Original Research Article

A MODEL FOR CALCULATING THE MACHINING TIME OF A LASER CUTTING MACHINE

Abstract

Laser cutting machine cuts a given profile with precision and accuracy that cannot be compared with other CNC cutting machines. This is made possible because the laser cutting beam forms a thin kerf of about 0.15mm during the cutting process. The heat affected zone (HAZ) on the material is also minimal. One of the commonly asked questions by our clients is, "how long would it take to cut this profile." The inability of the cutting software to predict the machining or cutting time becomes a challenge for the operator. In this paper, a model formula was developed relating speed and profile length to machining time. The actual machining time of five different profiles were obtained from the HG LCY 300 laser cutting machine and compared to the calculated machining time obtained using the model formula. By comparison, the slight differences between the actual and the calculated machining time are just in milli-seconds; this suggests that the model formula is valid and can be employed by laser cutting machine operators to predict the machining time for profilesto be cut even before cutting process commences.

KEYWORDS*: Laser cutting, Profile length, HAZ, Machining time, cutting software, Model formula*

Introduction

The term "LASER" is an acronym for Light Amplification by Stimulated Emission of Radiation". Over the past decade, laser cutting has developed into state-of-the-art technology. It is estimated that more than 25,000 cutting systems are used for the high-power cutting of metals and non-metals worldwide [1]. Laser cutting machines are used in workshops for cutting work piece since mild steel is a daily used material and dominantly used in the laser cutting industry [4].

The technology adopted in this laser machine involves amplification of light on a material which when focused on a work piece cuts a given profile. A high intensity beam of infrared light is generated by a laser. This beam is focused onto the surface of the workpiece by means of a lens. The focused beam heats the material and establishes a very localized melt (generally smaller than 0.5 mm in diameter) throughout the depth of the sheet. The molten material is ejected from the area by pressurized gas jet acting coaxially with the laser beam. (With certain materials this gas jet can accelerate the cutting process by doing chemical as well as physical work. For example, Carbon or mild steels are generally cut in a jet of pure oxygen. The oxidation process initiated by the laser heating generates its own heat and this substantially improves the efficiency of the process). The localized area of material removal is extended across the surface of the sheet thus generating a cut [12].

Laser pulse, frequency and discharged current control the beam quality while the cutting speed and *assist gas* control the cutting process. An invisible and almost parallel beam is generated in the laser source, re-directed by mirrors and focused by a lens to a small spot on the surface of the work piece.The CNC 2000 software coordinates the beam and the process parameters. By contour cutting 2-D thin sheet parts the use of machines with X-Y table coordinate is effective and real when CNC control unit is used for control. It is often a multi-axismechanical system which permits linear movements. The CNC is claimed to be superior to types conventionally used in the manufacture of machine tools. It is up to 10 times faster, compensates for overrun errors, adapts the programmed laser power to the processing speed, controls the cutting gas pressure and the laser parameters. CNC laser-cutting machine offers an optimal solution to cut all kinds of sheet materials economically [10].

Laser is a beam with high brightness, high power and very good direction.The laser cutting excels in applications requiring high productivity, high edge quality and minimum waste, due to the fast and precise cutting process [5, 6].

The laser machines used in workshops are of CLASS 4 type; the light this laser system produces, whose wave length is close to infrared light, is invisible, therefore, more attention needs to be paid to safety protection when using the system in the work place [7, 8, 9].

Laser cutting machine cuts a given profile with precision and accuracy that cannot be compared with other CNC cutting machines. This is made possible because the laser cutting beam forms a thin kerf of about 0.15 mm during the cutting process. The heat affected zone (HAZ) on the material is also minimal because of the thin kerf and the *assist gas* used [2, 3, 11]. The laser cutting technology has actually made industrial cutting of mild, silicon and carbon steel plates easy since the profile can be drawn in AUTOCAD and imported to the laser cutting machine for implementation.

The inclusion of machining time in the cutting software of the laser cutting machine would make its features complete and excellent. The task undertaken in this work is to develop a model for calculating the machining time of the laser cutting machine using the HG LCY 300 model.

Methodology

The resolution of the stepper motors used for the worktable is first determined by cutting out a circle of radius 20 mm on a 2 mm mild steel plate and taking the machining or completion time at different speeds. A relationship is then established to convert the profile length to number of revolution using the stepper motor's resolution obtained. The machining time is then obtained as a variable that depends on the cutting speed, profile length and stepper motor's resolution. The last step was to carry out validation test of the model formula; five different profiles/samples were cut at selected speeds and their actual machining times were recorded; the calculated machining times were also obtained using the model formula. The results obtained for actual and calculated machining time were tabulated and compared to see the extent to which the model formula is valid.

