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A REVIEW – PARAMATRIC STUDY OF STRAIGHT LINE LASER FORMING USING OPTICAL FIBER LASER

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ABSTRACT

In this paper literature has been studied in context to parametric study of Straight line laser forming. Laser Forming is a non-contact traditional process which uses laser beam as the forming tool. The capability of laser beam forming and bending demands more experimental studies to identify an optimized parameter setting and the likely parameters influencing the formed curvature. By Plasma arc cutting it is possible to cut is very easy. Optimization of the parameter will be carried out by full factorial method. We will use Stainless Steel 304 material which is more use in Food processing equipment, chemical containers and Heat exchangers. The parameters are the most important factors affecting the quality, productivity of the bend in Laser forming. Where the input parameters are Power, Feed rate, Thickness and Output parameters are bending angle. A plan of experiments based on Full Factorial techniques has been used to acquire the data.

Keyword: Laser Forming, SS 304, Full Factorial Method, ANOVA, ANSYS

1.INTRODUCTION

Laser forming is the process of shaping of metallic components, as a means of rapid prototyping and of adjusting and aligning. The process is similar to the well-established torch flame bending used on large sheet material in the ship building industry but a great deal more control of the final product can be achieved. There is no mechanical contact between tool and work material. These provide more advantage of process flexibility. The principle of the process is thermal deformation that occurs as the laser beam is guided across the sheet surface, where the path of the laser is dependent on the desired result.

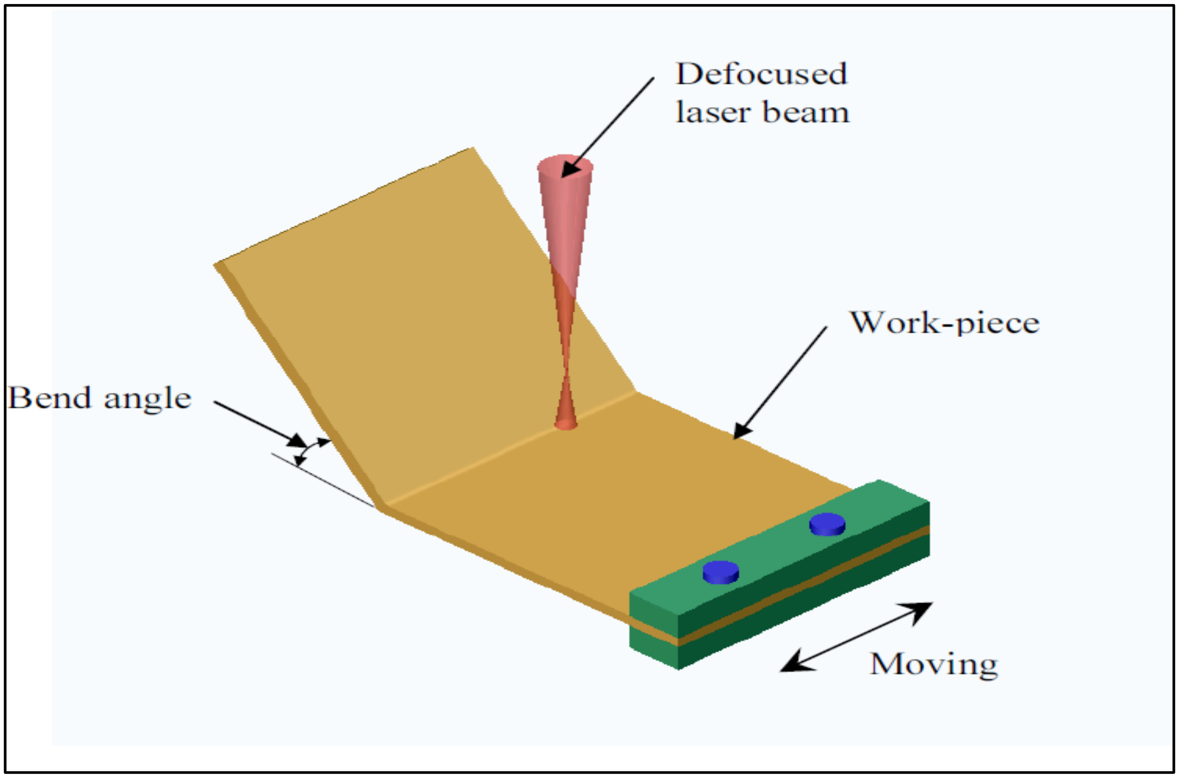


Figure 1.: Straight line Laser Forming [7]

