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Establishing a Hybrid Laser Lathing Technology

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Abstract: Traditional contact lathing is greatly challenged by the rapidly being developed super hard engineering materials. Being the earliest machining process, lathing operation captures 60 % of the total machining processes in most metal cutting industries. This paper reviews the literature related to the available technological solutions for non-contact laser lathing process. It also aims to establish a novel methodology to propose a hybrid non-contact lathing operation using a flatbed CO_2 laser cutting machine.While exposing the various techniques of laser lathing, preliminary empirical work conducted shows a promising future of hybridizing CO_2 laser flat cutting into laser lathing process. The summary of this paper is expected to create a leap in laser machining process towards developing a hybrid laser processing of materials involving transformation of 2D flat cutting into 3D laser turning to cater the market of precision machining.

Key words: Laser lathing % Laser turning % Laser lathing % CO_2 laser lathing % Laser cutting

INTRODUCTION

Laser cutting machine is one of new types of advanced machine tool that has been developed to improve machining process of almost any work materials. The quality of the laser cut is of the utmost importance in laser processing because it leads to an elimination of post-machining operations. Laser technology for industrial manufacturing applications has multiple functions and advantages. For example, it is mainly used to cut, drill, slice and mark the materials besides being applied for welding, sensing and measuring purposes. Materials processing of laser do not produce highly accurate cuts and complex shapes, clean cutting edges with minimal finishing requirement only; it also exerts a low edge loads during cutting which tremendously help in the reduction of distortion. A high intensity laser beam can be directed onto a narrow region to instantly evaporate the material with a narrow heat affected zone. The ability to cut instantly with an extremely narrow laser beam distinguishes it fromother cutting methods. Due to its remarkable performance, laser cutting is used widelyin the industrial lasers. There are two main types of industrial lasers, namely Carbon Dioxide (CO_2) and Nd:YAG. Carbon Dioxide (CO_2) with high power ratings are preferred for cutting and marking of both heavy metals and non-metal stocks; while Nd:YAG lasers are used for lower end precision laser processing including boring and trimming [1]. The advancement in laser cutting technology has reached to the flexibility of five axis operation which makes manufacturability simple in few easy steps.

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The integration of computer numerical control and laser axis enhancement enables materials processing to be flexible in producing intricate profiled parts. As such, it requires expert personnel to operate the machine in gaining best output quality as the laser processing technology is costly.This is among one of the main reasonsas to why the small medium industries are reluctant to own and invest the latest known laser lathing technology. Although the five axis laser cutting technology is capable of producing 3D parts, the industries are demanding for more economical and costeffective solutions. Thus, the objective of this paper is to review the related literature related to the available technological solutions for non-contact laser lathing process. Besides, it also proposes an economical and practical laser lathe using 2D laser cutting machine.

Laser Lathing Technology: A typical laser lathing uses afew nozzles to create a 3D material removal processwhich comprises a chuck, tail stock, flexible laser nozzle and sliding bed for lead control as shown in Figure 1. The typical laser lathing is used not only for circular milling, but it is also capable to produce the ring shape parts from the sold circular stock. In other words, any externally profiled part with a hollow interior is able to be produced [1]. The only drawback is that the machine is too costly which only giant machining industries can afford.

The following review illustrates the research done based on three schematic themes: 3D Laser Lathing, Skimming Technique in Laser Lathing and Effect of Laser Beam and Pulse. These themes, even though it is not fully comprehensive,this paper proposes a novel methodology in a hybrid lather machine.

3D Laser Lathing: The important issue in 3D laser lathing is to improve the dimensional accuracy along the optical axis without decreasing the materials removing rate.Previous studies[2,17] presents findings in the related matter.The concept of performing 3D laser lathing is done by using direct machining lasers as the photo source of the non-contact machining technique [1]. The closed loop controlled laser lathing system is shown in Figure 2. It integrates two ultraviolet laser sources, an excimer and a Diode Pumped Solid State laser (DPSS) in a nano-second pulse regime, with six degree of freedom positioning to precisely machine complex parts [2]. A new 'non-contact machine tool' for advanced material processing with a concept of two converging laser beams is introduced. At the same time, anoptical system around a beam splitter that generates two beams from the same

