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ABSTRACT

DEVELOPMENT OF LASER CUTTING AND ENGRAVING MACHINE UTILISING PC-NC CONTROLLER

(Keywords: Laser cutting and engraving machine, PC-NC based controller, controlling system)

Laser machining is one of the most popular applications of the laser material processing. New processes such as laser cutting and laser engraving have been evolved ever since laser machining became popular in the manufacturing industries over the past decades. Therefore, this study developed the laser cutting and engraving machine by utilizing PC-NC controller.

The controlling system that has been developed is capable of executing a stored program correctly and moving the laser smoothly in the desired way. Hence, the PC-NC controller specifically tailored for laser cutting and engraving which can control all the relevant parameters in real time except the laser beam power. So the moving table which attached to the laser head can run smoothly and control the crucial parameters accurately. The laser machine then is tested with different types of work piece to investigate the effectiveness of cutting and engraving processes using this system.

In general, the laser system for cutting and engraving utilizing PC-NC controller successfully developed.

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ABSTRAK

PEMBANGUNAN MESIN PEMOTONGAN DAN PENGUKIRAN LASER DENGAN MENGGUNAKAN PENGAWAL PC-NC

(Kata kunci: Mesin pemotongan dan pengukiran laser, pengawal PC-NC, sistem pengawalan)

Pemotongan laser merupakan salah satu penggunaan pemotongan bahan yang popular. Proses-proses baru seperti pemotongan dan pengukiran laser telah berkembang sejak pemesinan laser menjadi popular dalam industri pembuatan sejak beberapa dekad yang lalu. Maka, kajian ini dilakukan untuk menghasilkan mesin pemotongan dan pengukiran laser dengan menggunakan pengawal PC-NC.

Sistem pengawalan yang telah dihasilkan berkeupayaan untuk melaksanakan dengan betul program yang telah disimpan dan seterusnya menggerakkan laser dengan lancar mengikut kehendak. Justeru itu, pengawal PC-NC direka secara khusus untuk pemotongan dan pengukiran yang boleh mengawal kesemua parameter yang relevan dalam masa sebenar kecuali kuasa cahaya laser. Jadi, meja bergerak yang disertakan dengan bahagian kepala laser boleh melaksanakan dan mengawal parameter-parameter penting dengan lancar dan tepat. Mesin laser kemudiannya diuji dengan pelbagai jenis bahan kerja untuk mengkaji keberkesanan proses pemotongan dan pengukiran menggunakan system ini.

Secara khusus, system pemotongan dan pengukiran laser dengan menggunakan pengawal PC-NC berjaya dihasilkan.

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LIST OF ABBREVIATIONS

RP	rapid prototyping
RT	rapid tooling
RM.	rapid manufacturing
SLS	selective laser sintering
SLM	selective laser melting
PC-NC	personal computer – numerical control

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CHAPTER 1

INTRODUCTION

One important tool in technology, which is categorized by an outstanding future, is the laser. Laser is an artificial energy source, discovered by physics, which has become an important manufacturing tool. A laser beam is an artificially generated electromagnetic radiation, called laser light in the visible wavelength range. Its theoretical physical description is attributed to Einstein in 1917, namely the principle of stimulated emission of radiation. From this arise the acronym LASER, i.e light amplification by stimulated emission radiation. The first experimental implementation of lasers was achieved by the American Maiman in 1960.

The introduction of laser and related devices has revolutionized the high technology and made a great deal of contribution to both basic and applied research in different areas. Although the present laser systems have not fulfilled all the preliminary expectations, important advancements have been made by the advent of sophisticated laser systems in optical communications [1], medicine [2], industry [3], and other fields of interest [4, 5].

In industrial, the expansions of laser applications and relatively low cost of laser system with mass production, laser material processing has gained increased importance in variety of industries. Automotive, aerospace, defense, manufacturing, and many others sectors are widely adapting laser technology for welding, cutting, coating and hardening. Moreover, the growth of research and development of laser system for material processing has changed the technique of rapid prototyping (RP) or layer manufacturing from fabrication of prototypes to rapid tooling (RT) and rapid manufacturing (RM). Nowadays, many researchers successfully produced the direct fabrication of functional or structural end-use products, high strength alloys and high properties coating made by layer manufacturing techniques utilizing of laser system such as selective laser sintering (SLS), selective laser melting(SLM) and laser cladding on various kinds of metals, polymers and composite [6-9].

The increase growth of laser application because of several advantages such as relatively low cost when mass production, reduction of production time, reduction of waste, precision cutting due to laser beam diameter can be focused to micrometer and up to nano level, laser beam can clean, coat and machine at complex shape and limited surface, able to produce functional parts with different materials and etc. [10, 11].

For these reasons most developed countries have made huge investments in their laser research programs and as a result have found many interesting results [12]. This motivates more and more research in this field.

According to Olaf Rehme et al. [13] more than 130 different influence parameters affect on the laser material processing such as for cutting or melting. However, only approximately 13 of these parameters are crucial to produce quality parts. These parameters are divided into two categories, control parameter and disturbance variables. Control parameters consist of beam power, scan speed, hatch distance, layer thickness, and scan strategy. Disturbance parameters are involves in type of materials and parts geometry.

In developing laser system, controlling the control parameters is very importance. Moreover, the ability of the system to control these parameters accurately will improve its performances. In addition, the performance of this laser system is based on the advances of controller it's used.

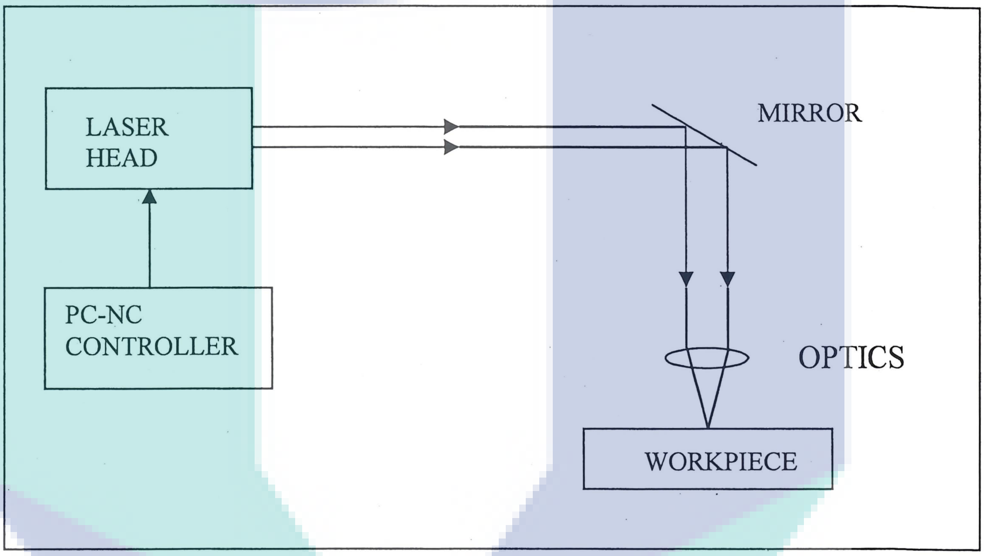

Figure 1.1 Schematic illustration of laser system for cutting and engraving

Thus, this research is aimed to develop laser system (as in figure 1) which can do cutting and engraving process utilising **PC-NC controller**. This system should consist of laser head, optical system (for focusing the beam), machine structure, monitoring system and computer controller.

Objective

To develop laser cutting and engraving machine utilising PC-NC controller

Scope of research

a. Literature study
The laser system configuration that will be developed is moving laser type as shown in the figure. 2. In the literature review the effects of 13 parameters which are crucial to produce quality parts will be studied. These parameters are divided into two categories, control parameter and disturbance variables.

Control parameters consist of beam power, scan speed, hatch distance, layer thickness, and scan strategy. Disturbance parameters are involves in type of materials and parts geometry. In moving laser type system, laser head is attached to the moving table which is controlled by PC-NC controller.

