

COMPUTER AIDED PART PROGRAM GENERATION FOR A LASER CUTTING MACHINE

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Abstract

In this study, a complete software package for the automatic part program generation for a CNC laser cutting machine is developed. The basic workpiece geometry (flat surface, cylinder and cone) and features on the geometry (line, arc, hole, ellipse, polygon, and rectangle) are defined interactively. Using the complete geometrical and dimensional information, cutter motion coordinates (CL Data-Cutter Location Data) are calculated, and from this information appropriate G-codes are produced for a Huffman Nd:YAG Laser Cutting Machine. Interactions with the program are supported through a user-friendly, graphical interface. The computer system used in this study is Borland's "Delphi" object-oriented program development package.

BİR LAZER KESME TEZGAHI İÇİN BİLGİSAYAR DESTEKLİ PARÇA PROGRAMI OLUŞTURULMASI

Özetçe

Bu çalışmada, bir CNC lazer kesme tezgahında kullanılmak üzere otomatik olarak parça programı oluşturan bir bilgisayar yazılım paketi geliştirilmiştir. Temel iş parçası geometrisi (düzelem yüzey, silindir, veya koni) ve bu iş parçası üzerindeki elemanlar etkileşimli olarak tanımlanmaktadır. İş parçasının geometric ve boyutsal bilgileri kullanılarak kesici ucun izleyeceği koordinatlar hesaplanmaktadır (CL Data). Kesici uç koordinatları kullanılarak Huffman Nd:YAG lazer kesme tezgahı için G-kod parça programı üretilmektedir. Kullanıcı ile grafik

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ara-yüz aracılığı ile iletişim kurulmaktadır. Bilgisayar programı, Borland "Delphi" programlama paketi kullanılarak geliştirilmiştir.

Keywords: G-code programming, postprocessors, computer aided manufacturing (CAM).

Anahtar Kelimeler: G-kod programlama, son-işlemciler, bilgisayar destekli imalat.

1. INTRODUCTION

The Electronic Industries Association (EIA) defines numerical control (NC) as "a system in which actions are controlled by the direct insertion of numerical data at some point." More specifically, numerical control, or NC, involves machines controlled by electronic systems designed to accept numerical data and other instructions, usually in a coded form consisting of numbers, letters, and other symbols. These instructions may come directly from some source such as punched tape, a floppy disk, directly from a computer, or from an operator. The key to the success of numerical control lies in its flexibility. To machine a different part, it is only necessary to play a different tape. NC machines are more productive than conventional equipment and consequently produce parts at less cost even when the higher investment is considered. NC machines also are more accurate and produce far less scrap than their conventional counterparts. Numerical control is applied to a wide range of manufacturing processes such as metal cutting, punch presses, EDM wire cutting machines, inspection machines, laser and other cutting and torching machines, tube bending machines, and sheet metal cutting and forming machines. These machines are also called CNC (Computer Numerical Control) Machines. The purpose of this study is to develop a computer program to generate G codes automatically, depending on the technical drawing of the workpiece, for a CNC laser cutting machine. The main objective is to give support to the manufacturing engineer during manufacturing process, because preparing the G codes for CNC machines is important, difficult and time consuming step of the manufacturing process. The program has been developed for a Huffman Nd:YAG Laser Cutting Machine located in a

maintenance center. A computer program is developed to generate G codes automatically. The program has been written in Delphi. A user-friendly graphical interface is supplied for the convenience of the user.

2. CNC Laser Cutting Machine Specification and NC Programming

2.1 CNC Laser Cutting Machine Specifications

The CNC laser cutting machine, used for this study, is a Nd: YAG (neodymium:yttrium aluminum garnet) solid-state laser machine. This machine was manufactured by S.E. Huffman Co. at 1988 and it has 400 Watts power. Its CNC control unit was manufactured by General Electric Industrial Control Systems and it has a GE 2000 CNC control unit. It has five axis X,Y,Z for linear motion and A,C for rotary axis.

2.2 NC Programming

Programs written to operate NC machines with control systems that comply with the ANSI/EIA RS 274-D standart consist of a series of data blocks, each of which is treated as a unit by the controller and contains enough information for a complete command to be carried out by the machine. Each block is made up of one or more words that indicate to the control system how its corresponding action is to be performed. These words are called as in Table 1.