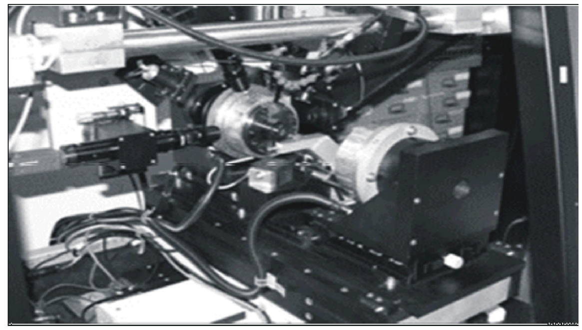

Fig. 1: The existing laser lathe system

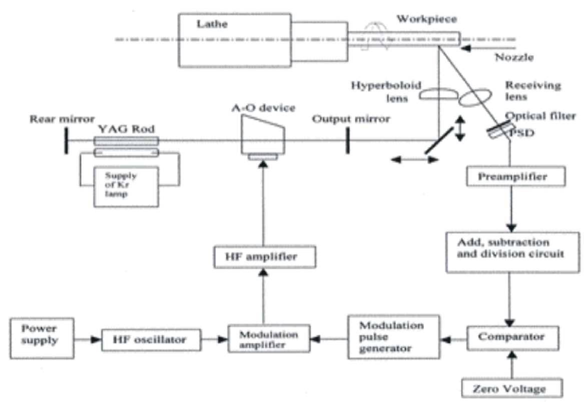

Fig. 2: The closed loop controlled laserlathing system [1]

laser head is demonstrated.Aconcept of performing three-dimensional laser machining using two laser beams and also the kinematic aspect of lathing technology is investigated [3].

Laser lathe machining ofa 3Dmicro part is performed and the model is based on layer by layer conceptto improve the material removal rate and energy efficiency of laser machining in lathing [4].Another laser lathing model is developed and investigated for lathing performance and quality investigation of end product. Three main parameters are set to optimize in this study, namely power, repetition rate and speed of laser process [5]. A concept of performing three-dimensional laser machining on composite materials using two intersecting laser beams to create grooves on a circular stock is presented. The amount of removed material removal volume is investigated at the micro and macro level in profiling the stock into shape when the two grooves converged [6]. In addition, a concept of three-dimensional laser machining which allows the implementation of turning, milling and threading principle is also investigated. Some issues relating to the material removal rate, surface quality and process control for laser grooving was established and discussed for the prototyping laser lathing technology [7].

The kinematics of established 3D laser concept is carried outfor the process of manufacturing metallic gears, threaded parts, lathing and milling. Its application is extended into the trial of making a complete die set for manufacturing environment [8]. A group of different three-dimensional laser processing concepts is described latter, where the prime concepts were focused mainly in the laser machining and laser welding processes by incorporating two or more laser beams simultaneously. A number of 3D laser processing concepts is observed and developed in a research at the industrial level to study the application drawbacks and advantages in real life applications [9].

The square micro-grooves on cylindrical surface experiment is presented and performed statistically based on five level central composite design techniques. A feed-forward artificial neural network (ANN) technique is employed to a model and establish laser lathing process input and response parameter [10]. Attempts to establish a theoretical model for laser 'blind' cutting is discussed with a new concept of laser machining using two proposed intersecting beams to optimize this process which requires an understanding of the phenomena involving laser 'blind' cutting [11]. The relationship of processes parameters for the pulsed Nd:YAG laser lathing operation for micro-grooving on cylindrical workpieceis also studied. The considered parameters were air pressure, lamp current, pulse frequency, pulsed width and cutting speed [12]. Figure 3 shows the schematic of CNC pulsed Nd:YAG laser lathing control system.

A method was carried out remove stock using two laser beams with first laser beam. It is focused along the workpieceaxis to produce first kerf while the second laser beam directedalong the second axis of workpiecewhich intersects the first axis to produced second kerf [13]. Figure 4 shows the position of those laser beams during the intersection to perform a3D laser machining process.In another study, a CO_2 laser of fivelinkage numerical control to perform three-dimensional cutting of auto-body panel was carried out. The cutting quality was evaluated with respect to kerf width, surface roughness and the distribution range of heat affected zone [14]. A new approach of CO_2 laser processing, particular for 3D laser cutting was performed by mounting a 2 kW laser directly to the arm of the robot was critically investigated. This set-up enables the customer to use simplebeam delivery systems for applications that require laser power levels of 2 kW [15]. The process features of three-dimensional laser machining with industrial robots, specifying the principal reasons for using lasers and describing the systems components as well as examples from real life practical application were also presented [16].

