

Automatic Generating CNC-Code for Milling Machine

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Abstract—G-code is the main factor in computer numerical control (CNC) machine for controlling the toolpaths and generating the profile of the object's features. For obtaining high surface accuracy of the surface finish, non-stop operation is required for CNC machine. Recently, to design a new product, the strategy that concerns about a change that has low impact on business and does not consume lot of resources has been introduced. Cost and time for designing minor changes can be reduced since the traditional geometric details of the existing models are applied. In order to support this strategy as the alternative channel for machining operation, this research proposes the automatic generating codes for CNC milling operation. Using this technique can assist the manufacturer to easily change the size and the geometric shape of the product during the operation where the time spent for setting up or processing the machine are reduced. The algorithm implemented on MATLAB platform is developed by analyzing and evaluating the geometric information of the part. Codes are created rapidly to control the operations of the machine. Comparing to the codes obtained from CAM, this developed algorithm can shortly generate and simulate the cutting profile of the part.

Keywords—Geometric shapes, Milling operation, Minor changes, CNC Machine, G-code, and Cutting parameters.

I. INTRODUCTION

IN the situation of competitive world with increasing in population, the consumer's requirement has become a vital influence for a manufacturer to position a new product onto the market and try to satisfy customer's expectations with containing high quality and providing good services. For supporting these circumstances, a manufacturer has been forced to rapidly develop and create new technologies and add an extra function onto the existing machine for enhancing its performance.

Recently, the traditional machining processes such as drilling, milling, turning, and joining processes have been applied for manufacturing various types of products which are required from different demands. These machines have been operated and controlled manually by human for turning on/off shaft controller, adjusting the feed rate, and turning on/off the coolant. Before performing manufacturing activities, the operator is required to understand the fundamental concepts and other important functions of the machines used in the process for the safety purposes. The skilled operator is required for minimizing the resources and the reproduced part. To obtain high quality of the surface finish, cutting parameters

(e.g., feed rate, spindle speed, or depth of cut) and the maintenance activities should be well-prepared for operation.

However, the traditional machining process is error-prone process where the possibility of the failed products is relatively high due to inadequate operations, dimensions, and surface finish [1], [2]. This has led to an alternative machining process called computerized numerical control (CNC) technology. CNC machine has been applied in all industries for fast production processes. The concept of this machine is about reading thousands of bits of information stored in the computer's memory. The program consists of code commands (i.e., G-code) which are a series of instructions interpreted from the human language to be the machine language. However, G-code is quite difficult for the user to generate since it requires the background knowledge in computing and programming.

In general, G-code is generated by computer aided manufacturing (CAM) where the computer software is applied for controlling machining tools and machine to produce a part. The input of CAM is the 3D virtual model. Once, the minor changes of geometric mold and die are required (e.g., the length and height), it becomes a very time-consuming for reconstructing all processes starting from creating CAD-drawing until generating G-code. So, it would be better to change only geometric parameters or some dimensions of the design directly through the simple platform.

The automatic G-code programming has been introduced as a user-friendly application which can be easily implemented on a clear platform (i.e., MATLAB). Using this developed platform can minimize time for editing the codes since re-creating CAM application is not required.

II. RELATED WORKS

Over the past ten years, the traditional machines have been used to produce the various features and shapes of the parts. Skilled operator and cutting parameters are the key components of the operations to obtain high quality of the part and to minimize reproduced part. For a complex shape, repositioning the part on the platform is required and it is very time consuming since setting up and calibrating the machine and cutting tool are required for every operation.

To quickly generate the entire part, casting technique is applied. In this process, the metal is melt and then poured into the provided cavity or mould which should be perfectly dried and be able to withstand the heat of the metal. In fact, the casting process provides less surface accuracy and it cannot control burr on the cast part. It spends very long time to get

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one product. When the errors are found, all steps are repeated starting from the beginning [3].

To easily cut and obtain high surface accuracy, the extra component of the cutting machine called metal working latch was invented for holding the workpiece during the operation [4]. After the traditional period, the rapid-improvement machines have become as new solutions for supporting the operation of several shapes of the workpiece over the casting processes. Drilling, turning, milling, and grinding machines have been applied for easily adjusting the cutting parameters and also providing sharp-edge shapes and these machining processes require low set-up cost and time comparing to forming, molding, and casting processes. However, these machining processes are more expensive for high volumes where skilled operator is required for reducing wastes and producing high tolerance on dimensions and surface finishes [5].