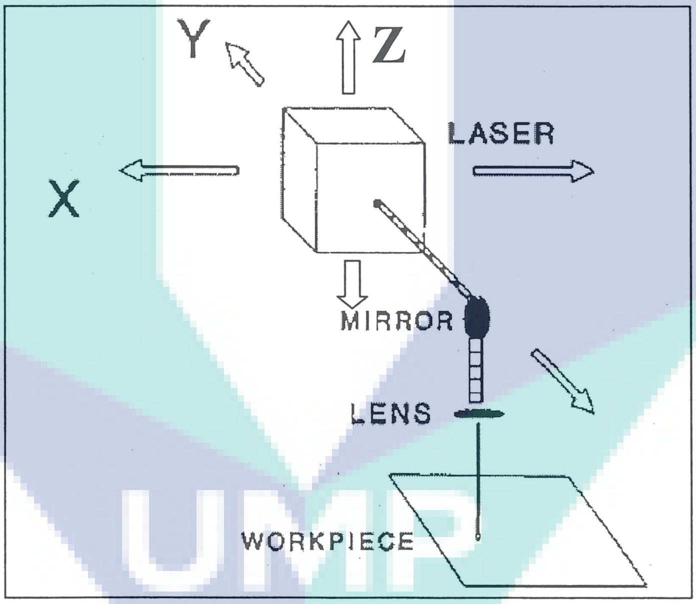

Figure 1.2. Schematic illustration of laser moving type for cutting and engraving

b. Programming of PC-NC
The controlling system must be capable of executing a stored program correctly and moving the laser smoothly in the desired way. Thus, PC-NC based controller need spesifically tailored for laser cutting and engraving, which can control all relevant parameters in real time except the laser beam power.

c. Integration between laser machine and controller
   It is important to make sure that the intergration between the PC-NC controller and moving table which attach with laser head can run smoothly and can control the crucial parameters accurately.

d. Testing
   Different types of workpiece will be used to investigate the effectiveness of cutting and engraving processes using this system. Furthemore, the optimum parameters for different materials for cutting and engraving will be investigated.

CHAPTER 2

OPTIMIZATION OF CUTTING PARAMETER FOR CO_2 LASER BEAM CUTTING USING TAGUCHI-GREY METHOD

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Abstract: Non-conventional cutting process recently have widely used in manufacturing industry. One of them is laser machining. It can replace mechanical material removal method which is conventional process. One of advanced machining process is laser machining. CO_2 laser beam cutting (LBC) is the most powerful type of industrial cutting process available. It can be used for generating complex and difficult shapes on wide range of materials such as metals, non-metals, alloys, superalloys, ceramics and composites. Mainly, the design of experiment based researches based on LBC process aimed on single characteristic optimizitation. In order to get the best quality product, some characteristics of finish product need to be considered. Optimization of multiple response characteristics is far more complicated compare to single response characteristic optimization. This paper is focus on optimizing machining parameters for CO_2 LBC by using Grey-Taguchi method. Response characteristics considered are Ultimate Tension Stress (UTS), Heat-affected Zone (HAZ), Depth-to-Width ratio (DW) and Surface Roughness (SR).Simulation and experimental works shows that machining parameters of LBC can be optimized and machining performance can be improved using this method.

Keywords: Laser beam cutting (LBC), Orthogonal Array, Grey-Taguchi method

INTRODUCTION

Laser stands for Light Amplification by Stimulated Emission of Radiation. Properties of laser are precisely defined wavelength specific for its type (monochromatic), coherence, low divergence, good focusability and easy polarization [1]. The laser was invented in 1960s and widely applied in fine cutting process, due to its high intensity and precision [2]. There are several types of laser such as CO_2 laser, Nd:YAG laser and excimer laser.

Laser beam cutting (LBC) is one of non-conventional cutting process, most widely used for generating complex and difficult shapes on wide range of materials such as metals, non-metals, alloys, superalloys, ceramics and composites [3]. Figure 1 below shows the schematic diagram of laser beam cutting (LBC). Workpieces is cut mainly due to melting and vaporization [4]. The properties of laser beam enable it to be focused on a small spot, allowing high-power density can be achieved. This advantage is the main feature in representing its potential as a cutting process and other manufacturing processes. Since LBC was introduced, it always had been major research area in getting the best quality of cut.

The carbon dioxide (CO_2) laser beam cutting is the most powerful industrial laser available. This type of laser mainly use for contour cutting and deep penetration welding. CO_2 light have long wavelength, which is 106μm is absorbed by most solid. This property plays a large role on its advantage that can be applied on wide range of materials. Laser medium are 9.5% of CO_2, 13.5% of N_2 and 77% of He. CO_2 is the primary lasing medium while N_2 excite CO_2 and He acts as a buffer heat to transfer heat. Both N_2 and He are additional gasses to improve efficiency and extend lifetime of lenses.

There are several types of CO_2 laser available for industrial purpose. Flatbed and robotic lasers are used for cutting purposes while the other types are axial gas flow laser, transverse gas flow laser, gas dynamic

CO_2 laser, chemical transfer laser and slab type CO_2 laser. In laser beam cutting (LBC), laser generates high intensity beam of infrared lights. Lens is used to focus the beam onto the surface of workpiece. The materials are heated and establish a much localized melts. Before the cutting begins, 90% of power is reflected and the remains absorbed by workpiece. Materials melt immediately and the molten pool is called as a key hole. As the cutting process starts, the key hole is blown away by assist gas and 10% of power reflected and 90% of power absorbed. Cutting begins when the laser beam is through the workpiece. The beam, or workpiece, or both must move in order to create the desired cutting path.

As the most powerful industrial laser available, CO_2 have several advantages. The advantages are low heat input to the workpiece, hence low distortion or warping of the final product. Secondly, flexible and very thin materials (as thin as 0.025mm) can be cut without distortion. LBC also can produce relatively smooth and approximately perpendicular to the surface cutting edges, so frequently did not need secondary operation for further fabrication. Materials savings also can be achieved by close nested because of narrow kerf width and heat-affected zone. CO_2 LBC also can be easily automated and can be interfaced other automatic devices.

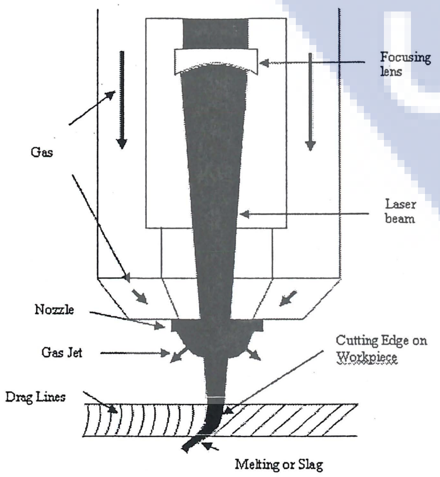

Fig. 1 Schematic diagram of laser beam cutting.

OPTIMIZATION USING GREY-TAGUCHI METHOD

Instead of applying Taguchi method, which is designed to optimize single characteristic problem, Grey-Taguchi method is implemented. This method can be used in optimizing multiple characteristics problem. Grey-Taguchi method was developed by a combination of grey-relational analysis (GRA) and Taguchi method. Experiment was designed using Design of Experiment (DOE) and a suitable Orthogonal Array was selected to design the frame of experiment. Then, GRA was used to calculate grey-relational coefficients (GRC) in order to find grey-relational grade (GRA). The basic idea is to use GRG to determine the optimal combination of laser cutting parameters. GRG was selected because it can be used for the optimization conversion of multi-objective case to single-objective case.

In context of Taguchi methodology, linear optimization of DOE data is depending on type of performance response. For the 'lower-the-better' performance responses:

$$x_i(k) = \frac{\max \eta_i(k) - \eta_i(k)}{\max \eta_i(k) - \min \eta_i(k)} \qquad (1)$$

Whilst on the other case, for 'higher-the-better' responses:

$$x_i(k) = \frac{\eta_i(k) - \min \eta_i(k)}{\max \eta_i(k) - \min \eta_i(k)} \qquad (2)$$

and finally, grey-relational coefficient (GRC) were calculated to determine the relationship between the ideal and actual normalized response:

$$\xi_i(k) = \frac{\Delta \min + \zeta \Delta \max}{\Delta_{0i}(k) + \zeta \Delta \max} \qquad (3)$$

where $\Delta_{0i}(k) = \|x_0(k) - x_i(k)\|$, ζ is the distinguishing coefficient between zero and one; in this study it was set to ζ =0.5,

$\Delta \min$ is the smallest value of Δ_{0i} and $\Delta \max$ is the largest value of Δ_{0i}.