Skimming Technique in Laser Lathing: An innovative technique of CO_2 laser machining to create 3D cavities for mould production was investigated [16]. The removal of a single layer is achieved using multiple overlapping straight grooves and the groove profile is predicted using theoretical models [17]. The ablation using femtosecond needs more concentration for micromachining because the

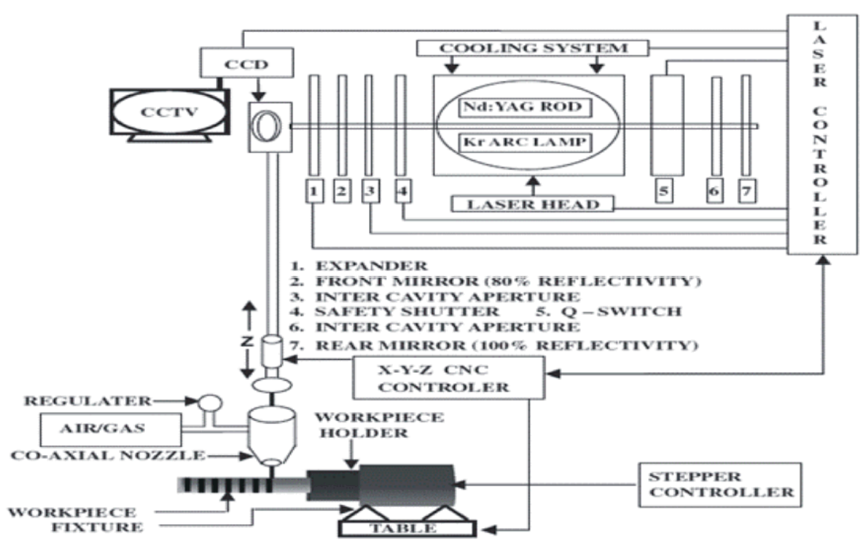

Fig. 3: Nd:YAG laser turning system [12]

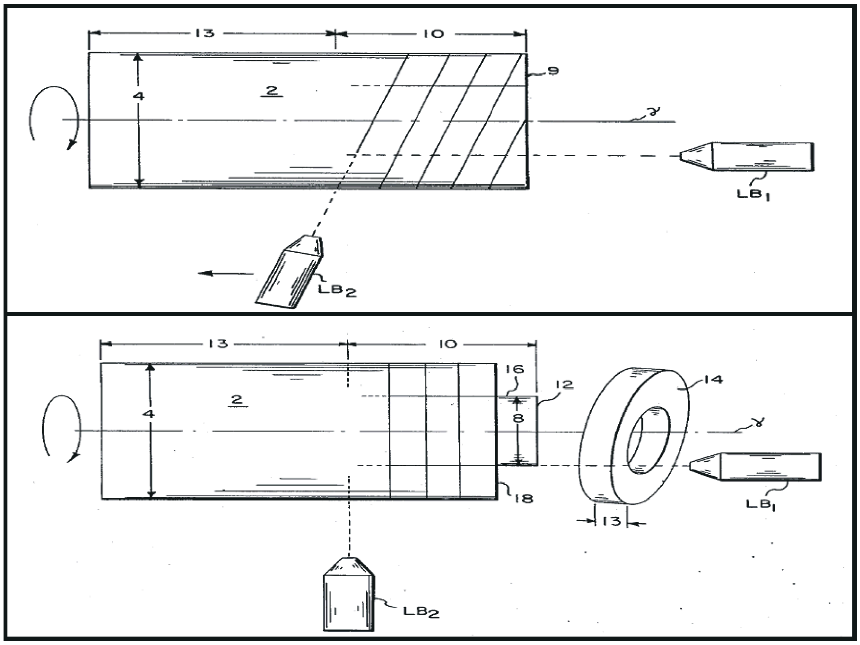

Fig. 4: The position of laser beams during cutting process [13]