Word	Explanation	Word	Explanation
N	Sequence Number	A/B/C	Rotary Motion Word
G	Preparatory Word	F	Feedrate Word
X/Y/Z	Linear Motion Word	E	Fixture Offset Word
R	Radius Dimension	M	Miscellaneous Word
P	Parameter Word	S	Number of Shots
H	Pulse Rate	V	Voltage
W	Pulse selection Number	E	Fixture Offset Word

Table 1: NC Program Words

3. SYSTEM DEVELOPMENT

In this study, a computer program called LaserCAM, is developed to generate G-codes automatically for a CNC laser cutting machine. The program has been prepared in Delphi. Delphi is an object-oriented programming language and has powerful programming facilities.

3.1 Program Development

The program consists of mainly two sections: Part description and Processing (CL Data generation and Postprocessing).

Part description is the collection of all data necessary to define the workpiece shape such as cylinder, cone, or other, laser specifications and elements that will be machined. Processing section is divided into two sections: CL data generation and postprocessing. The CL data is the cutter location data (cutter path) and is generated using the input workpiece description. Postprocessing is the generation of the appropriate G-codes from the CL data. Figure 1 shows the main screen of the program. The main screen contains several pull-down menus related to file manipulations, workpiece definition, processing requirements, viewing options, and help.

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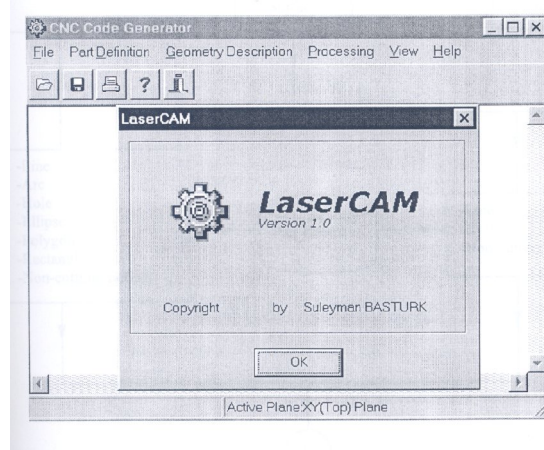


Figure. 1: Main screen and main menu

Simple flowchart of the program is given in Figure 2.

3.2 Part Description Section

All the information needed to define the part is input in this section. Part name, workpiece shape, laser specifications, geometry description (line, arc, hole, polygon, ellipse, rectangle) are some of these information. They are described in detail in the following sections.

3.2.1 System Definition

First step is to define the part name and basic parameters such as measurement unit, cutting speed, non-cutting speed, dwell time (used before opening of the laser and after closing of the laser for system stability), and sequence number increment. These parameters are input from System Definition screen.

3.2.2 Plane Selection

Second step is to choose working plane from the plane selection screen. In other words, the plane on which the laser cutting machine will cut the predefined elements. The appropriate values for workpiece zero and plane zero are entered on the other subscreen which is called by double-clicking the appropriate figure. The values entered in these screen are organized in the database according to plane selection.

3.2.3 Laser Specifications

There are default values for voltage, pulse rate, and pulse selection number. If “Use Multishot” checkbox is checked then Number of Shot (S) value becomes active and a value is requested from the user.

3.2.4 Cutting Shape Definitions

Cutting shape would be identified using different kind of screens according to its type of shape such as line, arc, hole, linear hole pattern,

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circular hole pattern, ellipse, rectangle and, non-cutting motion. If the working plane cylinder or cone then different screens will be used for the shape definition. Figure 3 shows some of these screens. All these data will be collected into a database so that they can be used for the postprocessing.



Figure. 3: Some Shape Definition Screens.

3.3 Processing Section

Processing section is divided into two sections; CL Data Generation and Postprocessing. CL Data is cutter location data (cutter path) and generated using the part data collected previous section. Postprocessing is generating the appropriate G-Codes using this CL data.

3.3.1 CL Data Generation

CL data generation is the generation of the laser head path in X, Y, Z, C, and A axes. When “CL Data Generation...” menu is activated, the program reads all records from the part database, calculates the cutter location points, and stores the output in another database called “Cutter Location Data”. In CL data, columns labeled with X-A indicate axis values, R indicates the radius of arc or hole, and V, W, H and S values indicate the laser specifications. The CL data generation operation must be performed before every postprocessing operation.

3.3.2 Postprocessing Section

To start postprocessing operation, the user must select “Postprocessing..” pull-down menu. Program Name, Program Position Preset, Air/Gas selection and Fixture Offset Values are entered on the upcoming screen. G-code program is generated as a text file and the name of the file is prompted from the user. Two subprograms are generated for creating a hole. If the hole is created by cutting, i.e. by making a circular motion, a subprogram with the extension of “CNCSUB” is generated. If the hole is created by shotting, then a subprogram with the extension of “CNCSShot” is generated automatically. These subprograms are parametric subprograms and they are used for every main G-code program.