The most critical part for applying the Grey theory to practical case is find the most suitable way to quantify and grade the performances for various ways of laser cutting. In order to determine the optimal level, combination of laser cutting parameters with the highest GRG was selected. According to J.L. Deng [5], larger normalized results correspond to the better performance and the best-normalized result should be equal to one.

SIMULATION WORK

For this study, a program was developed using MATLAB 7.0™ software, applying algorithm of Grey-Taguchi method. This program was used to get the optimized combination of machining parameters for CO_2 laser beam cutting. There are six control factors selected for this study, which are shielding gas, laser energy, traveling speed, laser focus position, pulse frequency and pulse shape. Each factor is divided into three levels, which are low, medium and high. Parameter for each factor and their corresponding level is selected by referring to manufacturer recommendation as one of safety precaution.

Table 1 Materials properties of acrylic (optical sheet)

Density (g/cc)	**Yield Tensile Strength (MPa)**	**Processing temp (°C)**	**Modulus of elasticity (GPa)**
1.17	52.1	156	2.31

Table 2 Machining parameters and their respective levels

Process parameter	**Symbol**	**Level 1**	**Level 2**	**Level 3**
Noise factors				
Temperature	A	22°	24°	26°
Control factors				
Materials thickness (mm)	C	3	6	9
Gap (mm)	D	9.3	9.5	9.7
Cutting speed (pulse/sec)	E	2600	2800	3000
Laser power (%)	F	85	90	95

Table 3 Standard L-27 orthogonal array of 27 different groups following Taguchi method

Sampling no.	Factor A	Factor B	Factor C	Factor D	Factor E
1	1	1	1	1	1
2	1	1	1	1	2
3	1	1	1	1	3
4	1	2	2	2	1
5	1	2	2	2	2
6	1	2	2	2	3
7	1	3	3	3	1
8	1	3	3	3	2
9	1	3	3	3	3
10	2	1	2	3	1
11	2	1	2	3	2
12	2	1	2	3	3
13	2	2	3	1	1
14	2	2	3	1	2
15	2	2	3	1	3
16	2	3	1	2	1
17	2	3	1	2	2
18	2	3	1	2	3
19	3	1	3	2	1
20	3	1	3	2	2
21	3	1	3	2	3
22	3	2	1	3	1
23	3	2	1	3	2
24	3	2	1	3	3
25	3	3	2	1	1
26	3	3	2	1	2
27	3	3	2	1	3

Numbers in each column represent the experimental levels for specific factors

Experimental set-up and procedure

The second step in Taguchi parameter design, after the orthogonal array has been selected is running the experiment. This experiment was conducted using the hardware listed below:

- CO_2 laser machine
- Surface roughness measurement device: Mahr Perthometer S2
- Thermometer
- Surface table: TK 1010003 Grade 0
- Image Analyzer
- MATLAB 7.0™
- MasterCAM v9
- SolidWorks 2005
- ArtCAM
- Borland C++

A simple cutting path was generated using SolidWorks and drawing file was impoerted to ArtCAM. Then toolpath of cutting was generated and saved in text format file. The workpiece used is 3, 6 and 9mm thick acrylic sheet. After each trial, surface roughness of cut surface was measured on the surface table. Three fixed spots on each machined surface, one in the middle and the other two on the edge as shown in Figure 3, were used to measure the surface roughness of the machined surface, and the mean of the three readings was readings was recorded in the orthogonal array.

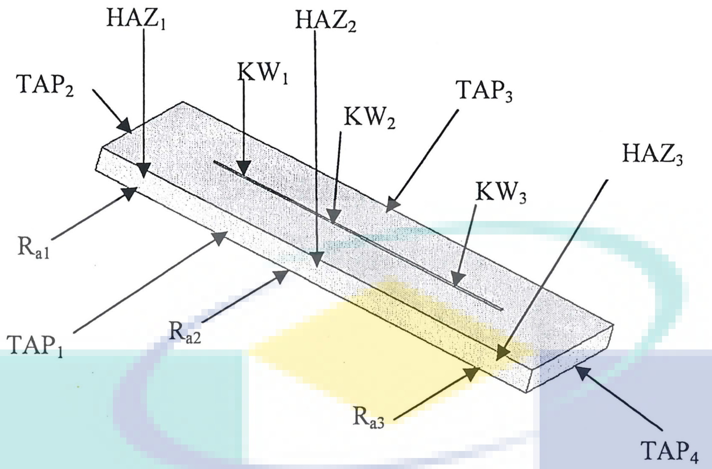

Fig.3. Three spots for taking surface roughness measurements.

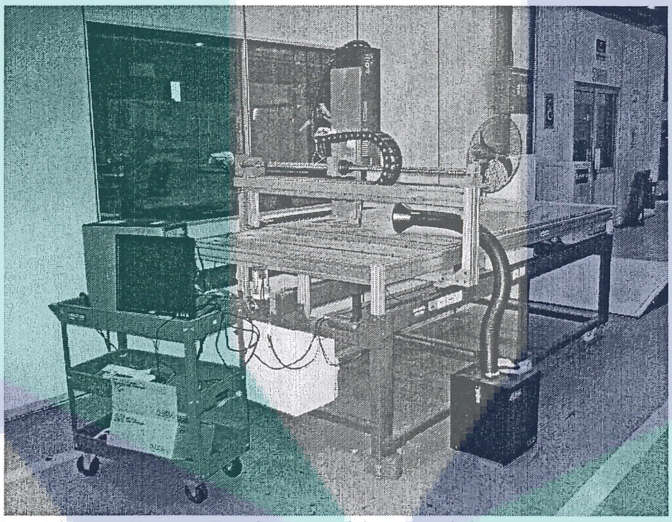

Fig. 4 Laser Beam Cutting machine used for experimentation

RESULT AND DISCUSSION

The first step in GRA is linear optimization of DOE data collected from experimental works. There are two types of linear optimization which is depending of demand of the type of data. For this study, only smaller-the-better type used for all response factors which are surface roughness (R_a), taper (TAP), heat affected zone (HAZ) and kerf width (KW).

Table 4 lists the mean surface roughness, taper, heat affected zone and kerf width measured on cutting path for 27 groups of measured samples.

Table 5 shows the Grey relational coefficient, weighted Grey relational coefficient and Grey relational grade evaluated for each group.

Table 4
The average surface roughness, taper, heat affected zone and kerf width along the cutting path for 27 groups, respectively as evaluated in this study

Sampling no.	Surface roughness (μm)	Taper (°)	Heat affected zone (mm)	Kerf width (mm)
1	0.0153	3.50	0.9402	0.5158
2	0.0113	3.88	0.9754	0.5583
3	0.0127	3.88	0.9780	0.5687
4	0.0203	2.38	0.8164	0.6595
5	0.0170	2.63	0.8385	0.3117
6	0.0147	2.38	0.8372	0.3214
7	0.0370	1.75	0.9728	0.2463
8	0.0480	1.50	0.9976	0.2427
9	0.0250	4.25	1.1033	0.2447
10	0.0130	3.50	1.5023	0.5558
11	0.0133	6.25	1.6363	0.5635
12	0.0143	4.50	1.6067	0.5454
13	0.0223	2.38	0.6559	0.2740
14	0.0353	2.50	0.6964	0.2865
15	0.0237	1.88	0.7381	0.2894
16	0.0170	2.13	0.9337	0.1792
17	0.0187	1.38	1.4487	0.1367
18	0.0183	1.25	1.1777	0.1454
19	0.0120	4.00	1.4893	0.3488
20	0.0133	2.75	1.5123	0.3430
21	0.0137	3.00	1.4343	0.3366
22	0.0173	1.00	0.9676	0.3411
23	0.0167	2.00	0.9910	0.3378
24	0.0163	1.13	1.0223	0.3518
25	0.0297	1.25	1.1513	1.1203
26	0.0370	0.50	1.0810	0.7387
27	0.0187	1.25	0.9780	0.5881

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CHAPTER 3

DEVELOPMENT OF OPEN ARCHITECTURE CONTROL SYSTEM FOR COMPUTERIZED NUMERICAL CONTROL LASER MACHINE

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ABSTRACT

The aim of this project is the development of Open Architecture Controlling (OAC) system to be applied in the Computerized Numerical Control (CNC) laser machine and also to provide this facility in a cost-effective manner. The system allows a new monitoring and controlling strategy. We present the implementation of laser cutting machine, which was being assembled in University Malaysia Pahang (UMP) in Manufacturing Department. As a result, the CNC laser machine interacts with user friendly software and increased the performance of the machine. In addition, it also reduces the time processing and the cost for production, while at the same time able to increase the safety of the machine operators.