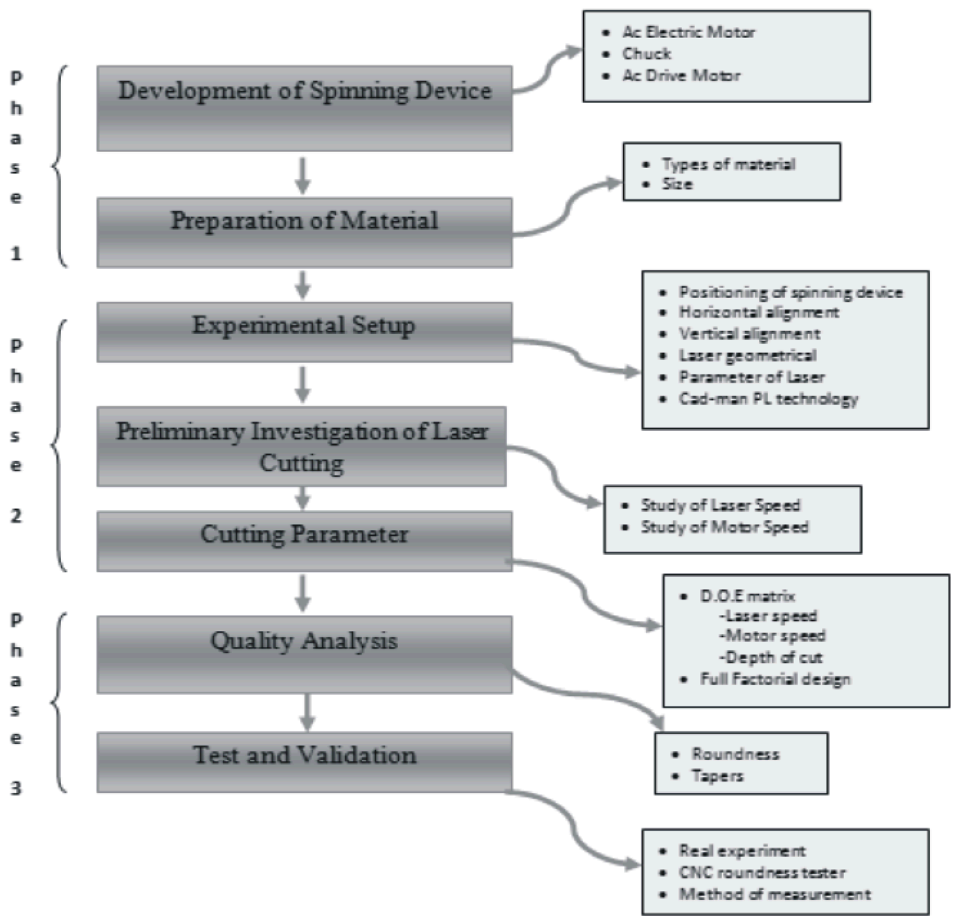

Fig. 5: Proposed methodology flowchart for hybrid laser lathing technology

advantages of efficient ultra-thin layer peeling without undesirable thermal effects for both opaque and transparent materials. The femtosecond laser turning is suitable for excellent surface finish techniques [18,19]. The integration of interference phenomenon into femtosecond laser micromachining was presented. In order to perform ablation using femtosecond laser pulse, the generation of circular interference pattern was demonstrated by the overlapping infrared femtosecond laser pulses [20,21].

The effect of laser beam and attitude involving cutting obliquity and cutting directionwithin the range of 3D upward and downward cutting was performed for sharply narrower than 2D cutting [20]. A novel ultra-short pulse laser lathe system for bulk micromachining of axisymmetric features with three-dimensional cylindrical geometry was studied.A total of 120 femtosecond pulses from an 800-nm Ti:sapphire laser is utilized to machine hexanitrostilbene (HNS) rods with diameters of less than 200 um and the result indicates that surface roughness is dependent upon the rotation speed and feed rate [22,23].

Proposed Hybrid Laser Lathing: Figure 5 shows the fundamental methodology flow chart of the proposed hybrid laser lathing solution.The development of spinning device is similar to the mechanical lathe concepts which consist of a chuck, control system and electric motor. There are three main components in transforming a CO_2flatbed laser cutting machine into a laser lathing. Mild steel is used in this experiment with less than 0.25% carbon and the term of ‘mild steel’ is also applied commercially to carbon a steel which is not covered by standard specifications. The experimentation was designed into six respective steps, namely; to position the spinning device on the laser table, horizontal and vertical alignment of spinning device, laser geometrical, parameter of laser and cad-man PL technology. 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.

