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## Experimental Investigation of Bowl Shaped Component Using Different Scanning Pattern in Laser Forming

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**ABSTRACT:** Laser forming process is a non contact forming process does not require external force and complex forming tools. It can be used for complex components. In 3D laser forming process determining an appropriate scanning pattern to get desired shape is the most important factor. In this study the attempts are made to suggest the optimum scanning pattern from cross spider, circular and five rotated hexagonal sequence for producing a bowl shaped component from circular sheet of SS 304. Experimental investigation of bowl height has been carried out on process parameter such as laser power, scanning velocity and work piece thickness in laser forming. Numbers of experimental runs has been decided using Taguchi method. ANOVA has been performed on MINITAB. Regression equation for bowl height has been generated for SS 304 stainless steel.

**KEYWORDS:** Laser forming, scanning pattern, design of experiment, ANOVA, bowl shape

### I. INTRODUCTION

Laser forming is non convectional process used for shaping and bending of metallic components by using laser beam of high power density. In this process, there is no mechanical contact between the tool and work piece which provide more flexibility to the process. The working principle of laser forming process is "By using high power density laser beam, thermal stresses are generated in the work material and this causes the plastic strain that bends the work piece".<sup>[1]</sup> When a high power laser beam is strike on the metal sheet, the sheet will absorbs some part of energy and this energy is conducted into the sheet material at lower rate than the absorption rate, resulting in steep temperature gradient along the thickness direction due to this the thermal expansion is taken place along the thickness direction. Firstly, the sheet expand in heated zone and sheet is bend away from the laser beam by surrounding material the free expansion of the heated sheet restricted so that the thermal expansion is turn into elastic tensile strain and compressive stress. After that when cooling process is occurred due to heat conduction in material, in the upper layer of the material contracts and in this region the higher tensile stress is occurs. Due to this the sheet is plastically bent towards the cooling laser path.<sup>[2]</sup>

**A.Tavakoli et al.**<sup>[5]</sup>, studied on principle for developing scanning strategies. They considered seven scan path parameters and performing numerical simulation to optimized the laser scan path. An optimized hexagonal path was compared with circular scan path. The experiments were performed on CO<sub>2</sub> laser machine of 3 kW with circular sheet of AISI 304 stainless steel of diameter 50 mm and 150 mm and thickness of 3 mm with laser power of 600 W scanning velocity 10 mm/s and beam diameter of 3 mm. An experimental results show that average height of bowl shape from linear hexagonal pattern is nearly two times higher comparing to circular path. As a results for producing a bowl shape the four-sequence hexagonal scan pattern is reveled as the optimized scan pattern.

**L.J. Yang et al.**<sup>[6]</sup>, investigated the relation between the process parameters and final shape obtained for 3D laser forming of sheet metals. The experiments were performed on stainless 1Cr18Ni9Ti sheet and laser source of Nd: YAG laser of 350 W. The process parameters used for the experiments were laser power, scanning velocity and scanning

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number. The work piece used for experiments were square sheet of 60\*60\*0.8mm, circle of Ø50\*0.8 mm and rectangle sheet of 100\*50\*0.8mm. the scanning strategies used to form dome shape were cross spider and radial line strategies. The results show that the dome height increase with increase laser power and scanning numbers. With increase in laser scanning velocity the height of the dome shape was decreased.

**A.Tavakoli et al.** [10], has performed FEA on five different scan path, three continuous circular paths and two discontinuous circular paths. The comparison of these paths is based on the average height of perimeter points, standard deviation and edge distortion of the final product. The experiments are carried out on CO<sub>2</sub> laser machine of maximum power 3000 W. The material selected for experiment was stainless steel AISI 304 circular blanks with diameter of 50 mm and 150 mm with thickness of 3 mm. The laser power was kept 600 W, scan velocity 10 mm/s and beam diameter of 3 mm.