In order to reduce processing time, cost for the waste material and human-labor required, computerized numerical control (CNC) machines have been introduced as the technology for producing the product due to the commands obtained from the computer analysis [6].

The two main objectives of applying CNC machine in cutting operation are to eliminate some human errors, and provide high surface accuracy of the part.

The input of this CNC operation is 3D CAD model which is then used for analyzing, calculating, and generating the toolpaths (i.e., program for cutting process). After obtaining the program, the CNC machine works by reading the thousands of bits of information stored in the program computer memory. To place this information in the memory, the programmer creates a series of instructions or commands where the machine can understand.

The program may consist of code commands or G-code, such as "M03" which instructs the controller to move the spindle to a new position, or "G99," which instructs the controller to read an auxiliary input from some process inside the machine. Code commands are the most common way to program a CNC machine tool. However, the advancement in computers has allowed the machine tool manufacturer to offer "conversational programming," where the instructions are similar to the plain words [7], [8].

In conversational programming, the "M03" command is entered simply as "MOVE," and the "G99" command is simply "READ." This type of programming allows faster training and less memorizing of the code meanings by the programmers. The difficulties and errors (e.g., selecting the wrong function provided onto the machine's screen, transferring the wrong codes, setting the wrong cutter's positions, assigning the wrong tool length, or creating the wrong toolpaths) are always presented at the initial of the CNC operation and the manufacturer have tried to generate the codes to be in simple formats from a compactable 3D virtual model. In general, codes for controlling machine contain the cutting tools applied, size and shape of the object, the properties of material, the toolpaths, and the starting/finishing points. They all are interpreted into the computer commands

rapidly through computer aided manufacturing (CAM) application when the input model is available [9], [10]. The simulation of the cutting process which mentions about function, status, and sequences can also be performed by this application before starting real cut.

In order to support mass production process where the maintenance activities can be well performed, the components of CNC machine have been developed and redesigned for providing quick and easy access. Mills typically consist of a table that moves in the X and Y axes, and a tool spindle that moves in the Z (depth). In order to provide highly accurate movements, the position of the tool is driven by motors with a series of step-down gears, or direct-drive stepper motors [8]-[10].

The new CNC systems, currently, are completely electronically controlled. CNC-like systems are used for any processes that can be described as a series of movements and operations. These include laser cutting, welding, friction stir welding, ultrasonic welding, flame and plasma cutting, bending, spinning, pinning, gluing, fabric cutting, sewing, tape and fiber placement, routing, picking and placing (PnP), and sawing [11]. CNC machines have many advantages [12], [13], such as producing the complex shapes/parts with less human required, reducing the lead time and the production time, and providing safety function for the user. The newest machine can be set up fast enough to be used just in time manufacturing environment, thus the inventory costs can be reduced. Since the pneumatic controlling system has been applied for CNC machine, urgent activity that disturbs machine during the operation can cause some errors and damages to the machine [14], [15]. When the machine stops immediately, some functions are definitely skipped to stopping-mode. To continue machining process, the entire steps are required. These activities are very time-consuming even for the simple geometric shapes of the part.

Pausing-mode application should be provided in CNC-machining function for easily performing some extra activities (e.g., cleaning stuck chips or changing some codes) which may occur during the operation, and machine can quickly resume to process again. Using this concept can increase the efficiency of the production process with maintaining high quality, reducing time, and cost of the product. This has led to our research which is about the automatic generating CNC-codes for milling machine where the machine can be paused and resumed immediately after a minor corrections or activities performed. The overall concept will be discussed in the next section.