In this experiment, there are three variable parameters: cutting speed, motor speed and depth of cut. The experiment is conducted using the Design of Experiment. Every experiment has its own target and must go through the quality analysis to ensure whether the target is achievable. In this experiment, there are two types of quality analysis which are roundness and taper. 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 eight experiments that should be tested in the actual experiment. The CNC roundness tester is used to validate the test on the roundness and taper.

Transforming Flatbed Laser Cutting into Laser Turning: The first stage ideation was to apply the 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 designed to support longer workpiece if they were to be lathed in the future. The function of the rail on the table was to create a path for the tailstock when dealing with a shorter workpiece. The rail and tailstock were not permanently fixed but can be utilized if deemed necessary to help in better accuracy of laser processing. Two rails on situated on the right and left sides are placed to guide the movement of headstocks and tailstocks.

The speed of a motor which has been mounted on a face plate was controlled by a specially designed motor speed controller from 0-1500 RPM. The laser head moved along the Y-axis for cutting process. The stand of distance is the distance of laser nozzle to workpiece which plays a vital role in laser processing. This laser machine has the laser head moving on to Y-axis and the table moved on X-axis. Thus, preliminary experiments were carried out by placing motor at two different axis positions of sacrificial laser table to ensure which axis gave a tighter tolerance during machining. Figure 6 shows the Y-axis position of a spinning mechanism/motor. This orientation focused 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. Figures 7 presents the motor orientation as described above.

This preliminary investigation is expected to produce a significant difference in determining whether the head or table movement is more precise on a 4’ x 8’ CO_2 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 investigated to decide on which orientation should the motor be mounted on. Based on the preliminary investigation of X-Yaxes 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

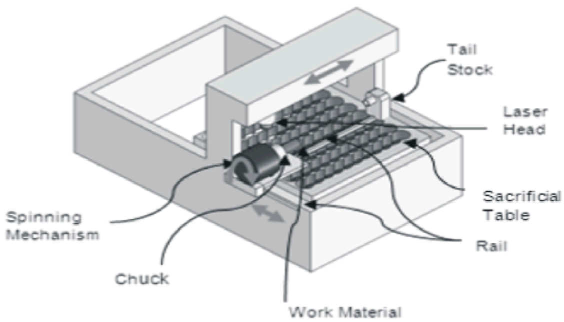

Fig 6: Y axis -Head Movement

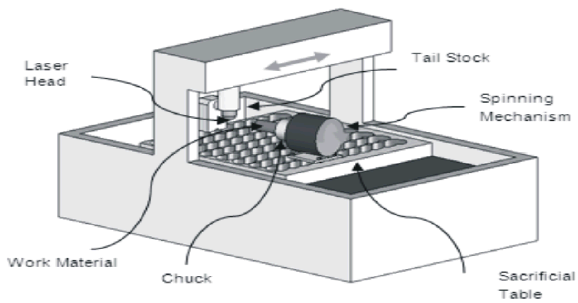

Fig. 7: X axis - table movement

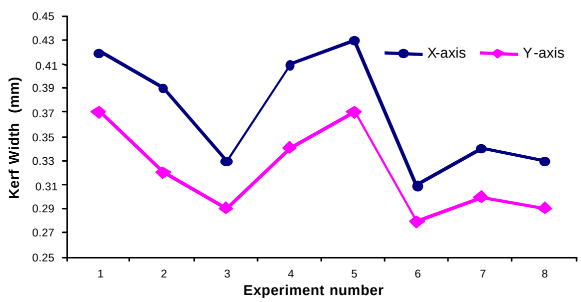

Fig. 8: The kerf width analysis of X to Y axis cutting quality

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 tailstocks are designed to be user friendly for easy installation and removal in case the machine is to be reverted into flat cutting of metal sheets.

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 bars as well as a hollow material is used in this experiment. There are six parameters controlled used; namely stand of distance, focal distance, gas pressure, frequency, duty cycle and cutting speed. The responses were kerf width, surfaces finishand surface roughness. The range of speed motor controller is between 0 to 1500 rpm.

CONCLUSION

Even though research in laser technology is scarce, there are laser lathing machines available in the market. These machines are highly-technology with two intersecting beams which make them costly which only giant industries can afford. Thus, the attempt of modifying laser cutting machine into laser turning is yet to be investigated extensively by researchers. Hence, the attempt to transform an existing 2D CO_2 laser cutting machine into laser lathing is seen to be very viable and highly potential to lathe super hard materials. 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 are to be attained by extensive experimental design.

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