This process involves scanning a focused or partially defocused laser beam over the surface of a work piece to cause localized heating along the bend line. The sharp thermal gradients in the material cause the sheet to bend either toward or away from the laser source. The resulting deformation of the material, which is, bending toward the laser beam, is permanent. By repeating the laser forming process, either with overlapping or parallel scans, bend of desired angle and radius can be obtained. The bending angle is in the range of 0.5-1.5 degree in one pass. This is the increment of the process. Therefore, there is a better control on bending angle without any spring back effect. Eliminating the spring back in this process is a major advantage over mechanical bending.[6]

During the laser forming process the sheet metal surface is irradiated by laser beam that leads to a thermal gradient between the upper and lower surface with the thermal expansion that causes a small counter-bending away from the laser source. The heated zone of the underneath surface which is not directly in contact with the laser beam is under compressive stress and plastic strain being caused due to restriction on the elastic part. Once the laser irradiation moves away, the heated zone exposes both to cooling and shrinkage, which induces a bending angle in the direction of the laser beam. In the laser forming process, materials with good deformation at ambient temperature like stainless steel, mild steel, light alloys of aluminum, magnesium, titanium etc., are used. As there is only localized heating involved below the melting temperature the bulk properties are not altered and good metallurgical properties are retained in the irradiated area. Because of the vast potential of this non-convectional manufacturing method, researches are made to in different industrial sectors, like aerospace, marine and automobile, where the implementation of laser bending can be replaced with some existing convectional forming processes is under investigation.

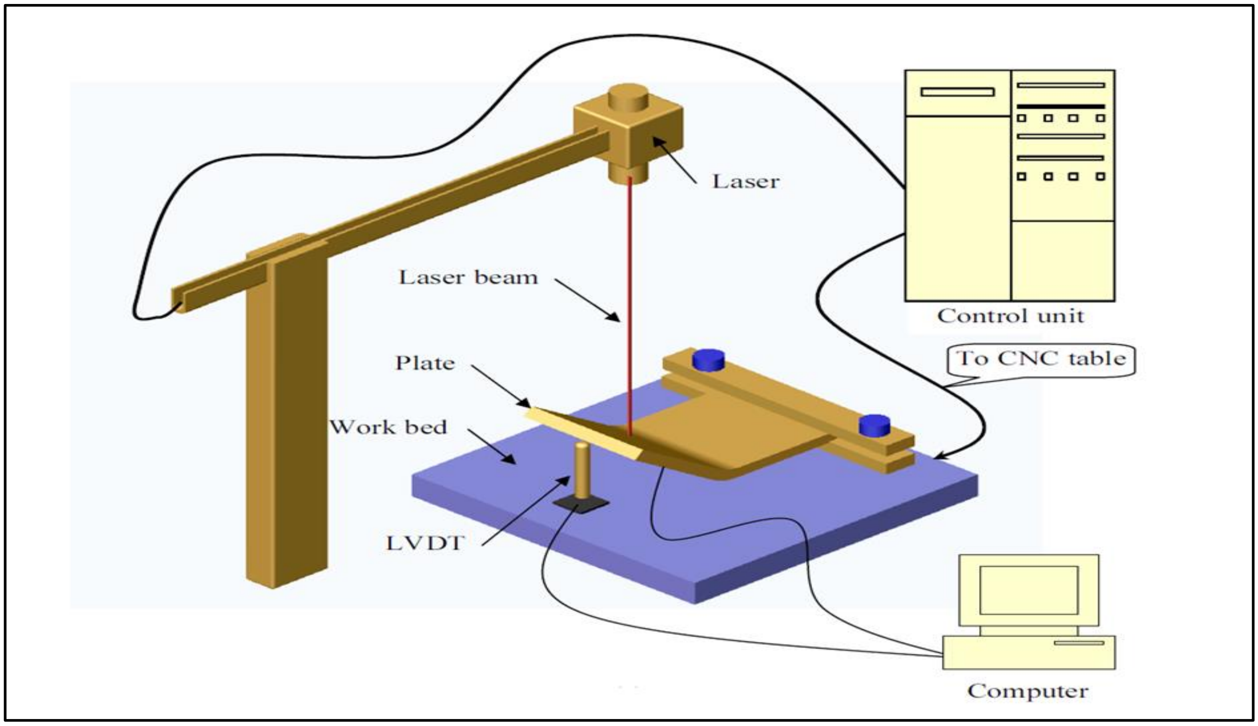


Figure 2: Schematic view of straight line laser forming[8]