1 INTRODUCTION

Malaysia is a one of the country in the world that leading in science and technology growth. Engineering sector gives us high revenue to our economy growth and development. In order to maintain and improve our excellent, we have to improve machines efficiency. Although automated machines have become important, humans are still the ones who load the program, set up the machine and start it. Humans also have to monitor the production process, stepping in if any break down occurs. Ergonomics or human factors such as ability, experience, memory level and perception become as the scientific discipline that examines an interaction between humans and machines. More specifically, human-computer interaction concerns the interaction between humans and computers. Machines that can be operated quickly and safely have a direct impact on productivity by reducing downtimes [1]. Engineers and technicians are limited as far as hardware and software are concerned when they need to expand, maintain and integrate the "production islands". Hardware and software problems usually do not allow the use of the same control hardware, elevating costs for increase in production. Solutions were proposed, which seek the "open way". The meaning of "open way" is the independence from the manufacturer's technology, allowing the user to buy hardware and software from several different manufacturers and freely assemble the acquired pieces of equipment [2].

Open Architecture Control (OAC) is a well known term in the field of machine control [3]. Since the early nineties several initiatives world-wide have worked on concepts for enabling control vendors, machine tool builders and end-users to benefit more from flexible and agile production facilities. The main aim was an easy implementation and integration of customer-specific controls by means of open interfaces and configuration methods in a vendor-neutral, standardized environment. An open-architecture is the definition of a set of components with well-defined behavior and well-defined relationship, and for which the definition is known to all. Often the definition is standardized, either through a standards body or through de facto adoption by a wide community. In some cases, component vendors provide the definition. Desktop computing is one of the most widely known examples of an open architecture, where components include display monitors, input devices, storage devices, and software functions provided by the operating system or applications [4]. There are a lot of benefits for suppliers and users of using OAC [5]. Figure 1 shows the benefits of using OAC.

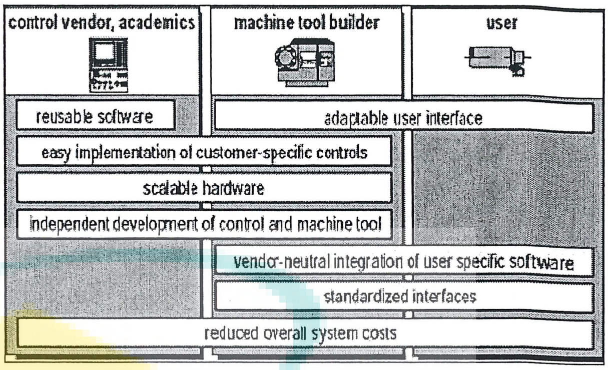

Figure 1. Benefits of using Open Architecture Control

In this paper, we present the development of a new OAC system for Computerized Numerical Control (CNC) laser machine. The objectives of this development are: to reduce the time processing and the cost for production, while at the same time able to increase the safety of the machine operators. In particular, this development was motivated by the necessity of industrial sector. Due to their high initial costs, the laser wear must be reduced during cutting and their benefits must be fully explored in production. These PC-based monitoring controlling systems have, as the most important feature, the fully integrated possibilities of communication with the controller, getting and sending information from and to the Numerical Control (NC), acting on its up and low level routines. It allows the execution of corrective actions during the cutting or engraving, monitoring and adjusting the core cutting parameters, permitting the operation and the monitoring of the process through Ethernet/Internet.

This paper is organized as followed: Section 2 describes the proposed OAC system to be developed for laser machine. In Section 3, we implement the proposed OAC system. We present the major characteristics of the system by focusing on operator graphical interface in server and also the benefits that can be obtained by its application in the cutting or engraving process. Finally, we conclude this paper in Section 4.

2 PROPOSED OAC SYSTEM FOR LASER MACHINE

In this section, we present the OAC system for laser machine. The OAC system allows new monitoring and controlling operation in the cutting or engraving process, locally or remotely. In addition, it able to monitor or control the laser machine and make it available to the high management levels through Ethernet/Internet.

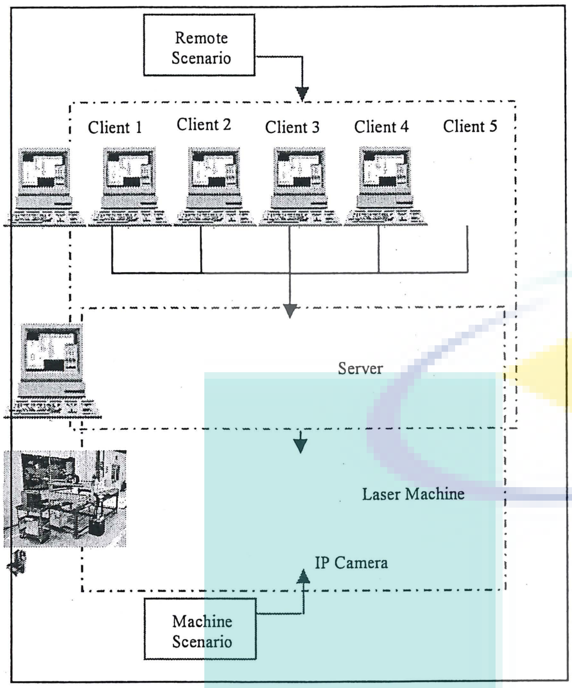

Figure 2. System overview

An overview of the OAC system is presented in Figure 2. There are two scenarios of the OAC system that include the remote scenario and machine scenarios. In the remote scenario, clients can perform monitoring and controlling actions and/or collect information sharing it with the management systems. The client's graphical user interface will be developed using web browsing. The client computers will be connected with the server via Ethernet as depicted in Figure 3. View and/or control can be performed, in which machine setup, diagnostic and operation will be performed remotely. Thus, it able to maximize the operation and reduces machine down time.

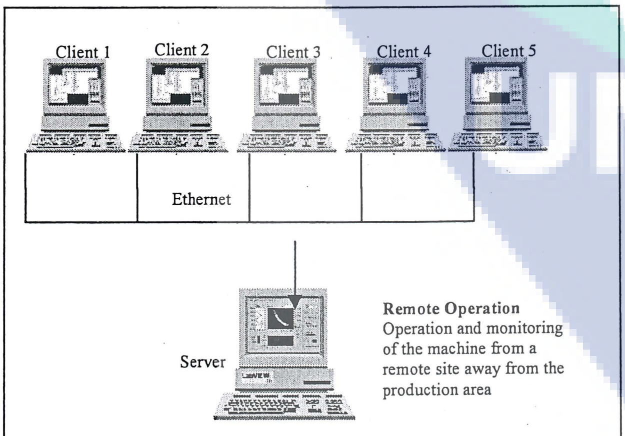

Figure 3. Remote scenario for five clients.

The machine scenario represents the connections design between the server, Fanuc CNC machine, IP Camera and laser machine. An IP camera will be installed around the machine. The PC - CNC communication is performed by using a parallel port cable to connect PC to the CNC.

Operator interface is developed using the C++ language. Figure 4 shows the machine scenario.

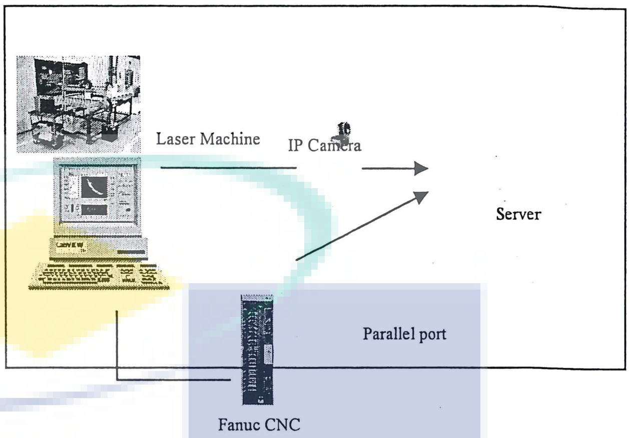

Figure 4. Machine scenario

3 *IMPLEMENTATION*

In this section, we implement the proposed OAC system. In addition, we present the hardware and software specification for this implementation. Table 1 shows the hardware specification for the server and client pc's.