## II. MATERIAL AND PARAMETER SELECTION

Present research work has been done by using material SS304. Main iron constituents in SS304 are chromium and nickel. For analyze laser forming process circular sheet of 50mm diameter has been taken and the process parameter and their levels selected for the experiments as given in table 1.

### 2.1 Input Process Parameters

The input process parameter selected for this research work were scanning pattern, laser power, scanning velocity and work piece thickness.

#### 2.1.1 Scanning Pattern

Different scanning patterns were used in this research work such as cross spider, hexagonal scanning pattern and circular scanning pattern. Different scanning pattern gives different heat region during scanning so it important to study deformation of sheet using scanning pattern and for that scanning pattern is selected as an input parameter.

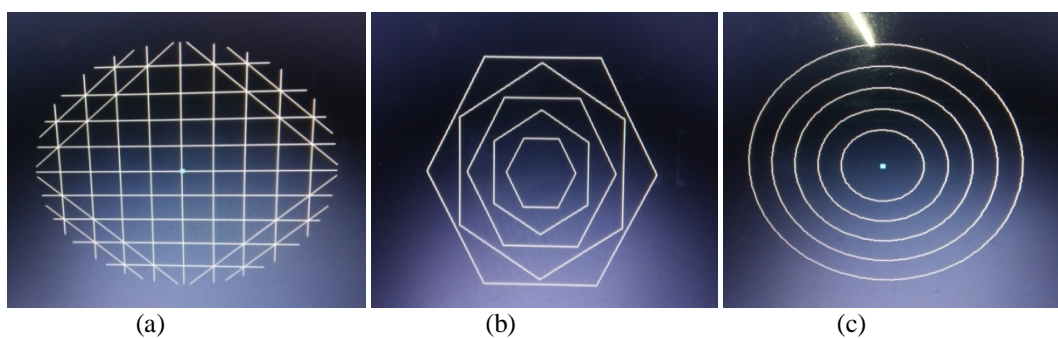


Fig: 1- Scanning pattern

Process parameter	Level
Scanning pattern	S,C,H
Power(W)	600,700,800
Scanning velocity (mm/sec)	20,25,30
Thickness of work piece(mm)	0.5,1.2,1.6

Table 1- Process parameter and Level for Experiments

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## 2.2 Output Process Parameters

Bowl height is selected as a measuring parameter of this work.

### III. EXPERIMENTAL WORK

The experimental work has been carried out on fiber optic laser machine. The scanning pattern is drawn in the AUTOCAD. The specimen is held on the work table the laser beam is moved as per scanning pattern on the work piece and due to the stresses generated in material the deformation is occurred. Similarly for different combination of parameters the experiments were performed. The fig-2 shows the experimental set up.



Fig -2: Experimental set up

Following table shows the specification of the fiber laser machine used for the experimental purpose.

Laser type	Fiber
Nominal output power	1Kw
Laser cooling	Chiller system
Work table	1500 * 3000 mm
Polarization	Random
Lens	F-theta
Software	Most 2d
Emission wave length	1060-1080 $\mu\text{m}$
Fiber optic tube core diameter	800 $\mu\text{m}$

Table 2- Machine specification

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Following is the table of the measuring of response parameter for different combination of parameters.

Sr. no	Pattern	Power( W)	Speed (mm/sec)	Thick. (mm)	Bowl height (mm)
1	S	600	20	0.5	4.146
2	S	600	25	1.2	2.440
3	S	600	30	1.6	1.513
4	C	700	20	0.5	2.673
5	C	700	25	1.2	1.201
6	C	700	30	1.6	0.997
7	H	800	20	0.5	3.980
8	H	800	25	1.2	1.217
9	H	800	30	1.6	1.013
10	C	800	20	1.2	1.816
11	C	800	25	1.6	1.049
12	C	800	30	0.5	2.947
13	H	600	20	1.2	2.298
14	H	600	25	1.6	0.874
15	H	600	30	0.5	2.987
16	S	700	20	1.2	2.890
17	S	700	25	1.6	1.917
18	S	700	30	0.5	3.368
19	H	700	20	1.6	0.978
20	H	700	25	0.5	3.343
21	H	700	30	1.2	2.403
22	S	800	20	1.6	2.750
23	S	800	25	0.5	4.565
24	S	800	30	1.2	3.312
25	C	600	20	1.6	0.989
26	C	600	25	0.5	2.123
27	C	600	30	1.2	1.664