Resolution of the stepper motor

There are two stepper motors attached to the worktable. The movement of the table in both x and y axes are carried out by each of these motors [9]. The table can move 500 mm in both directions. Speed selection during the cutting process is effected on the worktable. If a cutting speed is selected to cut a particular profile, using work piece of different thicknesses, the machining time will be the same.Therefore, it was assumed that there is a constant value that makes this possible, which is referred to as the “resolution of the stepper motor (R)”

To get the resolution R of the stepper motor, the following data were taken while cutting out a circular profile of radius 20 mm from a 2mm thick mild steel plate:

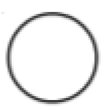

Fig 1: Profile sample

Radius = 20 mm

Profile length = πD

= 125.68 mm

Table 1: Machining time for cutting profile sample

Speed(Rev/min)	Machining time(s)
60	126
120	63
180	42
240	31

- Relating machining time to profile length and number of revolution

126 s $\approx$ 125.68 mm at 60rev/min

$$1\ \text{s} \approx \frac{125.68}{126}\text{mm}$$

1 s $\approx$ 0.9975 mm at 60rev/min

Also,

60 rev $\approx$ 1 min

60 rev $\approx$60 s

1 rev$\approx$ 1 s

Therefore,

1 rev$\approx$ 1 s$\approx$ 0.9975 mm

This means that the stepper motor makes 1 revolution in 1 second and a linear movement of 0.9975 mm at the same time. This is the resolution R of the stepper motor.

- Converting profile length to number of revolution

Since the profile length is determinable, there is need to convert it from linear value to number of revolution made in cutting the profile. Using the deduction made from the resolution of the stepper motor, we can conclude that,

1 rev$\approx$ 0.9975 mm

X rev $\approx$ profile length in mm

Therefore,

$$\text{X rev} \approx \frac{profile\ length}{0.9975} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ (1)$$

Where X rev is the number of revolutions made by the stepper motor for a given profile length.

- Model formula for calculating machining time

Linear speed is given as the rate of change of distance moved with time, i.e.

$$\text{Speed} = \frac{Distance}{Time} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (2)$$

But in the case of HG Laser LCY 300 model, the cutting speed is given in revolution per minute, (rev/min), i.e.

$$\text{Speed} = \frac{Number\ of\ revolution}{Time\ (min)} \ldots\ldots\ldots\ldots\ (3)$$

Therefore, machining time (T) in second is,

$$T = \frac{Number\ of\ revolution\ X\ 60}{Speed} \ldots\ldots\ldots\ldots\ldots (4)$$

Substituting equation (1) for number of revolution in (4), we have,

$$T = \frac{Profile\ length\ X\ 60}{Speed\ X\ 0.9975} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Equation (5) is the model formula for calculating machining time in second for a given profile length.

Validation of the model formula

The model formula was used to calculate the machining time for profiles 1 to 5 shown in fig 2. The result obtained were then tabulated and compared to the actual machining time recorded in the process of cutting. The results are shown in table 2.

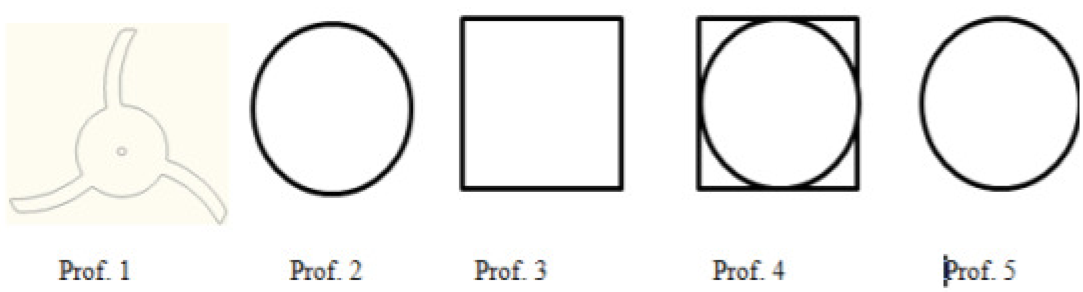

Fig 2: Test profiles

Profile 1 has a length of 58.56mm

Profile 2 has a radius of 4mm with a length of 25.136mm

Profile 3 has side 10mm each with a length of 40mm

Profile 4 has a circle of radius 5mm inscribed in a square of side 10mm each with a total length of 71.42mm

Profile 5 has a radius of 20mm with a length of 125.68mm

Table 2: Results for actual and calculated machining time for prof. 1 to 5

Profile number	**Speed(rev/min)**	**Actual machining time (T_A)**	**Calculated machining time (T_C)**
1	50	70.0	70.44
	100	35.0	35.22
	150	23.0	23.48
	200	17.0	17.61
2	60	25.0	25.19
	100	15.0	15.11
	150	9.0	10.08
	200	7.0	7.56
3	60	40.0	40.0
	120	20.0	20.05
	150	15.0	16.04
	200	12.0	12.03
4	60	72.0	71.42
	80	54.0	53.70
	120	36.0	35.80
	200	22.0	21.40
5	60	126.0	125.99
	120	63.0	63.00
	180	42.0	42.00
	240	31.0	31.50

Conclusion

Comparing the results, it was observed that there is a slight difference, in the order of milli-seconds, between the actual and calculated machining time. This is probably due to the fact that the laser cutting machine is not designed to recognize machining time in decimal values. It actually rounds up the cutting time to the nearest whole number. Therefore, rounding up the calculated machining time to the nearest whole number makes it exactly the same as the actual machining time.Since there is only a slight difference between the actual and calculated machining time, the model formula can be said to be valid. It is therefore recommended that it be written in software to be able to determine the profile length of an imported sample with the aim of predicting the machining time. The HG LCY 300 laser cutting machine executes the cutting process through cnc 2000 cutting software which could be upgraded to include machining time prediction for a given profile length using the formula.

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