2.LITERATURE REVIEW

NijeshSivankuttyet al[1] were investigates the effects of process parameters that affects the bending angel most for straight line laser forming using AISI 304 Stainless Steel. Three process parameters viz. laser power, feed rate and number of pass are considered and keeping all other parameter constant experiments are conducted. Process responses viz. bending angel is measured for every experimental runs. The aim of this study is to determine the parameters which affect the bending angel most. Analysis of variance (ANOVA) is performed to get the contribution of each process parameters on the performance characteristics and FE simulation is also performed with ANSYS 12 (Mechanical APDL) standard software package as an aid to improve the knowledge in this process. Nd: YAG pulsed laser machine having maximum mean laser power of 400 W is used for the experiment. Twenty seven Rectangular sheet metal of AISI 304 Stainless steel of 80 mm × 15 mm is selected as work piece.

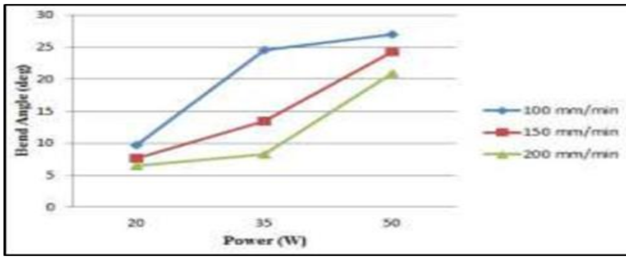


Fig. 3.1: Variation of bend angel vs power[1]

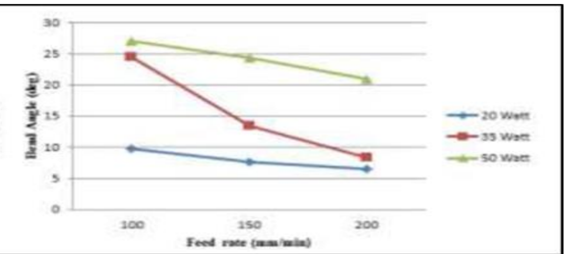


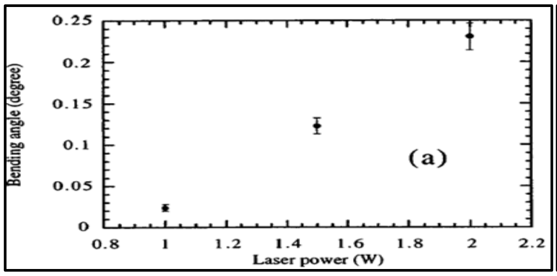
Fig. 3.2 Variation of bending angel vs feed [1]

From the figure it can be seen that at higher feed rates, there is increase in the bend angle as power increased. At higher and lower powers, the bend angle variation is almost linear embossing the fact that the thermal gradient formed at this feed rates cause uniform heating to occur throughout the metal. At moderate power, the heating of metal is not uniform which shows the exponential decrease in the bending angle.

The comparison of results shows a difference in the bend angle values i.e., the analysis values are lower than the experimental value.

Guofei Chen and Xianfan Xu[2]have investigated deformation of stainless steel sheet in laser bending process under temperature gradient mechanism. FEA was carried out to determine the temperature field and deformation of the sheet metal for different laser powers. Laser bending process was also investigated beyond the surface melting temperature. Temperature fields of the laser bend samples in different zones were investigated through numerical simulations. Metallurgical changes of the samples for different processing region were also studied using the scanning electro microscopy and Vickers micro hardness tester. experimentally in the present paper for precision, micro scale bending of small and thin sheets. In this work, a 4W continuous wave argon ion laser is used as the energy source and the laser beam is focused to a beam diameter of tens of micron to induced bending of thin stainless steel sheets. The bending angle is measured at different processing condition. A fully 3D finite element analysis is performed to stimulate thermo-elasto-plastic deformation process during laser forming. The specimen used is full hard 301stainless steel having size of 10 x 1 x 0.1 mm. The process parameters under study are laser power, feed rate and laser beam diameter keeping other parameters constant. Process response i.e., bending angle is measured for each experimental run. In this work 3D finite element analysis is applied to simulate the CW laser bending process induced by the temperature gradient mechanism. The nonlinear finite element solver, ABAQUS is employed to investigate both the thermal and mechanical parts of the process. Comparison between experimental and numerical results shows that bending angle increases linearly with increase in laser power because of the increase in temperature. The bending angle decreases with increase in beam diameter because of the decrease of the leaser flux which leads to lower temperature. Similarly increase in scan velocity decrease the bending angle because of the decrease of the energy input.

