

# CRITICAL REVIEW AND TECHNOLOGY PROPOSAL FOR FUTURE ECONOMIC LASER LATHING

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**ABSTRACT:** Laser cutting is a thermal process in which a focused laser beam is used to melt material in a localized area. The effectiveness of this process depends on the thermal properties and at certain extent the optical properties rather than mechanical properties of the material. Besides that, laser cutting is one of the advanced manufacturing technology which are capable to machine various materials include metal and non-metal but it has a limitation to cut cylindrical components. Although it has been made possible by the introduction of new laser lathe technology, the cost is exceptionally expensive. The intention of this paper is, therefore, to figure out solutions to the problem of cutting cylindrical components using flat bed laser cutting and to review the laser lathe technology.

**KEYWORDS:** 3D laser, laser lathe, laser lathe technology, CO<sub>2</sub> laser cutting and laser turning.

## 1.0 INTRODUCTION

Laser cutting is a technology which is typically used for industrial manufacturing applications to cut materials. Due to the advantages of laser cutting, there are several types of industrial laser which is suited to the specific application for example, CO<sub>2</sub> laser are specific to cutting and marking both metals and nonmetals while Nd:YAG laser more to boring and trimming process. The advanced technology of laser cutting was achieved to the existence of five axis laser cutting machine but many companies and industries are still awaiting for 3D laser turning and milling machines. The five axis laser machines can easily create a 3D part but the companies demand for economically oriented cost, and effective. The available laser lathe is very limited and highly cost. Figure 1 shows the available laser lathe system. There are several advantages of laser

cutting over mechanical cutting, since the cut is performed by the laser beam, there is no physical contact with the material, therefore, contaminants cannot enter or embed into the material.

Laser cutting can produce high accuracy cuts, complex shapes, cut several parts simultaneously, produce clean cutting edges which require minimal finishing, as well as, low edge loads during cutting, which will reduce distortions.



**Figure 1:** Shows the existing laser lathe system.  
([www.resonetics.com/pages/LaserTechnology](http://www.resonetics.com/pages/LaserTechnology))

## **2.0 LITERATURE REVIEW**

### **2.1 Concept of Performing 3D Laser**

The important issue in three-dimensional laser shaping is improving the dimensional accuracy along the optical axis without decreasing the materials removing rate. The concept of performing three-dimensional laser shaping was explained by directly using machining laser as the photo source of the non-contacting measuring device (Liu, J.S., *et al.*1999). Figure 2 below shows the closed loop controlled laser shaping systems.

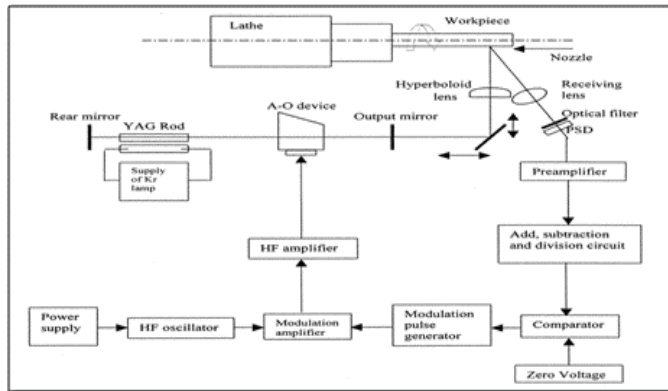


Figure 2: Shows the closed loop controlled laser shaping system (Lui, et al. 1999)

The main features and potential applications of a fully automated 3D laser micromachining based on the main concept of geometrical flexibility. It integrates two UV laser sources, excimer and diode pumped solid state laser (DPSS) in ns pulse regime, and an advanced positioning system (with six degrees of freedom) for complex parts machining (Molpeceres C., *et.al.*, 2007). A new 'machine tool' for advanced material processing, based on a concept of two converging laser beams was introduced. Laser lathe prototype and built optical system around a beam splitter that generates two beams from the same laser head was demonstrates (Chryssolouris, *et.al.* 1985). A concept of performing three-dimensional (3-D) laser machining using two laser beams and also the kinematic aspect was discussed.

The purpose is to improve the material removal rate and energy efficiency of laser machining (Chryssolouris, G., *et.al.* 1991). Laser machining on general 3D micro part was applied and the model is based on layer by layer concept. Three main parameters were set to optimize the process quality, which is power, repetition rate and the speed of laser process (Young, H.-T., *et.al.* 2008). A concept of performing three-dimensional laser machining on composite materials, using two intersecting laser beams to create grooves on a workpiece was present. The volume of material is removed when the two grooves converge (Chryssolouris, G., *et.al.* 1990). A concept of three-dimensional laser machining which allows implementation of turning, milling, and threading processes was study. Some issues relating to the material removal rate, surface quality, and process control for laser grooving was discussed (Chryssolouris, G., and Sheng, P. 1991a).