**Table 3-The experimental test results**

#### IV. MEASUREMENT OF RESPONSE PARAMETER

In laser forming process response is bowl height which is measured for each number of runs in experiment. The bowl height is measured on VMC using dial indicator. The work piece is held on a work table and the set the zero position in dial indicator as well in VMC machine monitor after that taken the dial indicator tip at the centre of the work piece where bowl height is to be measured.

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Fig -3: Measurement of bowl height

## V. RESULTS AND DISCUSSION

Using DOE the analysis of the process has been done. The analysis of variance is carried out to determine the effect of different parameters on the response parameter. As increasing laser power the bowl height is increases because as we increase laser power the temperature gradient is increase and also the line energy is increase which result in the increasing the bowl height. As an increases the thickness of work material the bowl height is decreases because increase in flexural modulus.

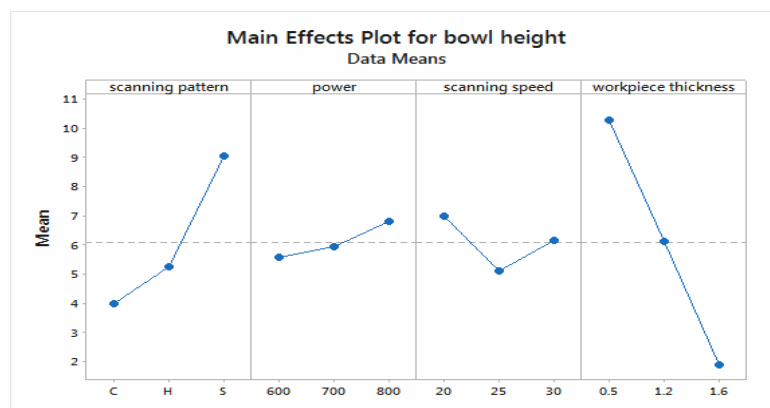


Fig -4: Main effect plot for Bowl height



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## 5.1 Regression Model

By comparing the p -value and F- value of regression model has been identified. Generally the p- value preferred is equal to 0.05 which makes strongly significant to the model.

Source	DOF	Sum of square	Mean of square	F- value	P- value
Pattern	2	124.894	62.447	20.29	0.000
Power	2	7.154	3.577	1.16	0.335
Speed	2	15.866	7.933	2.58	0.104
Thickness	2	316.370	158.185	51.39	0.000
Error	18	55.409	3.078		
Total	26	519.693			

Table 4- ANOVA table for model

Regression Equations:

For circular scanning pattern:

$$\text{Bowl height} = 9.94 + 0.00614 \times P - 0.0828 \times V - 7.433 \times t$$

For hexagonal scanning pattern:

$$\text{Bowl height} = 11.20 + 0.00614 \times P - 0.0828 \times V - 7.433 \times t$$

For cross spider scanning pattern:

$$\text{Bowl height} = 15 + 0.00614 \times P - 0.0828 \times V - 7.433 \times t$$

## VI. CONCLUSIONS

In present study the bowl shape product is made from circular sheet of SS304 by laser forming process using different scanning pattern and also the effect of parameters is studied and conclusion are as follows:

1. The bowl height has linear relationship with laser power.
2. Work piece thickness has a reverse effect on bowl height if we increases thickness bowl height is decreases.
3. The cross spider scanning pattern gives uniform bowl.

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