Chapter

1

INTRODUCTION

1.1 Lasers in Materials Processing

The ability of a laser to deliver a high intensity beam of radiation which can be precisely beam steered by an inexpensive microcomputer system has revived a lot of attention on its use in the material working industry for sheet cutting, drilling, welding, heat treating, melting, etc. In cutting, the aim is to vaporise or melt the material so that the material can be removed as quickly as possible and produce as narrow a heat-affected zone as possible with a minimum distortion of the workpiece.

Among various applications, metallic materials cutting is the most popular accounting for approximation 80% of industrial laser applications. The reasons are as follows:

- Fine and high precision cutting due to the fact that laser beams can be focused onto very small spot, which cannot be achieved by press cutting and other contact processes
- Cutting of thick metal plates which cannot be cut by press cutting method
- High speed processing
- Low noise processing
- No tool wear due to contactless cutting. No tooling to design, build, test, maintain or modify
- Clean cut; cuts with smooth, bright oxide- and dross-free edges
- Kerf width is thinner than other thermal methods

- Ideal for prototyping
- Much better accuracy than plasma or flame cutting methods; Heat affected zone is small; Cut edges are nearly perpendicular; Uniform edge eliminates grinding and deburring
- Works well on diverse materials such as metals, wood and Plexiglass

1.2 Brief Review of the Development of Laser Cutters

The development of laser material processing was initiated by the development of the high power lasers. Today, the market of this application has thus far been dominated by just two types of lasers: carbon dioxide (CO_2) gas laser and Nd:YAG solid state laser[1]. Indeed, the major laser for cutting, i.e., the CO_2, laser was developed in 1963 by Patel[2,3]. Throughout the following decade, the output power of the CO_2 laser was improved from an initial level of a few milliwatts up to several tenths of kilowatts for commercial units, and 100kW at the laboratory level[4].

The fast-axial-flow laser[5] was first reported in 1969. The system was operated in an open-cycle manner. The active gas was rapidly flow through the discharge channel before removing to the atmosphere. According to a survey report presented by Locke[6], this operating configuration was later enhanced in 1976 to a partial closed-cycle configuration. Wastage was reduced significantly because there was only a very small amount of active gas being removed to the atmosphere while the rest was re-circulated. Also, the electrical discharge method has since been enhanced from the older DC-excited discharge to RF-excited and microwave-excited discharge[1]. Extensive research works are still being conducted in laser discharge channel, such as electrode configuration, turbulence and gas dynamics[7,8] besides improvement on the beam quality.

The application of a coaxial gas jet[9] for laser cutting was reported by Sullivan et al in 1967. For the following 10 years, industrial CO_2 laser was used mainly for non-metallic material cutting. In 1979, the effect of the polarisation[10,11] of the laser radiation on metal cutting was discovered and the technological obstacle of laser metal cutting was removed. It was pointed out that the cut rate can be almost doubled for the cut direction parallel with the plane of polarisation compared to when perpendicular to it. Soon after the discovery of this major parameter in laser metal cutting, the phase-shift reflective mirror becomes available, and so do the circularly polarised radiation being implemented in laser cutting. The development of the laser cut system for sheet metal oxylaser cutting has then grown rapidly and has become an important market for high-power laser manufacturers.

Powell[12] has reported on the possibility of achieving a totally smooth cut surface when the laser beam is pulsed at the natural frequency of the striation. In another study, the dependence of cut rate and cut quality in metal oxylaser cutting[12] to small quantity of inert gas mixed with the oxygen was demonstrated by Chen in 1992.

On the other hand, the laser cutting technology has not only depended on the development of laser sources and the processing techniques, it has also been facilitated and benefited from the development of the computer technology, i.e. inexpensive numerical controller (NC). The speed, the acceleration, the resolution of the NC-system and rigidity of the positioning system are highly required, besides the beam quality, in order to obtain good quality, precision and high cut rate in the laser cutting process.

The development of a zoom lens system for laser cutting applications has been reported by Arai[13] et al. An automatic zoom lens system for laser cutting with no need of optical axis readjustment has been developed to overcome drawbacks of conventional single-lens (fixed-focal-length lens) laser machine, which requires lenses with different focal lengths for different thicknesses of material. The use of aspheric lenses has been reviewed by Myler et al[14]. The depth of the focus can be enhanced by aspheric overcorrection without the need for a longer working distance optics. Several authors[15,16,17,18] have shown that the range of the process parameters, where a high cut quality can be obtained, expanded significantly by the use of the off-axis system in on-line beam positioning system and various gas jet nozzle configurations.

1.3 Research Objective

Although the laser material processing system is readily available in the market, there is room for the development of material handling technology of such high power laser systems. In this project, we have extended the scope of work of an earlier study by improving the design and integration of the x-y positioning system[19] with a home-built higher power CO_2 laser[20] system.

In an earlier study, a laser cutting system[19] was constructed based on a low power CO_2 laser with three laser tubes, and the fixed beam-moving workpiece configuration. There are several drawbacks in that development. Owing to the low laser output power (around 100W), the thickness and the types of cut materials were limited in that laser cutting system. Besides, the size of the workpiece was also constrained to half the length of the guide rail in each axis.

In another study, a fast axial flow (FAF) continuous wave (CW) CO_2 laser[20] was developed for an investigation of the effect of electrode configurations to the performance of laser output power. This laser is capable of delivering output power of around 300W.

The main objective is to construct a hybrid laser cutting system with a higher power CO_2 laser as the thermal source with nozzle-centring laser head and programming-free environment for material cutting. The fast axial flow CO_2 laser developed in the previous work[20] was adopted. Hybrid configuration was chosen so as to reduce the system size in one axis, and yet to avoid the critical optical alignment in the two-axis moving beam system. The system performance has been characterised and optimised. The system is used for studying the material cutting on various materials with various system parameters to investigate the best cut quality and cut rate achievable in this system for each material. Finally, the application of this system in the 2-D profile cutting of material was investigated.