III. RESEARCH CONCEPT

When the machine is asked to cut the part that contains the same shape of the previous design but the size is different, the new CAD model is to be redesigned and recreated. It is time-consuming for regenerating the new set of the G-codes for CNC machine since the new design is changed only dimensions. In order to reduce the time and avoid back-and-forth process, the alternative technique for editing or modifying G-code by using MATLAB program has been

introduced in this research. The users will be allowed to input and change parameters of simple geometric shapes without reconstructing CAD models and G-code due to minor changes. The strong knowledge about CAD, CAM or G-code is not required. The user just needs to know the shape, size, radius of work piece, radius of diameter tool and other basic parameters which are all basic information. For the regular channel of manufacturing process, a CAD model is firstly required and G-code is then generated by CAM applications [16]-[18] for inputting to the CNC machine. G-code is used as commands to control movement of cutting tool and operation in CNC machine so called toolpaths [19]. Using this technique can prevent the duplicate activities which are recreating CAD model or regenerating CAM simulation.

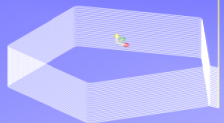
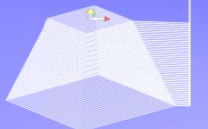
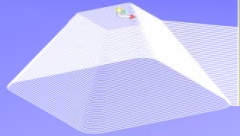
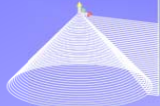
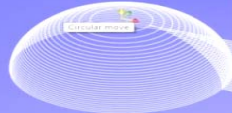
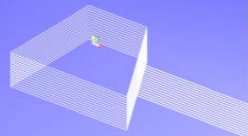
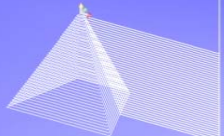
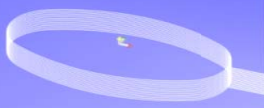
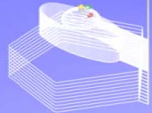
In order to accomplish the proposed technique, four main steps are required; creating command based on MATLAB program, generating G-Code to get a toolpaths, simulating new G-code in the interfacing program, and setting and operating CNC machine. Illustrated in Fig. 1 is the overall process of this research. MATLAB platform is asked for programming the design of the simple commands that provide the questions for filling the desired shape and their dimensions from the user. MATLAB calculates the input data and it can provide the function for automatically changing the dimensions (according to mathematical formulas of geometric shapes) in the same ratio with template. The interfacing program (e.g., CIMCO program) is then attempted to change the toolpaths and control the operation according to new dimensions which are just assigned on MATLAB platform. So, this interfacing program will save the time for adjusting and re-creating the geometric shape in CAD application.

The geometric shapes (e.g., basic geometric shapes as shown in Table I) are used as sample models for creating MATLAB platform to test these research concepts. The MATLAB platforms have been created to allow user inputting the data Then MATLAB is automatically asked for generating a new set of the G-codes to control the operation on CNC machine. Some questions are raised during the process such as how to know whether or not the commands written or formulas applied are correct. The drawn virtual models are presented and checked their coordinates. These models are used as the reference data for cutting profile parameters which are required for CNC-milling operation. CIMCO program [20] is used to simulate the toolpaths. The obtained G-codes are used for operating CNC machine by sending the commands directly from the computer to the CNC machine. After completely setting the positions of the machine and workpiece on work table, the machine starts operating to cut the profile onto the workpiece.

IV. APPLICATION OF THE PROPOSED TECHNIQUE

In this section, four topics are presented; creating commands based on MATLAB, generating G-code, simulating new G-code in the interfacing program (CIMCO), and setting and operating on CNC machine.

TABLE I
GEOMETRIC SHAPES

Type	Models
Polygon (<u>with</u> fillet at every corner)	
Pyramid polygon and frustum (<u>without</u> fillet at every corner)	
Pyramid polygon and frustum (<u>with</u> fillet at every corner)	
Cone and frustum cone	
Hemisphere and frustum hemisphere	
Trapezoid	
Pyramid trapezoid and frustum	
Ellipse	
Combined shapes	

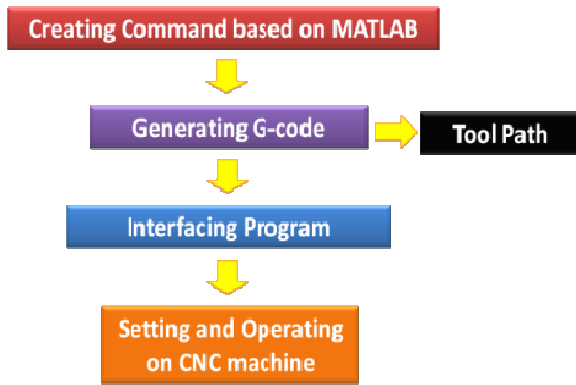


Fig. 1 Four main steps of the research

A. Creating Commands Based On MATLAB

MATLAB program is used for creating simple commands, calculating, converting, and writing G-code for operating CNC machine.