A three-dimensional laser machining concept and its implementation on a laser machine tool was present.

The concept is kinematically investigated regarding its application to gear making, threading, turning, and milling/die making (Chryssolouris, G., *et.al.* 1991b). A group of different three-dimensional laser processing concepts was described. The most important concepts are focused mainly in laser machining and laser welding processes by incorporating one or two laser beams simultaneously. A number of three-dimensional laser processing concepts was observed and developed in research or industrial level, along with their advantages, drawbacks and fields of application (Tsoukantas, G., *et.al.* 2002).

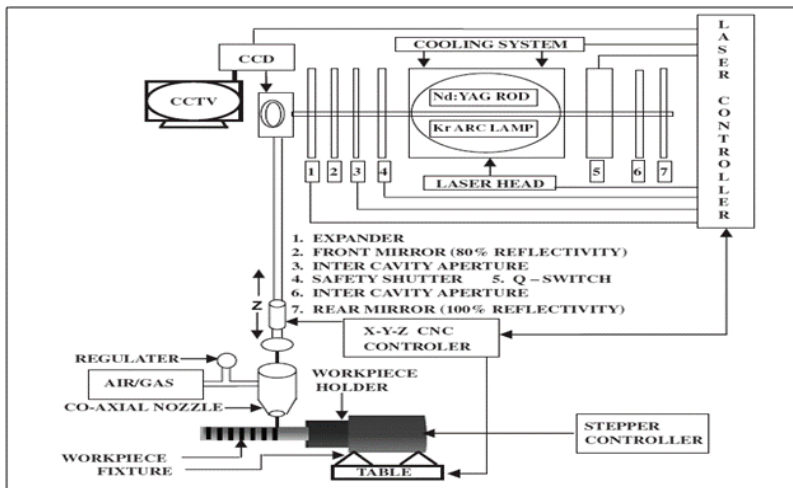


Figure 3: CNC pulse Nd:YAG laser turning system (Dhupal, D., *et.al.* 2009)

## 2.2 Process parameter of laser lathe

The relationship of processes parameters of pulsed Nd:YAG laser-turning operation for production of micro-groove on cylindrical workpiece was investigated. The parameters study such as air pressure, lamp current, pulse frequency, pulsed width and cutting speed are considered as laser machining parameter (Dhupa, I. D., *et.al.* 2008). Figure 3 above demonstrates the CNC pulse Nd:YAG laser turning system.

## 2.3 Model of laser lathe

The square micro-grooves on cylindrical surface experiment was presented and performed based on the statistical five level central composite design techniques. A feed-forward artificial neural net work

(ANN) technique was create for modeling laser turning process parameter (Dhupal, D., *et.al.* 2009). A first attempt to establish a theoretical model for laser 'blind' cutting was discussed. A new concept of laser machining using two intersecting beams is proposed and the optimization of this process requires an understanding of the phenomena involved in laser 'blind' cutting (Chryssolouris, G., *et.al.* 1988).

## 2.4 Method of Laser Lathe

A method of removing stock using two laser beams was discussed. First laser beam at a workpiece along a first axis to produced a first kerf and second laser beams direct at the workpiece along a second axis which intersect the first axis to produced second kerf (Chryssolouris, G.M., 2005). Figure 4 show the position of laser beams while cutting process.

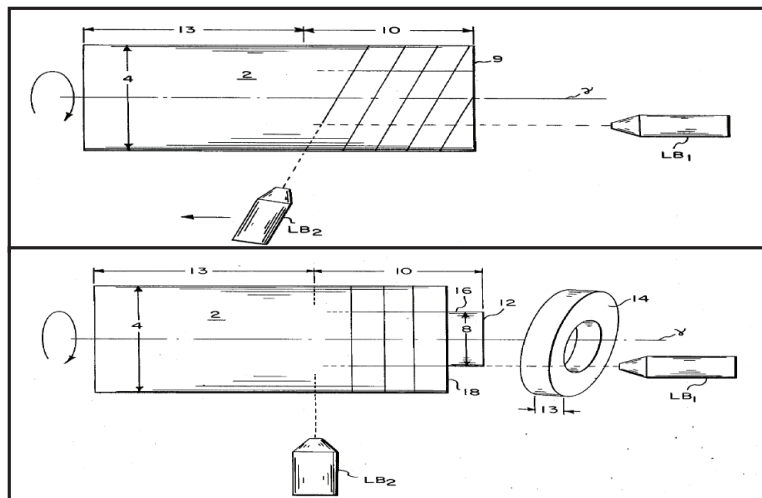


Figure 4: The position of laser beams during cutting process.  
(Chryssolouris, G.M., 2005)

