Chapter

5

SUMMARY, CONCLUSION AND SUGGESTIONS FOR FURTHER STUDIES

5.1 Summary of Result

At the end of this project, a laser cutting system has been integrated and optimised for various profile cutting.

Initially, the structural design of the laser cutting system was carried out with AutoCAD Mechanical Desktop. The planning included materials selection and re-use of existing available components in order to minimise the research budget. A fast-axial-flow CO_2 laser was adopted and optimised for high output power. The beam delivery system and the laser head were designed and integrated to the entire system.

Thereafter, the hybrid positioning system was tuned for its *PIVF* parameters. Both the motions of the jig and beam delivery system were fined-tuned for smooth movement at high speed and acceleration. Interfacing software was developed to offer a user-friendly and programming-free operating environment for setting the profile cutting process.

Later, parametric studies on the dependence of the cut quality on various materials have been carried out. At last, the laser cutting system was tested in profile cutting. Various shapes were cut and the desired outline was achieved successfully.

5.2 Conclusion

The maximum laser output power was 280W with a gas composition of CO_2:N_2:He to be 1.2:6.7:92.0 ratio. When the operating pressure in the discharge tube is higher, the breakdown voltage across the plasma column has to be increased too. The efficiency of the laser system was improved and the maximum achievable laser output power was boosted. On the other hand, it narrowed down the operable voltage and the uniformity of glow discharge became more difficult to be maintained.

The specifications of the system performance are summarised in the table below.

Laser	
Type	Continuous-wave CO_2 Laser (wavelength 10.6μm)
Resonator Type	Fast-axial-flow
Laser Operating Gas	CO_2, N_2, He mixed gas
Max Output Power	300 watt
Beam Mode	TEM_{01}*
Beam Diameter	7mm
X-Y Motion	
Max Workpiece Size	550mm x 550mm
Rapid Traverse Rate	200mm s^{-1} (or 12 m/ min)
Max Acceleration	400mm s^{-2}
Optical Resolution	0.025 mm
Repeatability	0.1mm

Table 5-1: Specification of LaserCAM Laser Cutting System

Observations in the studies on the cut quality on various materials have led to the following conclusions. Generally, the kerf depth and kerf width are inversely proportional to the cut speed for all the materials tested. When the pressure of the assist gas is higher, the kerf depth and kerf width are increased as well. However, there is an exception when cutting wood with nitrogen gas jet. This is believed that the nitrogen has hindered the burning and therefore the cut penetration. Cutting with assist gas could improve the cut quality. For instance, cutting wood with nitrogen gas jet reduced the charring effect at the cut edge. Furthermore, cutting steel with oxygen gas jet enhanced the cut penetration due to the generated heat from the exothermic reaction at the cut spot. A summary of the cut penetration with respect to its cut parameters is outlined in Table 5-2.

Material	Range of Cut Speed	Assist gas	Thickness Range
Mild Steel	5mm s^{-1} to 30mm s^{-1}	4bar, 6bar and 8bar Oxygen	1mm to 8.5mm
Stainless Steel	5mm s^{-1} to 20mm s^{-1}	4bar, 6bar and 8bar Oxygen	0.8mm to 3mm
Stainless Steel	5mm s^{-1} to 20mm s^{-1}	2bar and 8bar Compressed air	0.5mm to 2.1mm
Pinewood	5mm s^{-1} to 100mm s^{-1}	2bar and 8bar Nitrogen	1.2mm to 18mm
Acrylic	5mm s^{-1} to 100mm s^{-1}	8bar Nitrogen	1.7mm to 12mm
Glass	40mm s^{-1} to 100mm s^{-1}	2bar and 8bar Nitrogen	0.1mm to 0.7mm

Table 5-2: Summary of the LaserCAM Cutting Performance with 250W CO_2 Laser

5.3 Suggestions for Further Studies

Generally, the performance of this laser cutting system could be enhanced from the laser system, the motion controller, the beam delivery system and the structural design of the jig.

Both theory and experiment have shown that at higher cut speed, there is partial melt around the laser beam and therefore reduces the cut quality[38]. In order to achieve high cutting rates with satisfactory cut quality, there should be a higher power density to provide steeper

temperature gradient around the cut spot. Hence, a laser system with higher output power is suggested to be developed and integrated to this laser cutting system. (Note: A four-tube FAF CO_2 laser system with 650W has since been developed and integrated to the system. An eight-tube system is currently under development.) A laser system with 1kW or 2kW laser output power[25, 39] is recommended as this is the typical power range in the commercial laser cutting systems. Besides offering higher cut rates, higher laser power would also enable cutting on more types of material, e.g., marble, glass, alloy, aluminium, etc. For instance, cutting of marble is made possible with 400W laser power[40].

A laser system which produces circular-polarised radiation[10,11] is also suggested to be deployed in the future development so that to maintain high cut quality in all cut directions throughout the cut profile.

Introducing a power supply that is capable to produce super-pulse or hyper-pulse would modify the profile of the laser output power, and therefore would improve the cut quality on high reflectivity materials[12,41] and on sharp contour where the velocity of the beam movement reduces at high curvature.

In order to hold and cut the standard-sized workpiece which is 8' x 4', a bigger jig is recommended to be designed and integrated to the laser cutting system. Owing to that, a servomotor with higher torque needs to be incorporated to the system to drive the additional load.

Improvement could also be carried out on the laser head by deploying a zoom lens system[13] and automatic positioning[42,43] capability. This would facilitate the cutting process instead of manually adjusting the laser head height with various thicknesses of the cut materials.