Original Research Article

1
2 **A MODEL FOR CALCULATING THE MACHINING**

3 **TIME OF A LASER CUTTING MACHINE**

4

5 **Abstract**

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

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

20 **Introduction**

21 The term "LASER" is an acronym for Light Amplification by Stimulated Emission of
22 Radiation". Over the past decade, laser cutting has developed into state-of-the-art technology. It
23 is estimated that more than 25,000 cutting systems are used for the high-power cutting of metals
24 and non-metals worldwide [1]. Laser cutting machines are used in workshops for cutting work
25 piece since mild steel is a daily used material and dominantly used in the laser cutting industry
26 [4].

27 The technology adopted in this laser machine involves amplification of light on a material which
28 when focused on a work piece cuts a given profile. A high intensity beam of infrared light is
29 generated by a laser. This beam is focused onto the surface of the workpiece by means of a lens.
30 The focused beam heats the material and establishes a very localized melt (generally smaller than
31 0.5 mm in diameter) throughout the depth of the sheet. The molten material is ejected from the
32 area by pressurized gas jet acting coaxially with the laser beam. (With certain materials this gas
33 jet can accelerate the cutting process by doing chemical as well as physical work. For example,
34 Carbon or mild steels are generally cut in a jet of pure oxygen. The oxidation process initiated by
35 the laser heating generates its own heat and this substantially improves the efficiency of the

36   process). The localized area of material removal is extended across the surface of the sheet thus
37   generating a cut [12].

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

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

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

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

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

65   **Methodology**

66   The resolution of the stepper motors used for the worktable is first determined by cutting out a
67   circle of radius 20 mm on a 2 mm mild steel plate and taking the machining or completion time
68   at different speeds. A relationship is then established to convert the profile length to number of
69   revolution using the stepper motor's resolution obtained. The machining time is then obtained as
70   a variable that depends on the cutting speed, profile length and stepper motor's resolution. The
71   last step was to carry out validation test of the model formula; five different profiles/samples

72 were cut at selected speeds and their actual machining times were recorded; the calculated
73 machining times were also obtained using the model formula. The results obtained for actual and
74 calculated machining time were tabulated and compared to see the extent to which the model
75 formula is valid.

76 **Resolution of the stepper motor**

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

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

85

86 Fig 1: Profile sample

87 Radius = 20 mm

88 Profile length $= \pi D$

89      $= 125.68$ mm

90 Table 1: Machining time for cutting profile sample

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

91

92 • Relating machining time to profile length and number of revolution

93   126 s $\approx$ 125.68 mm at 60rev/min

94 $1 s \approx \dfrac{125.68}{126} mm$

95   1 s $\approx$ 0.9975 mm at 60rev/min

96   Also,

97   60 rev $\approx$ 1 min

98   ~~60 rev ≈60 s~~

99   1 rev$\approx$ 1 s

100   Therefore,

101   1 rev$\approx$ 1 s$\approx$ 0.9975 mm

102   ~~This means that the stepper motor makes 1 revolution in 1 second and a linear movement of~~
103   ~~0.9975 mm at the same time.~~ This is the resolution R of the stepper motor.

104   • Converting profile length to number of revolution

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

108   1 rev$\approx$ 0.9975 mm

109   X rev $\approx$ profile length in mm

110   Therefore,

111   X rev $\approx \dfrac{profile\ length}{0.9975}$ ………………… (1)

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

113

114   • Model formula for calculating machining time

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

116         $\text{Speed} = \dfrac{Distance}{Time}$……………………………… (2)

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

119         $\text{Speed} = \dfrac{Number\ of\ revolution}{Time\ (min)}$………………… (3)

120   Therefore, machining time (T) in second is,

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

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

123

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

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

127   **Validation of the model formula**

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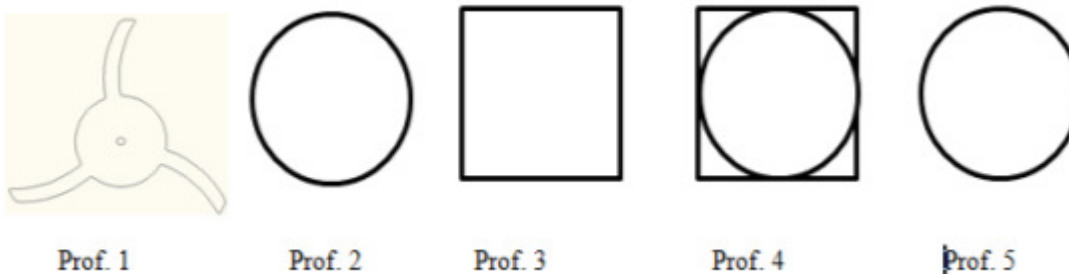130   the process of cutting. The results are shown in table 2.

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| Prof. 1 | Prof. 2 | Prof. 3 | Prof. 4 | Prof. 5 |

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134   Fig 2: Test profiles

135   Profile 1 has a length of 58.56mm

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

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

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

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

141   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

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143   **Conclusion**

144   Comparing the results, it was observed that there is a slight difference, in the order of milli-
145   seconds, between the actual and calculated machining time. This is probably due to the fact that
146   the laser cutting machine is not designed to recognize machining time in decimal values. It
147   actually rounds up the cutting time to the nearest whole number. Therefore, rounding up the
148   calculated machining time to the nearest whole number makes it exactly the same as the actual
149   machining time.Since there is only a slight difference between the actual and calculated
150   machining time, the model formula can be said to be valid. It is therefore recommended that it
151   be written in software to be able to determine the profile length of an imported sample with the
152   aim of predicting the machining time. The HG LCY 300 laser cutting machine executes the

153   cutting process through cnc 2000 cutting software which could be upgraded to include
154   machining time prediction for a given profile length using the formula.

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