PC / Specifications	Server	Client
Operating System	Windows/ Linux	Windows/ Linux
Processor	Intel(R) Core(TM)2 CPU 1.86 GHz	Pentium III 800 MHz or higher
Memory	2.00 GB of RAM	256 MB or higher
Hard Disk Drive	160 GB	20 GB or higher

Table 1. Hardware specifications

We used a D-Link 802.11g wireless pan, tilt and zoom internet camera for this OAC. Table 2 depicts an Internet camera specification. The camera is capable to pan or/and tilt for better viewing. The main purpose for this viewing method is to make sure the process is working properly although it's operate at the other place.

Specifications	Features
Overall	• 1/4 inch color CCD sensor • AGC/AWB • Electronic shutter: 1/60~1/15000 sec. • Fixed focus glass lens, F2.0, 1 LUX • 43mm Lens Size • 53° Field of View
Network Application	• DDNS support with several popular DDNS servers • UPnPTM support • SMTP client • FTP client • FTP server • HTTP server
Networking Protocols	TCP/IP, HTTP, SMTP, FTP, Telnet, NTP, DNS and DHCP
Remote Management	Configuration and system log can be accessed via Web browser and FTP application remotely
Viewing System Requirement Protocol	ActiveX
Pan, Tilt, and Zoom Control	• Auto pan and auto patrol mode with preconfigured stops • Pan: Range 270o • Tilt: Range 90o • 4x Digital Zoom1

Table 2. Internet camera specifications

The software specifications for this implementation are depicted in Table 3.

Place \ Specifications	In Server PC	In Client PC
Language	C++	HTML, PHP
GUI	Microsoft Founded Class (MFC) in C++	HTML
Type	Software	Web Browsing
Task	• To control the CNC laser machine • Accept the G-Code file and start the process	• Monitor/view the machine via IP camera • Send G-Code file to sever pc

Table 3. Software specifications

The reason we deploy web browsing as a GUI for client because it is universal and easy to be use. In order to increase the security of the operating process, the web pages are equipped with user id and user password so that only an authorized user can use the machine.

There are 4 phases in our implementation. Figure 5 shows the phases for this implementation.

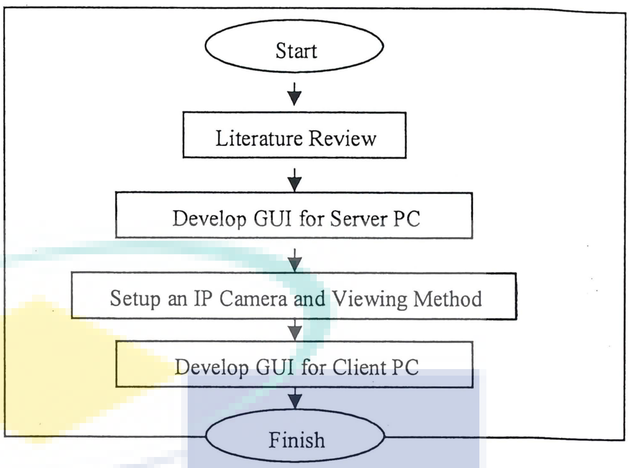

Figure 5. Phases in implementation

3.1. Phase 1: Literature Review

Literature review is a background study of areas related to the proposed system. The purpose is to get the latest information and knowledge on the system. The study reveals the weakness of current system and this motivated us as an input to improve the proposed system. We have studied about the characteristics of OAC as mentioned in Section 2. This phase required to be review all the time during the development of the OAC in order to ensure that the system developed will be benefits the users and marketable.

3.2. Phase 2: Develop GUI for Server PC

The implement OAC system is now being tested in order to develop new cutting and engraving strategies. New monitoring systems, based on the developed Graphical User Interface (GUI), will permit the most effective and reliable data processing. In order to make GUI, the parameter for the machine has been identified. The lists of the parameter or selection in this laser machine are as in the Table 4 below.

Parameter/Selection	Unit/Type	Calculation
Moving Direction	Forward, Forward & Left, Forward & Right, Left, Right, Backward, Backward & Right, Backward & Left	-
Moving Speed	5- 50 or higher	> higher, > faster
G-Code File	.txt file	-
Laser Strength	200 – 3000 or higher	> higher, > Strength

Table 4. Parameter or selection to be considered

For the time being, the development of graphical user interface is being implemented in server in the Windows environment. Figure 6 shows the GUI that works in server. There are two panels to control different part. One is for laser moving and other is laser starting. For moving the laser, the user has to choose the direction and the laser speed as shown in Figure 6. The higher number of laser speed is the faster the laser will be move because we set the laser speed as an integer (int) so the higher number is the fastest. To start the moving process, click the start button. To stop the process, press the stop button. Figure 7 shows the selected items interface for laser moving

To start the cutting or engraving process, the user need to insert the G-Code file that contain the information of the drawing that wanted by the user. The user can browse the file as presented in Figure 8 and add it or by creating a new file by clicking the new button. It will go directly to the drawing software, ArtCAM Pro software. The drawing information will be saving in form of axis-x and axis-y. The laser will be move accordingly to the coordinate position.

For laser strength selection, the higher number is the higher strength of laser. For engraving process, it is suggested to use the lower number. But it is depending on the material we are using to engraving the drawing. For example, if we are using wood as the medium to engrave, it is advisable to use lower strength rather than using an acrylic as the medium. This research to determine the laser strength to cut a various type of medium also has been made in University Malaysia Pahang (UMP) by my research colleague.

3.2.1. The Important of GUI

The difficulties for operator if there is no graphical user interface to control the machine are:

- The user has to change all the parameter for laser machine such as the laser speed and the laser strength manually and will make difficult for beginner user
- GUI is built in user friendly environment. Therefore the operator can easily understand how to operate it in a very short period. No need to training the user and this will reduce the cost of production.
- A GUI may be easier to use because of the mouse, however using a mouse and/or keyboard to navigate and control your operating system for many things is going to be much slower then someone who is working in a command line environment.
- GUI users have windows that enable a user to easily view, control, and manipulate multiple things at once and are commonly much faster to do when compared to a command line.
- Although new users may have a difficult at time learning to use the mouse to operate and use a GUI most users pick up this interface much easier when compared to a command line interface.

We are using C++ language to develop the operator interface for server pc. The reasons [6] for selection of this language are because:

- C++ is easy to learn. C++ was designed to be easy to use and is therefore easy to write, compile, debug, and learn than other programming languages.
- C++ is object-oriented. This allows user to create modular programs and reusable code.
- C++ is easy-to-use interface library. C++ has Abstract Window Toolkit that enable programmer to uses native facilities to display windows.
- C++ is low cost programming language because the tool is easy to get.

The primary advantage is developing windows applications more rapidly using Microsoft Founded Class (MFC) vs. Win32 while still using C++. In visual C++, we get a good base for document/view architecture that eases the programming functionality. Visual C++ also gives MFC supports that make "everything possible" in windows programming.

3.3. Phase 3: Setup an IP Camera and Viewing Method

For the time being, we have identified the suitable Internet Camera for this purpose as mentioned in Section 2. The purchasing of the camera is still under process. Currently, we are ongoing to setup an IP Camera and viewing method as soon as we get the camera.

3.4. Phase 4: Develop GUI for Client PC

We have proposed to use web browsing technique to implement GUI in clients. PHP language, HTML, MySQL with networking environment are the basic necessity for this phase. Currently, we are still studying these language and technique for this purpose.