## 2.5 3D Laser Machining

CO2 laser on five-axis linkage numerical control in cutting three-dimensional of auto-body panel was investigated. The cutting quality was evaluated with respect to kerf width, surface roughness, and the size of heat affected zone (HAZ) (Li-fang, M., *et.al.* 2009). A new approach to CO2 laser processing, and in particular to 3D laser cutting by mounted 2 kW laser directly to the arm of the robot was studied. This set-up enables customers to use a simple, off the shelf solution without complicated beam delivery systems for applications that require laser power levels of 2 kW

(Deile, J., *et.al.* 2006). The process features of three-dimensional laser machining was presented with industrial robots, specifying the principal reasons for using lasers and describing the systems components as well as examples from practical application (Lange, F.J., Ruhland, G., 1989);

## **2.6 Ultra-thin layer peeling**

The ablation using femtosecond needs more concentration for micromachining because the advantages of efficient ultra-thin layer peeling without undesirable thermal effects for both opaque and transparent materials. The femtosecond laser turning is suit for excellent surface finish techniques (Atsushi Yokotani, *et.al.* 2002).

## **2.7 Removal of a single layer**

An innovative technique of CO<sub>2</sub> laser machining in order to create 3D cavities to be used as moulds was discussed. The removal of a single layer is achieved using multiple overlapping straight grooves and the groove profile has been predicted by theoretical models (Romoli, L., *et.al.* 2007).

## **2.8 Generation of Circular Interference**

The integration of interference phenomenon into femtosecond laser micromachining was presented. In order to performed ablation using femtosecond laser pulse, the generation of circular interference pattern was demonstrated by overlapping infrared femtosecond laser pulses (Liang, W.L., *et.al.* 2003).

## **2.9 Effect of laser beam attitude**

The effect of laser beam attitude, including cutting obliquity and cutting direction, on 3D laser cutting quality was investigated. In this experiment, the range of 3D upward cutting is slightly wider than 2D, and the range of 3D downward cutting is sharply narrower than 2D cutting (Yong-Qiang, Z., *et.al.* 2006).

## **2.10 Ultra – short pulse laser lathe**

A novel ultra-short pulse laser lathe system for bulk micromachining of axisymmetric features with three-dimensional cylindrical geometry was

studied. One hundred twenty femtosecond pulses from an 800-nm Ti:sapphire laser were utilized to machine hexanitrostilbene (HNS) rods with diameters less than 200 micrometers and the result indicate that surface roughness is dependent upon rotation speed and feed rate (Jeremy, A.P., and Eric, J.W., 2007).

### 3.0 METHODOLOGY

There are three phases in this project development flow chart, which is shown in Figure 5. The first phase discusses about the development of spinning devices and the selection of material and the second phase explains the laser speed and motor speed. The final phase evaluates the experiment conducted which is to test the roundness and taper. The details of each step of the methodological flow is bulleted immediately after the flow chart.