Continuous wave laser forming of thin stainless steel sheet was studied. When surface of the work piece was kept below the melting point, the repeatability of the obtained bending angel was better than 0.01 deg. The laser forming process was simulated using a fully 3D finite element model to illustrate the transient temperature, stress, strain and displacement development.



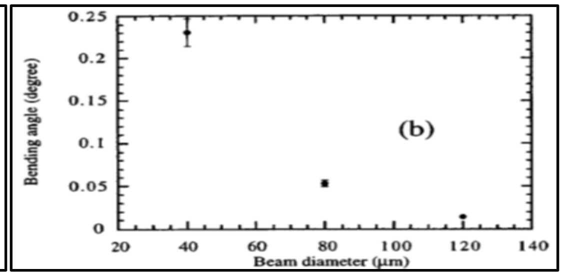


Fig. 4.1: Bending Angle vs Laser Power[2] **Fig. 4.2: Bending Angle vs Beam diameter[2]**

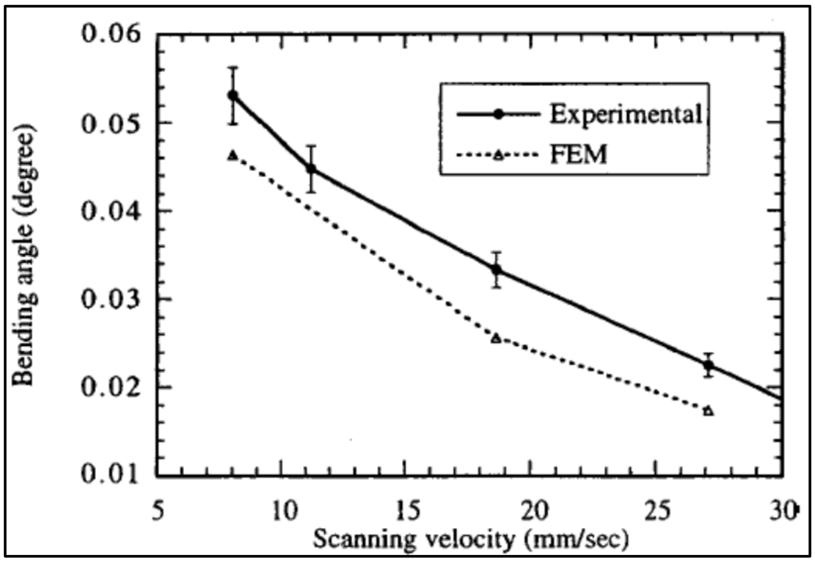


Figure 4.3: Bending angle Comparison between experimental result and FEM[2]

The calculated result agreed with the trend of experimental data. When the laser scanning velocity was high, bending was due to temperature gradient mechanism, while decreasing the scanning velocity led to bending by the buckling mechanism.

D.P.Shidid et al [3]were worked on bending titanium component using laser. In titanium laser bending process serious issue such as oxide film formation and subsequent deleterious changes in material properties are encountered. They investigate method to minimize oxidation with minimal change in bending result for Grade-2 titanium. Inert gas shielding is used as a means of reducing oxidation. A 550 W multimode Nd:YAG laser system was used for experiments. The wavelength of laser is 1064 nm. Material used for this research is commercially pure grade 2 titanium sheet. Bending angle was measured with help of a laser displacement measuring machine. Rockwell B scale was used to measure surface hardness of sheets. Samples were coated with graphite and thermal paint to improve absorption of laser beam. Effect of inert gas shielding on laser bending of titanium sheet were studied. Coating has significant effect on bending angel therefore use of graphite coatings is recommended for improved absorption of the laser beam. Argon and helium gas shielding for top and bottom surface respectively has significant effect on bending angle as temperature gradient increases. Rapid heating due to concentrated laser irradiation and cooling due to inert gas shielding increases the hardness of the titanium plate. This hardening coupled with excessive oxidation makes the plate more brittle by reducing the ductility and this contributes to reduction in final bending angle. However, this effect is over shadowed by reduction in oxidation , HAZ, width, section thickness and over all better quality of bend.