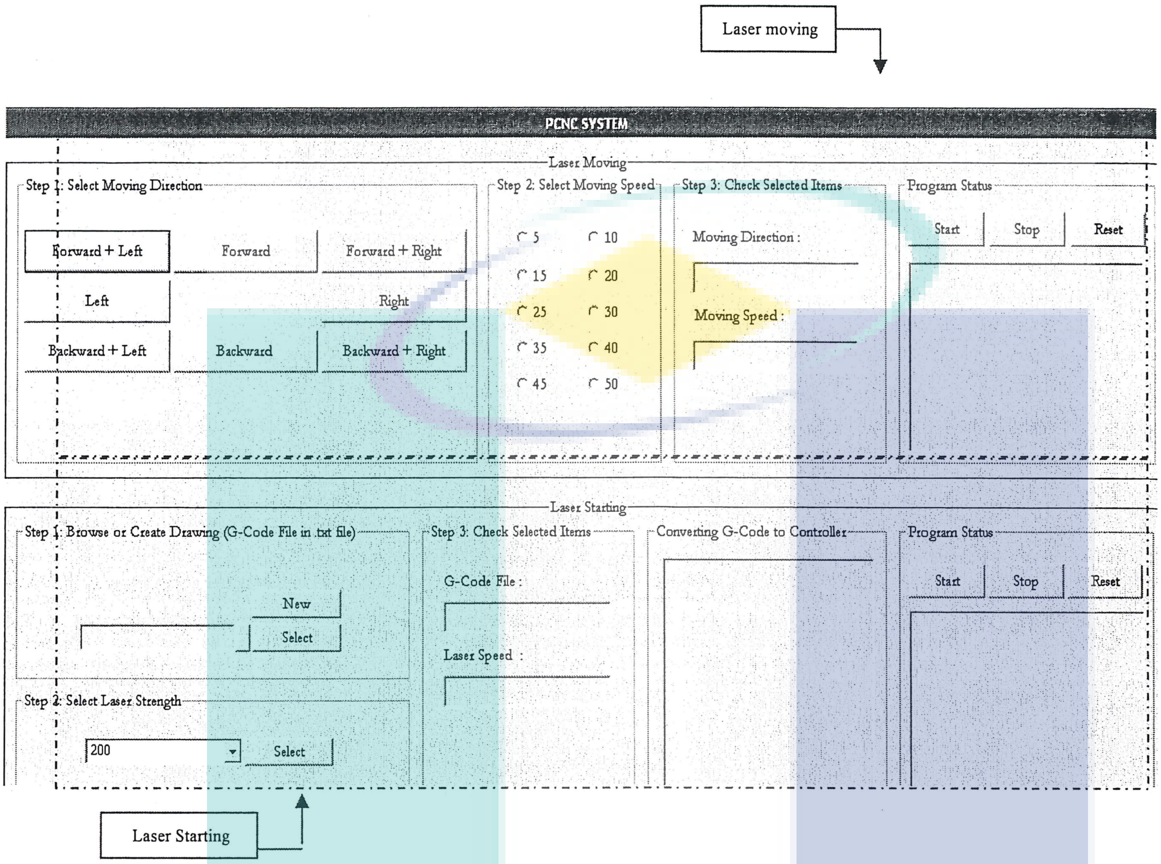

Figure 6. Operator GUI in Server PC

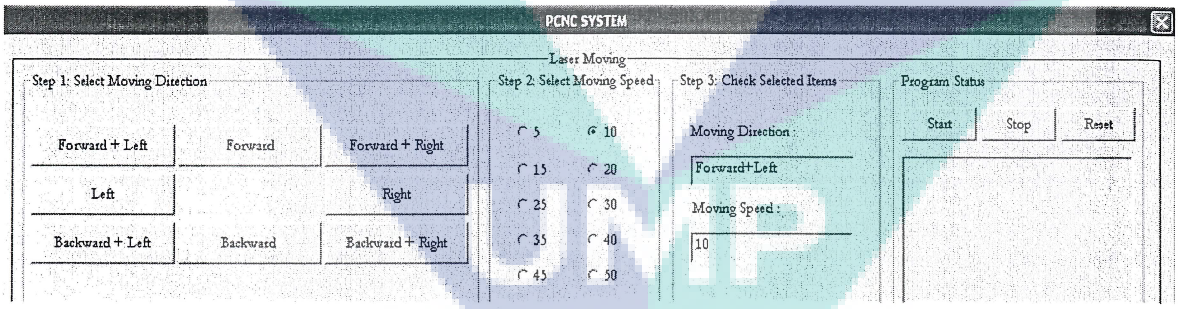

Figure 7. Selected Items for Laser Moving

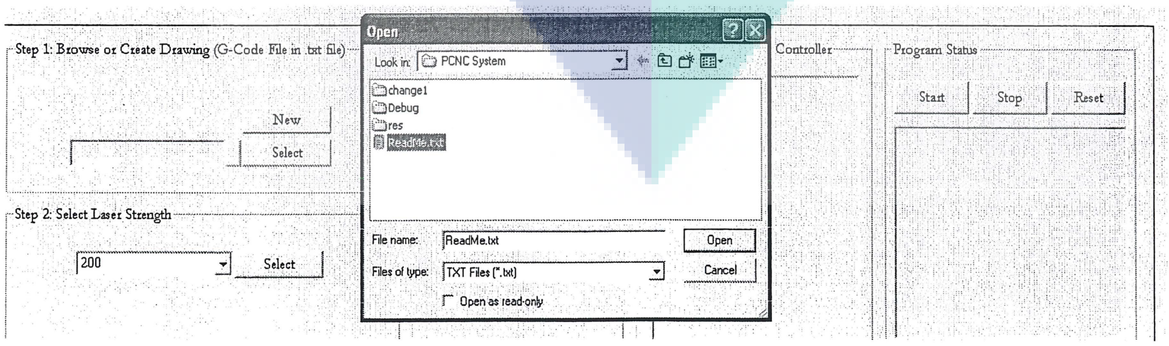

Figure 8. Browse for G-Code File

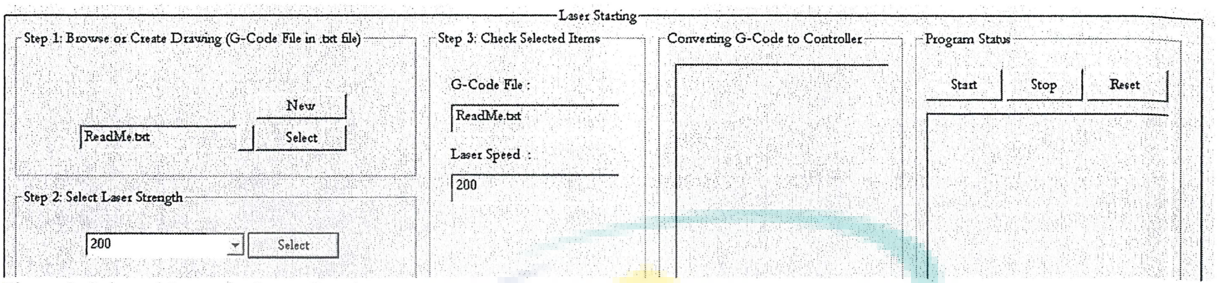

Figure 9. Selected Items for Laser Starting

4 CONCLUSION AND FUTURE WORKS

The development of the OAC controlling system creates a new automation level in the cutting process. The laser cutting process can be transmitted to the upper levels of the business system. New monitoring strategies will be implemented combined with the possibility of remote machine diagnostic and operation. There will be a technological improvement in the area monitoring and controlling systems, improving the machine automation level, reducing cutting costs. The implementation of OAC to the CNC laser machine is only at the beginning stage. In other part we will be discussing on about remote scenario and client GUI as another part of the OAC development.

For ongoing research to further improve GUI in server pc, we are experimenting to implement the GUI in Linux environment. For the time being we are using Windows as operating system in server. Furthermore, we are experimenting to improve the user-friendly environment for user in this GUI. More interactive or user-friendly button will be added to the GUI. For the future studies, we are thinking to add a touch screen panel to make it more user-friendly environment. Further work, we also will do an experiment to add-on teleoperation on the machine by using an IP camera in the remote scenario. The machine will be equipped with moving IP camera so that it can be monitored from anywhere. We will develop web browsing as a graphical user interface for users to monitor and also to operate the machine. The user will send the drawing information to the computer that connected to the machine.

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CHAPTER 4

A Surface Roughness Prediction Model for Laser Beam Cutting on Acrylic Sheets

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ABSTRACT

Response Surface Method is used to find the effect of laser cutting parameters (power requirement, cutting speed, gap distance and material thickness) on surface roughness when machining Acrylic sheets. This simulation gain more understanding of the surface roughness distribution in laser cutting. Response Surface Method (RSM) has been used to minimize the number of experiments. The contour plot from the RSM shows the relationship between variables (beam power, scan/cutting speed, gap distance and material thickness) and response (surface roughness.It was found that surface roughness is affected significantly by the cutting speed followed by the power requirement, hatch distance and then by the layer/material thickness. Generally, the increase in beam power, layer/material thickness, hatch distance and decrease in cutting speed will cause surface roughness to become larger.