4. Case Studies

4.1. Case Study I

A theoretical workpiece is designed to show the capabilities of the program. The workpiece is a sheet metal with 0.76 mm (0.030 inch) thickness. Technical drawing of the workpiece is shown in Figure 4. The basic features that exist on the workpiece are a rectangle, an ellipse, a polygon, a hole pattern, two lines, and an arc. Lower left corner of the workpiece is taken as the workpiece zero. The data will be input with respect to this zero.

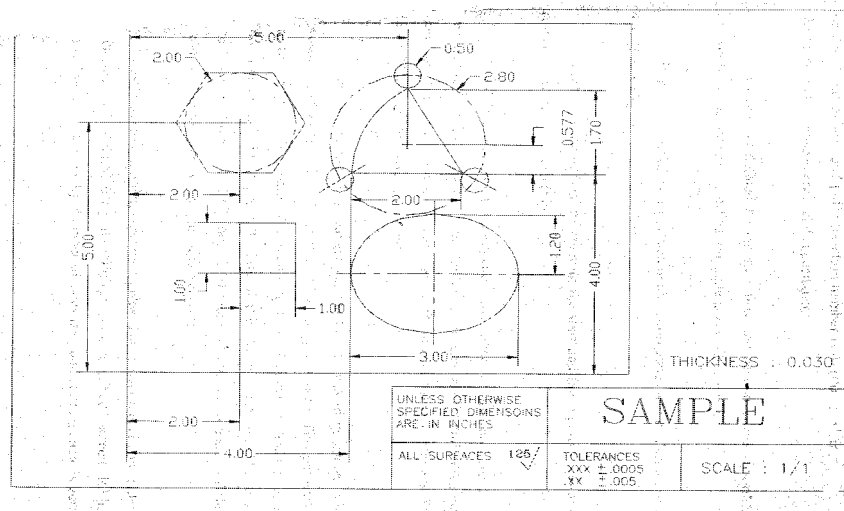


Figure 4: Technical Drawing of the Case Study I

After defining the all elements on the drawing to the LaserCAM, the program generates following main program and one subprogram. Subprogram is generated for creating holes.

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```
N10 (ID,PROG,ex1)
N20 G70
N30 G90
N40 G92 X0 Y0 Z0
N50 G90 G53
N60 G00 X0 Y0 Z24 A0 C0
N70 V1800 W4 H11 M28
N80 (FMT1,FOV(X),FOV(Y),FOV(Z))
N90 (STO,11,FMT1,0,0,0)
N100 G43 G42 G01 X2 Y2 Z0 E11 F50
N110 M07 G04 X2
N120 M04
N130 M03
N140 G21 Y3 F5
N150 G21 X3
N160 G21 Y2
N170 G21 X2
N180 M05 G04 X2
N190 G40
N200 G43 G42 G01 X4 E11
N210 M07 G04 X2
N220 M04
N230 M03
N240 G17 G22 X4.48 Y2.83138 R0.96
N250 G17 G22 X6.52 R1.875
N260 G17 G22 Y1.16862 R0.96
N270 G17 G22 X4.48 R1.875
N280 G17 G22 X4 Y2 R0.96
N290 M05 G04 X2
N300 G40
N310 G43 G42 G01 X5 Y5.7 E11
N320 M07 G04 X2
N330 M04
N340 M03
N350 G21 X6 Y4
N360 G21 X4
N370 G17 G22 X5 Y5.7 R1.97231
N380 M05 G04 X2
N390 G40
N400 P15=0 !C Axis Revolution
N410 P12=5 !Cutting Speed
N420 P11=0.25 !Hole Radius
N430 G43 G42 G01 Y5.977 E11
N440 (GSUB,SUBDEL)
N450 G40
N460 G43 G42 G01 X3.78756 Y3.877 E11
N470 (GSUB,SUBDEL)
N480 G40
N490 G43 G42 G01 X6.21244 Y3.877 E11
N500 (GSUB,SUBDEL)
N510 G40
N520 G43 G42 G01 X3.1547 Y5 E11
N530 M07 G04 X2
N540 M04
N550 M03
N560 G21 X2.57735 Y4
N570 G21 X1.42265
N580 G21 X0.845299 Y5
N590 G21 X1.42265 Y6
N600 G21 X2.57735
N610 G21 X3.1547 Y5
N620 M05 G04 X2
N630 G40
N640 M09 M05 G04 X2
N650 V600
N660 G90 G00 Z10
N670 G90 G0 Z24 X0.0 Y-11.999 C0 A0
N680 E0
N690 M30
N9999 (END,PROG)
```

The subprogram as is follows:

```
N10 (ID,GSUB,SUBDEL)
/N20 M07 G04 X2
/N30 G21 G91 X(-P11) F(P12)
/N50 M03
/N60 G22 X0 Y0 I(P11)
N70 M05 G04 X2
/N80 G91 G21 X(P11) F15
N90 G91 G0 C(P15)
N100 G90
N9999 (END,GSUB)
```

4.2 Case Study II

Case II is an aircraft engine combustion chamber part (Figure 5). There are number of circular hole patterns around the chamber.

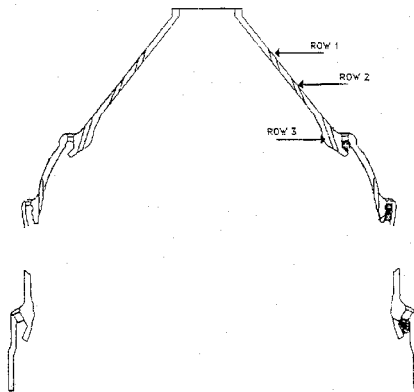


Figure 5: Case Study II

After defining the all elements on the drawing to the LaserCAM, the program generates following main program and two subprograms. Subprograms are generated for creating holes.

N10 (ID,PROG,ex2)	N180 G90
N20 G70	N190 G92 X0 Y0 Z0
N30 G90	N200 G90 G53
N40 G92 X0 Y0 Z0	N210 G00 X0 Y0 Z24 A56 C0
N50 G90 G53	N220 G54 Y-4.16383 Z3.76734
N60 G00 X0 Y0 Z24 A56 C0	N230 P15=(360/105) !C Axis Revolutio
N70 G54 Y-4.41955 Z3.76734	N240 G01 Z0 C0 A-19 E11
N80 V1800 W2 H8 M26 S20	N250 (GSUB,SUBSHOTDEL) P0=105
N90 (FMT1,FOV(X),FOV(Y),FOV(Z))	N260 M05 G04 X2
N100 (STO,11,FMT1,0,0,0)	N270 G70
N110 G90 G53	N280 G90
N120 G54 Y-1.9914 Z-1.85244	N290 G92 X0 Y0 Z0
N130 P15=(360/105) !C Axis Revolutio	N300 G90 G53
N140 G01 Z0 C1.7144 A-19 E11 F50	N310 G00 X0 Y0 Z24 A56 C0
N150 (GSUB,SUBSHOTDEL) P0=105	N320 G54 Y-3.70788 Z3.76734
N160 M05 G04 X2	N330 V1800 W2 H8 M28
N170 G70	N340 P12=5 !Cutting Speed

The subprogram as is follows:

```
N350 P11=0.01875 !Hole Radius
N360 P12=5 !Cutting Speed
N370 P15=(360/140) !C Axis Revolution
N380 G43 G42 G01 Z0 C1.2855 A-19 E11
N390 (GSUB,SUBDEL) P0=140
N400 G40
N410 M09 M05 G04 X2
N420 V600
N430 G90 G00 Z10
N440 G90 G0 Z24 X0.0 Y-11.999 C0 A0
N450 E0
N460 M30
N9999 (END,PROG)
```

5 DISCUSSION

The software developed in this study is a computer-aided part program (G-Codes) generation for Huffman CNC Laser Cutting Machine. The program generates appropriate G-codes automatically for a given workpiece. Some advantages of the program are:

- Operating the program is simple.
- Geometric elements on any workpiece shape (cylinder, cone, or any flat plane) can be defined.
- Basic geometric elements (line, arc, hole, ellipse, rectangle, polygon) are available for part definition.
- Input part data can be converted to a text file for the usage of other program.
- According to a data obtained from the programmers, it takes approximately one hour to prepare the part program for the part given in the case study II. However, approximately it takes ten minutes to produce the

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same program using the developed program, LaserCAM. Thus, the program reduces the part program preparation time.

- Preparation of G-codes manually is also prone to make errors such as calculation errors, wrong G-code usage, and so on. However, the generation of G-codes automatically prevents the formation of such errors.

- G-codes are generated as a text file. This text file can be exported directly to the CNC laser cutting machine control system using a simple data transfer socket, such as RS232.

As a result, preparing part programs manually, is a time consuming task, that requires many calculations, and prone to errors. The developed program prevents the formation of these disadvantages.

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