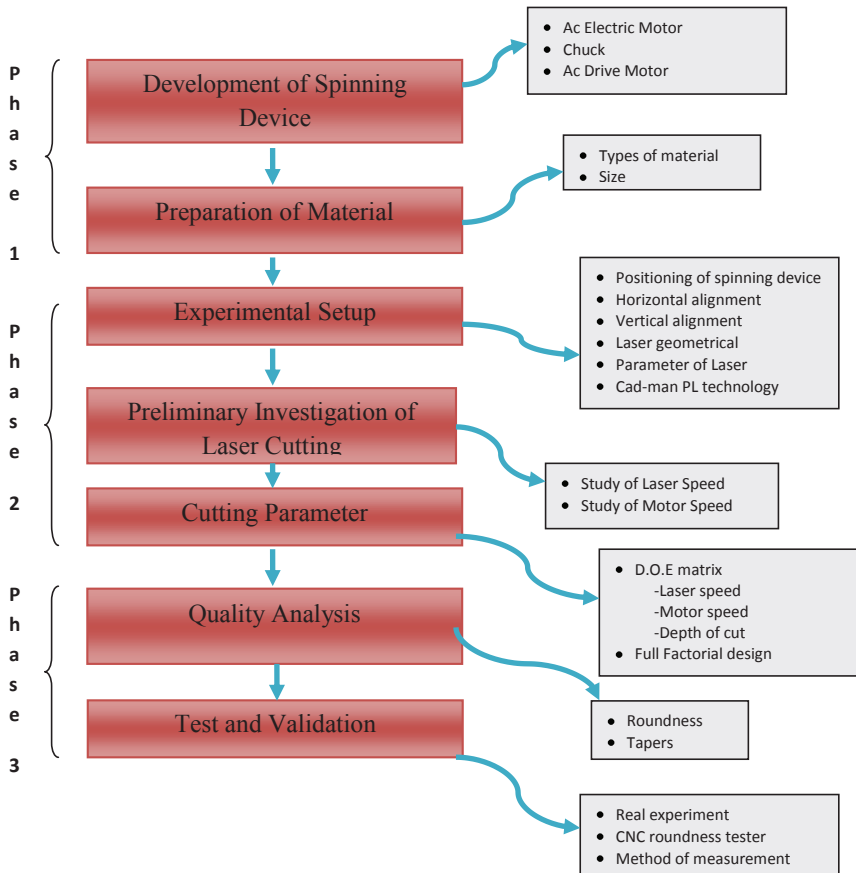


Figure 5: Project Flow Chart

### **3.1 Development of Spinning Device**

The development of spinning device is similar to mechanical lathe concepts which consists of a chuck, control system and electric motor. There are three main components in transforming a CO<sub>2</sub> flat bed laser cutting machine into a laser lathing.

### **3.2 Preparation of Material**

Mild steel was used in this experiment. Mild steel has less than 0.25% carbon and the term of 'mild steel' is also applied commercially to carbon steels not covered by standard specifications. Carbon content of this steel may vary from quite low levels. Generally, mild steel has reasonable cold bending properties.

### **3.3 Experimental Setup**

The experiment is separated into six sections. The first section is to position the spinning device on the laser table. The second and third section describes about the horizontal and vertical alignment of spinning device. In the fourth section, it focuses on laser geometrical. The laser geometrical involves the measurement of the work thickness, the stand of stand, and the depth of cut. The fifth section explains the parameter of laser while the last section discusses the cad-man PL technology.

### **3.4 Preliminary Investigation of Laser Cutting**

A preliminary investigation of the laser cutting focuses on two factors; namely the laser speed and motor speed. Based on the preliminary investigation, the value of controllable parameter can be determined.

### **3.5 Cutting Parameter**

In this experiment, there are three variable parameters which are the cutting speed, motor speed and depth of cut. The experiment is conducted using Design of Experiment (DOE).

### **3.6 Quality Analysis**

Every experiment has their own target and it must go through the quality analysis to ensure whether the target is achieved or not. In this experiment, there are two types of quality analysis which are roundness and taper.



### 3.7 Test and Validation

The final part of each experiment is to test and to validate. Each experiment can be categorized using a test to determine its success. There are 8 experiments that should be tested in a real experiment. To validate the test on the roundness and taper, the CNC roundness tester is used.

## 4.0 EXPERIMENTAL PROCEDURE

### 4.1 Transforming Flatbed Laser Cutting Into Laser Turning

The first stage idea was to apply the same conventional lathe machine conception onto existing 2D laser machine. Similar to the traditional lathe concept, it has a motor and chuck. The tail stock was design to support longer workpiece if they are required to be lathed in future. The function of the rail on the table is to create a path for the tailstock when dealing with a shorter workpiece. The rail and tailstock are not permanently fixed but can be utilized if necessary to help in better accuracy of laser processing. There are two rails on the right and left side to guide the movement of headstocks and tailstocks.