Keywords: Laser beam cutting (LBC), Response Surface Method (RSM), Surface roughness, Acrylic sheet

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

Laser system for cutting and engraving utilising PC-NC controller has successfully developed. The controlling system is capable of executing a stored program correctly and moving the laser smoothly in the desired way. Thus, PC-NC based controller can control all relevant parameters in real time except the laser beam power.

It is important to make sure that the integration between the PC-NC controller and moving table which attach with laser head can run smoothly and can control the crucial parameters accurately.

Different types of workpiece were used to investigate the effectiveness of cutting and engraving processes using this system. Furthemore, the optimum parameters for different materials for cutting and engraving were also investigated.

5.2 Recommendation

It is recommended for the future research to increase the power of laser source from currently 30W to at least 100W. This is due to the limitation capabilities of the 30W laser source to cut thicker and different materials such as metal.

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ATTACHMENTS

A. Research Achievements / Awards

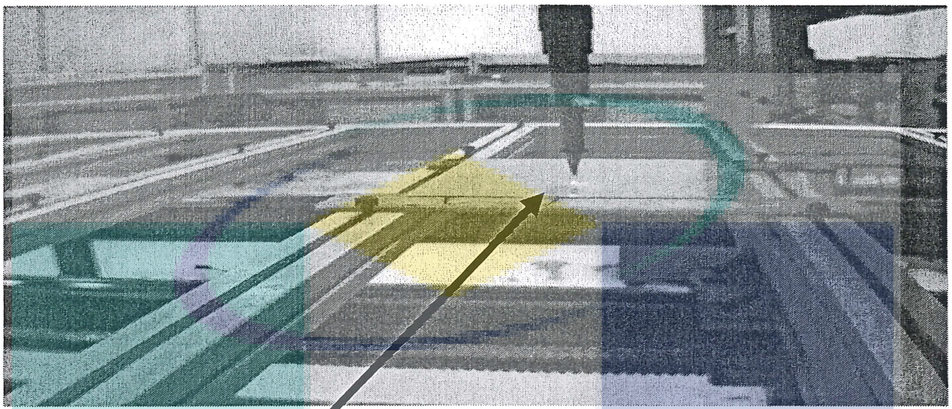
1. Gold Medal Research Award – Development of laser cutting and engraving machine utilizing PC-NC controller. International Exhibition Ideas- Inventions - Novelties, Nuremberg, Germany (IENA07). 2007.

2. Silver Medal Research Award – Development of laser cutting and engraving machine utilizing PC-NC controller. PECIPTA, Kuala Lumpur. 2007