Bliedtner J. et al [4]were used modified high power laser system with an output power of 2.0 kW and an effective focus diameter of 1 mm allows a flexible forming of flat glass products. Due to the high absorption of most glasses in the mid infrared wave length range the CO2 laser can be used very efficiently. Beam power of up to a maximum of 2000W could be used in the experiments. Flat glasses which are preferably used in the display technology were treated in the examination. During treatment it is intended to heat the area to be formed homogeneously. A respective temperature distribution can be detected by means of a pyrometer or IR-thermography camera. Laser beam forming is advantageous for thin flat glasses as they are used e.g. for displays. Very fast forming processes can be repeatedly realized with scanner-based laser applications. The fast heating and cooling processes of the laser treatment require a subsequent cooling of the processed components.

Kuntalmajiet al [5] was investigating the deformation of stainless steel sheet in laser bending process under temperature gradient mechanism. FEA was carried out to determine the temperature field and deformation of the sheet metal for different laser powers. Laser bending process was also investigated beyond the surface melting temperature. Temperature fields of the laser bend samples in different zones were investigated through numerical simulations. Metallurgical changes of the samples for different processing regions were also studied using the scanning electron microscopy and Vickers' micro hardness tester. Numerical simulation was first carried out by Vollertsen and Geiger to obtain temperature and bending angle distributions in laser forming process using the FDM and FEM. A nonlinear transient indirect coupled field analysis was performed using the ANSYS APDL. Laser bending experiments were conducted on an Yb fiber laser integrated with a 5-axes CNC machine and having a maximum laser power of 2.0kW. AISI 304 stainless steel were used as a work piece material. Rectangular samples of size, 100x30x1 mm3 were used for the experiment. Modeling of laser bending process using the finite element method was implemented successfully for determining the temperature distributions and bending angle. The bending angle calculated from FE simulations was validated through experiments and analytical results. Bending angel was found to increase with laser power non linearly.

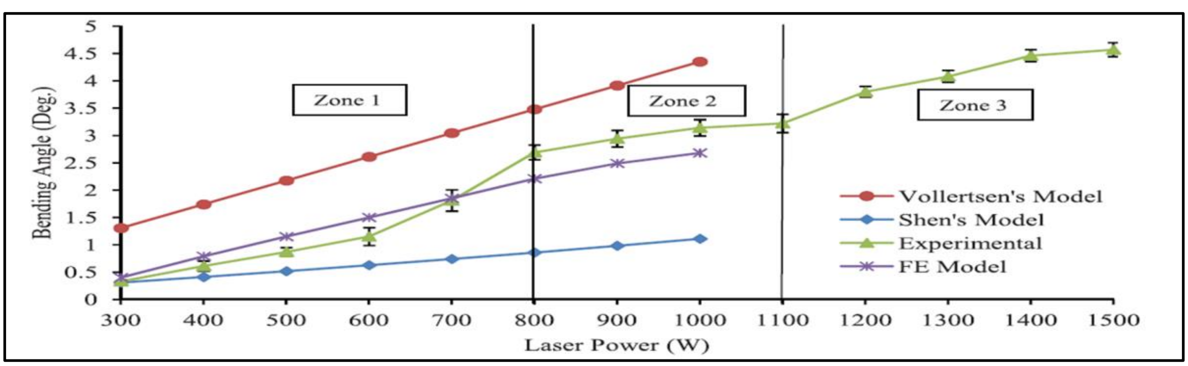


Fig.5 Variation of bending angle with laser power for AISI 304 Stainless steel sheet[5]

In the entire processing zone of laser bending three different regions were identified. In zone 1, the bending angle increased with laser power up to saturation laser power. In saturation zone increase in bending angle with laser power was very less. After saturation zone bending angle again increased with laser power due to surface melting and solidification. There was no change of microstructure of the laser bend samples up to saturation laser power. After the saturation zone the surface melting occurred and microstructures got refined. Micro hardness of laser formed samples with and without partial surface melting was improved in comparison with the base metal due to fine structure of re solidified region and deformation due to thermal stress.

3. CONCLUSION

Following Conclusion is Derived From Above Literature Survey

- In laser forming process laser power, scan speed and material thickness has considerable effect on bending angle while laser beam diameter has less effect on bending angle.
- When the laser scanning velocity was high, bending was due to the temperature gradient mechanism, while decreasing the scanning velocity led to bending by the buckling mechanism.
- Coating has significant effect on bending angle for first pass which is important in multi-scan system as bending angle per pass degrades as number of passes is increased.
- Micro hardness of the laser formed samples with and without partial surface melting was improved in comparison with the base metal due to fine structure of solidified region and deformation due to thermal stress.

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