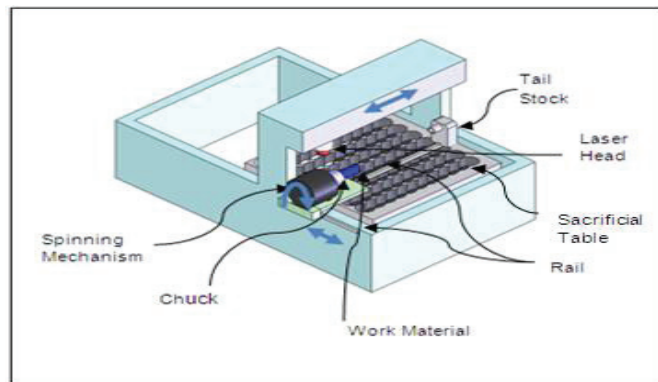


Figure 6: Y axis -Head Movement

The speed of a motor which has been mounted on a face plate is controlled by a specially designed motor speed controller from 0-1500 RPM. Laser head moves along the Y-axis for cutting process. Stand of distance (SOD) is the distance of laser nozzle to workpiece which plays an important role in laser processing. This laser machine has the laser head moving on Y axis and the table moves on X axis. Thus, to ensure which axis gives tighter

tolerance during machining, preliminary experiments were carried out by placing motor at two different axis positions of sacrificial laser table. Figure 6 shows Y-axis position of a spinning mechanism / motor. This orientation focuses on the quality evaluation by laser head movement. The second motor orientation was designed to move the table while the laser head is kept stationary. Figure 7 shows the said motor orientation.

This preliminary investigation is expected to result a significant difference in determining whether the head or table movement is more precise on 4' x 8' CO2 laser cutting machine to decide on how should the circular workpiece positioned during lathing process. Thus, the comparison of cut quality by considering kerf width as response can be easily investigated to decide on which orientation should the motor be mounted. Based on the preliminary investigation of X to Y axis cutting quality, kerf width in Y axis was found to be better than X axis. Figure 8 shows the results of preliminary investigations. The Y axis orientation was found to be providing tighter tolerance as compared to X axis. Thus, the motor is fixed on Y axis for the rest of lathing experimentation in completing the work. Both head stock and tailstock are designed to be user friendly enables easy installation and removal in case the machine is to be turned back into flat cutting of metal sheets.

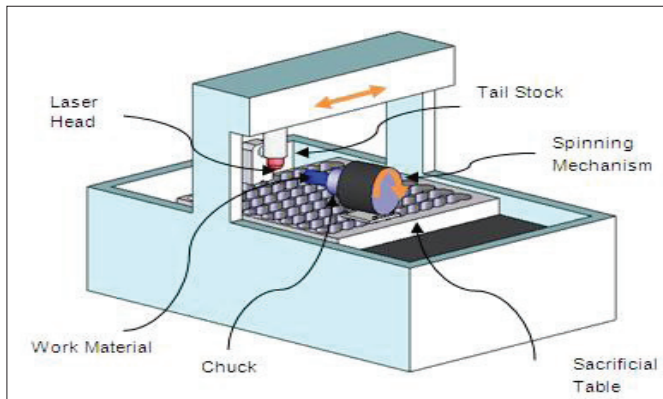


Figure 7: X axis – Table Movement

## 4.2 Specifications for Future Cost-effective Laser Lathe

In this experiment, a motor of 1.5 hp with the chuck of 30 mm diameter was used. A workpiece of 25 mm round bar as well as a hollow material can be used in this experiment. There will be six (6) parameter controlled in this experiment; namely, stand of distance (SOD), focal distance (FD), gas pressure (GP), frequency (Hz), duty cycle (DC), and cutting speed (CS). The responses are kerf width, surfaces finish and surface roughness. The range of speed motor controller is between 0 to 1500 rpm.

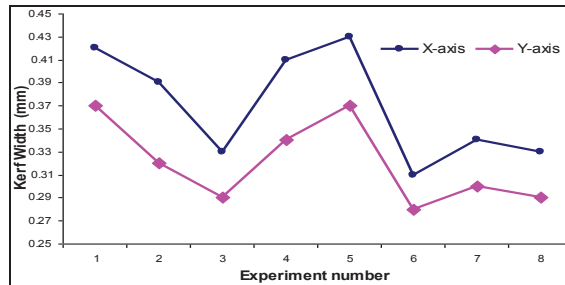


Figure 8. The kerf width analysis of X to Y axis cutting quality

## 5.0 CONCLUSION

Even though there are laser lathing machines available in the market, yet they pose very high technology with two intersecting beams which makes them very expensive to be utilized. Thus, the attempt of modifying laser cutting machine into laser turning is yet to be investigated extensively by researchers at any part of the world. Thus, the attempt to transform an existing 2D CO<sub>2</sub> laser cutting machine into laser lathing is seen to be very viable and highly potential to lathe super hard materials. Thus, the challenges pose by conventional machining in compensating machining time, expensive tool and precision could be overcome via this approach. The detailed experimentation and its significant effect of actual running condition(s) is to be attained by extensive experimental design.

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