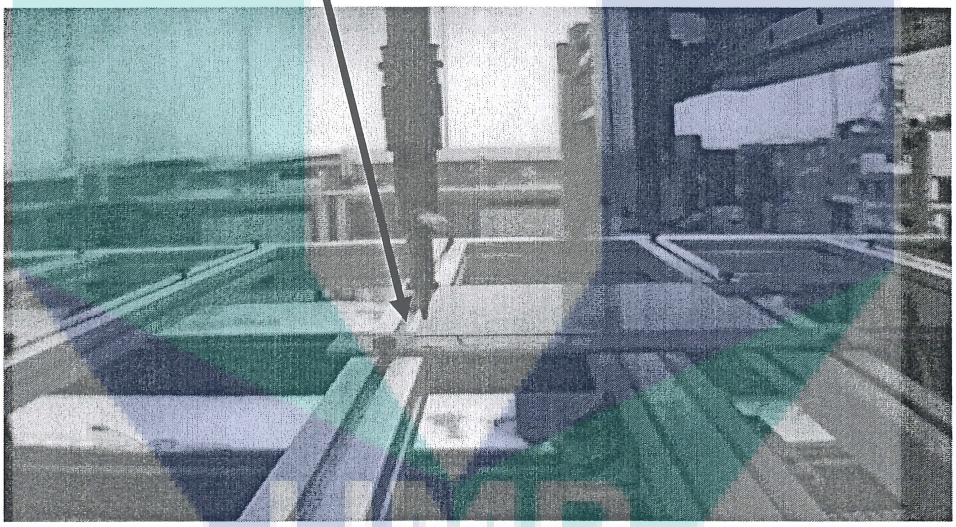
3. ECER exhibition – 26/10/07 ~ 1/11/07

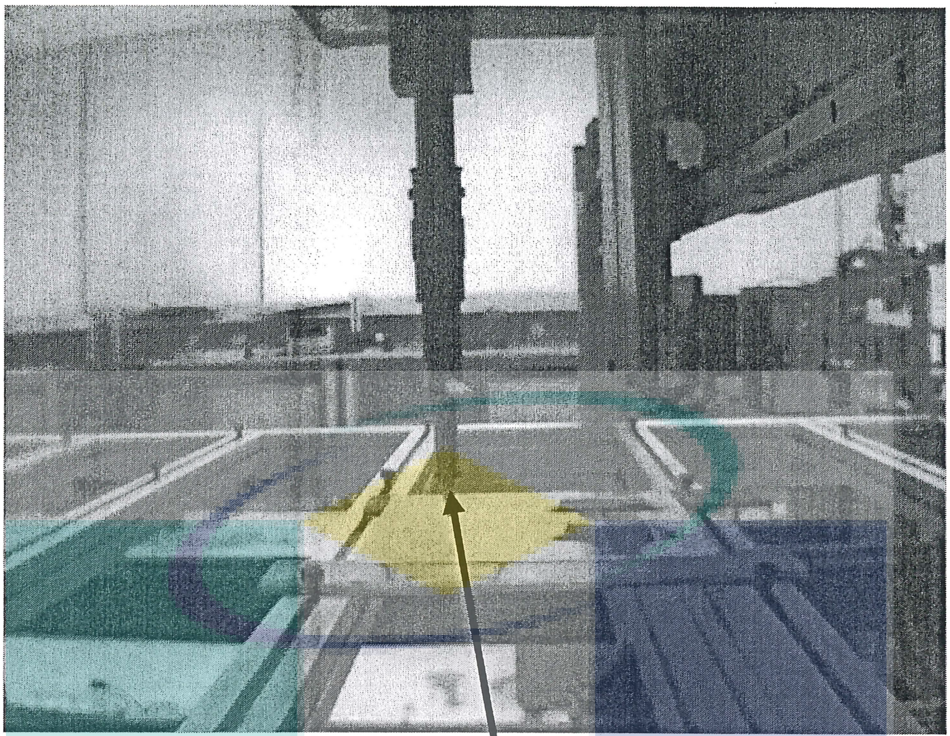
4. SMIDEC exhibition – 4/6/08 ~ 6/6/08

B. Photos



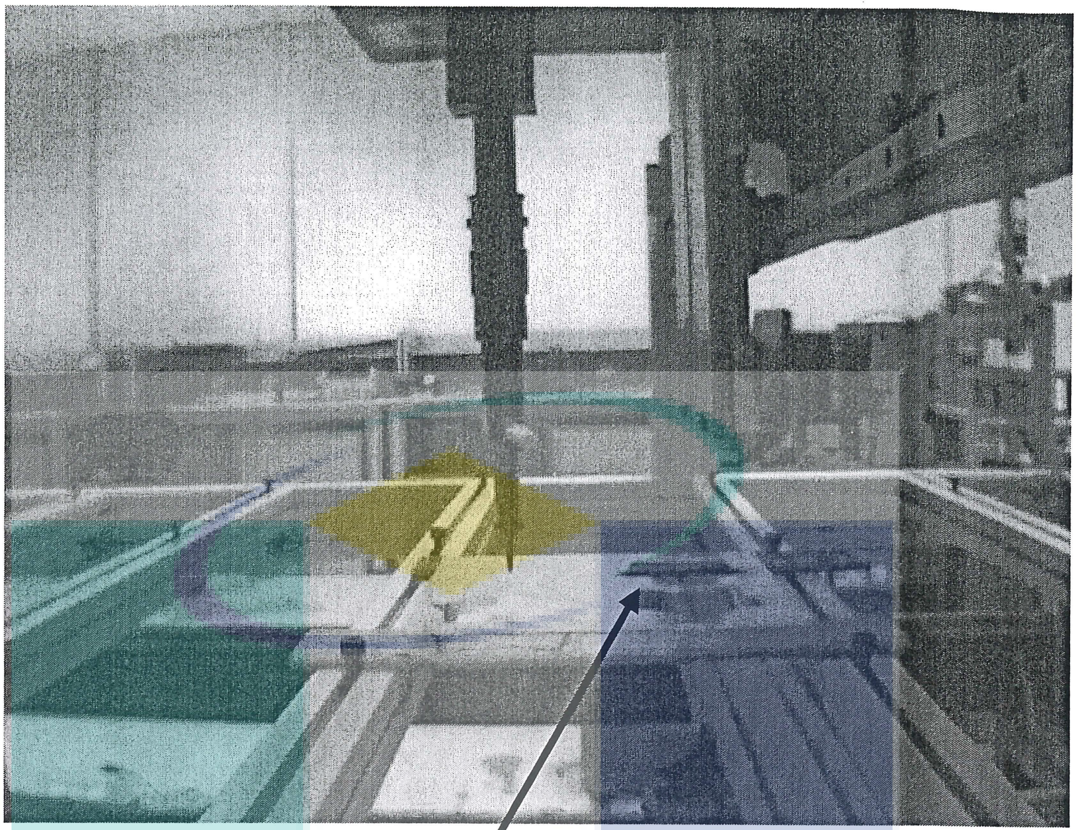
Laser is cutting acrylic





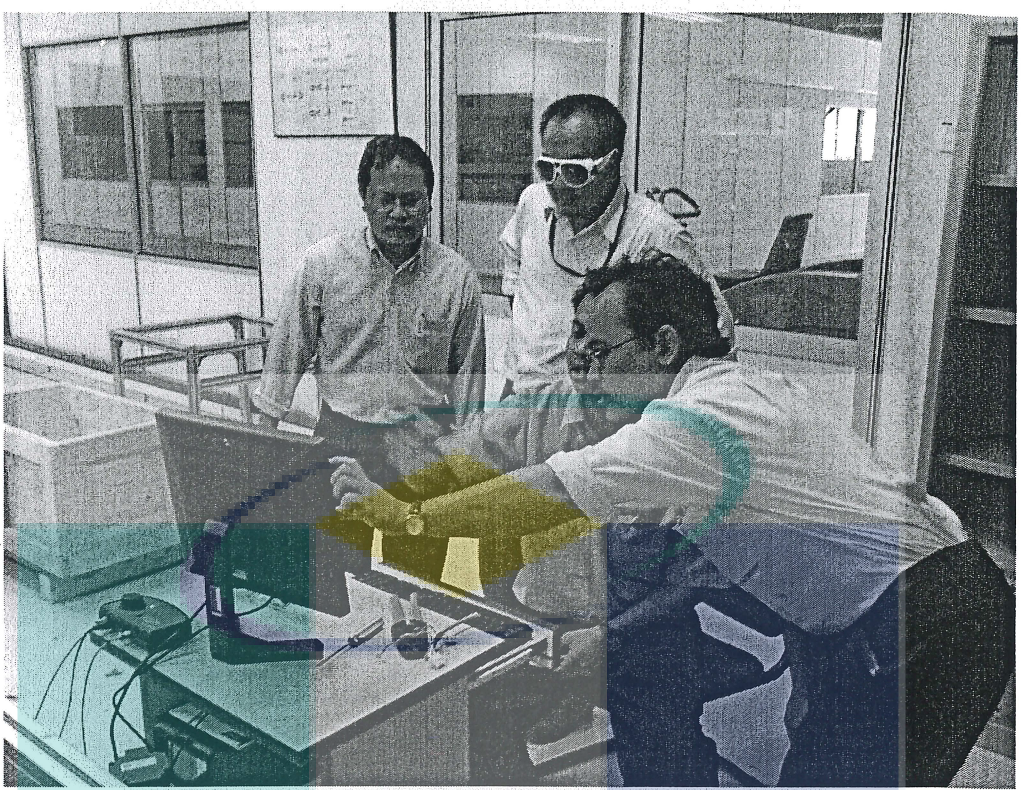
Laser lens

Laser source

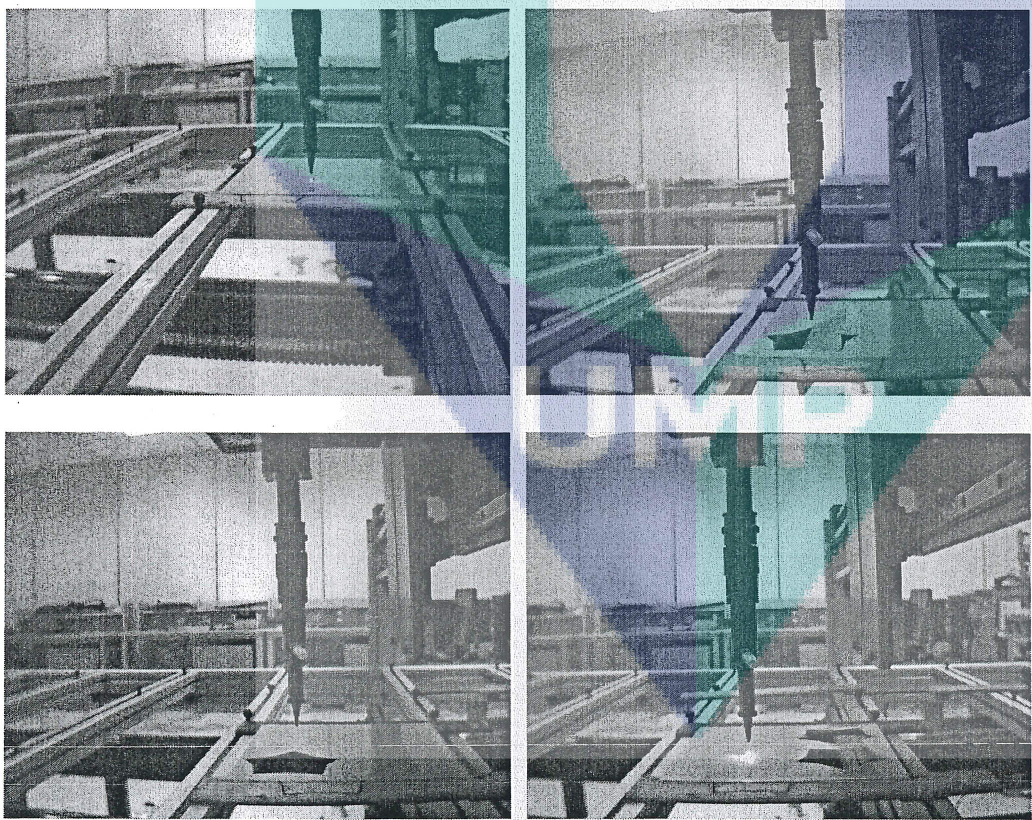


Sample of cutting

During laser installation

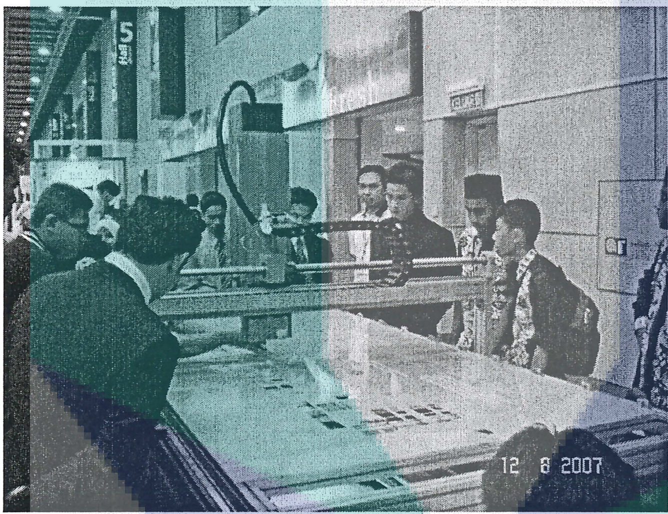


PC-NC and laser integration testing



Laser cutting processes

PECIPTA'07 Exhibition



PECIPTA'07 Exhibition

PECIPTA'07 Exhibition