MATLAB platform concludes the numbers of syntax. In order to create commands on MATLAB platform, three main parts are required; inputting parameters, calculating data, and converting as shown in Fig. 2.

The platform provides some questions for assigning the basic parameters of the object such as shape, and dimensions (according to mathematical formulas of geometric shapes). Then MATLAB calculates and analyzes the input data and converts them automatically into the template provided.

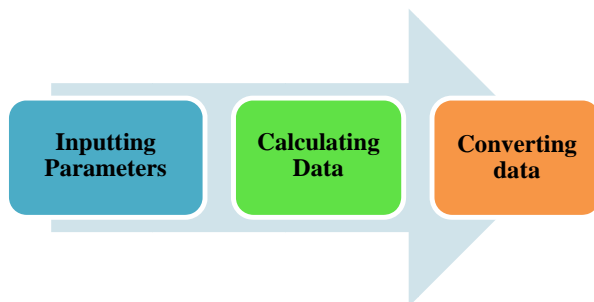


Fig. 2 Three steps of creating MATLAB platform

B. Generating G-Codes

After converting data to be in the machine's language, MATLAB starts to print the set of G-code which is the new commands for controlling CNC machine into the simple format (i.e., *.txt). Presented in Fig. 3 is the G-code stored in Notepad platform. The input data are listed:

- The turret number 10 (T10).
- M08 represents flood coolant.
- Diameter of tool is 16 mm.
- Depth per cut is 3 mm of depth per cut.
- Polygon with 7 corners with 2 mm of radius of fillet.
- Clockwise contour path with feed rate of 211 mm/min.
- Spindle speed of 5252 rpm.

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STEP2 (G-CODE) - Notepad
File Edit Format View Help
N100 G21
N101 G0 G17 G40 G49 G80 G90
N102 T10 M6
N103 G0 G90 G54 X36.290 Y4.339 A0. S5272 M03
N104 G43 H10 Z100.000 M08
N105 Z30.000

N106 G01 Z-3.000 F211.0
N107 G02 X36.290 Y-4.339 R10.0 F211.0
N108 G01 X26.019 Y-25.667 R10.0 F211.0
N108 G02 X19.234 Y-31.078 F211.0
N109 G01 X-3.845 Y-36.345 R10.0 F211.0
N109 G02 X-12.305 Y-34.415 F211.0
N110 G01 X-30.813 Y-19.655 R10.0 F211.0
N110 G02 X-34.579 Y-11.836 F211.0
N111 G01 X-34.579 Y11.836 R10.0 F211.0
N111 G02 X-30.813 Y19.655 F211.0
N112 G01 X-12.305 Y34.415 R10.0 F211.0
N112 G02 X-3.845 Y36.345 F211.0
N113 G01 X19.234 Y31.078 R10.0 F211.0
N113 G02 X26.019 Y25.667 F211.0
N114 G01 X36.290 Y4.339 R10.0 F211.0

