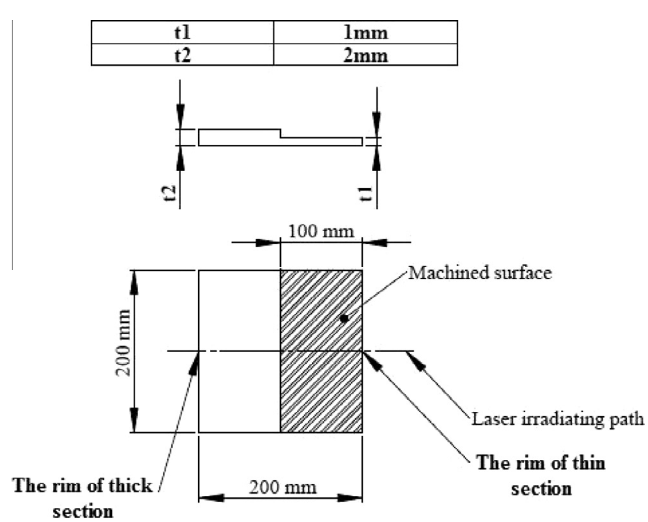

Figure 1 Dimensions of tailor machined blank and laser beam irradiating path.

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