N115 G01 Z-6.000 F211.0
N116 G02 X36.290 Y-4.339 R10.0 F211.0
N117 G01 X26.019 Y-25.667 R10.0 F211.0
N117 G02 X19.234 Y-31.078 F211.0
N118 G01 X-3.845 Y-36.345 R10.0 F211.0
N118 G02 X-12.305 Y-34.415 F211.0
N119 G01 X-30.813 Y-19.655 R10.0 F211.0
N119 G02 X-34.579 Y-11.836 F211.0
N120 G01 X-34.579 Y11.836 R10.0 F211.0
N120 G02 X-30.813 Y19.655 F211.0
N121 G01 X-12.305 Y34.415 R10.0 F211.0
N121 G02 X-3.845 Y36.345 F211.0
  
```

Fig. 3 G-code on Notepad program

C. Simulating New G-Codes in the Interfacing Program (CIMCO)

Next, the process starts to copy the new set of G-code which is written in text file, and it is pasted on CIMCO program. In order to check toolpaths obtained from MATLAB platform, the simulation of CIMCO program is applied for virtually running the contour profile in graphic view (as shown in Fig. 4).

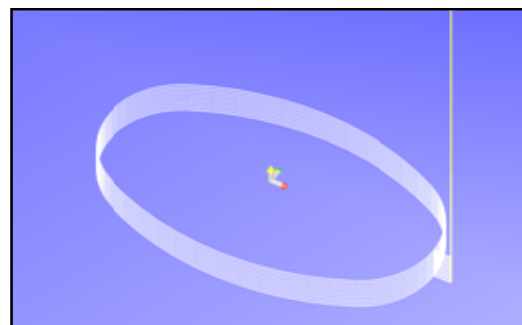


Fig. 4 Screen of simulation program (CIMCO)

D. Setting and Operating on CNC Machine

The process of setting XYZ-coordinate points (on CNC machine) is started after G-code simulation. The first position at the center of circle on top cylindrical billet is set to be zero (as shown in Fig. 5), then, the new G-code in CNC machine is performed to control the operation.

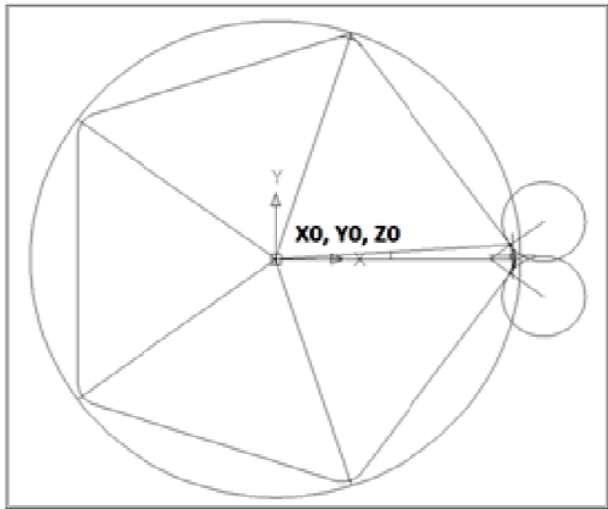


Fig. 5 TOP view of cylindrical billet

TABLE II
RESULT OF CONE AND FRUSTUM

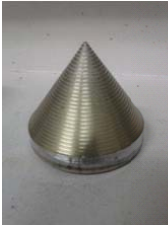
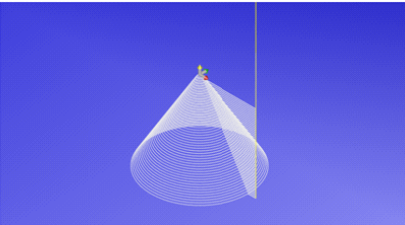

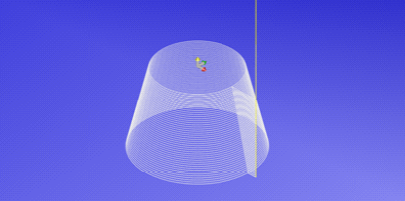

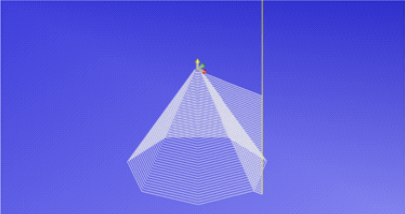
Type	Parameters
Cone and frustum cone	1. Base radius (rb) 2. Top radius (rt) 3. Height (H)
	
	

TABLE III
RESULT OF PYRAMID POLYGON AND FRUSTUM WITHOUT FILLET

Type	Parameters
Pyramid polygon and frustum (without fillet at every corner)	1. Number of Corner 2. Radius of fillet (rf)
	

V.RESULTS

The results of the proposed approach are shown in Tables II to X. On each table, the input parameters, tool paths and shapes are asked and shown on the parameter's column

whereas the type of the part which is being machine is presented on the left column. Since the part is different in shape, the significant parameters are assigned and considered with different criteria and calculations.

TABLE IV
RESULT OF PYRAMID POLYGON WITH FILLET


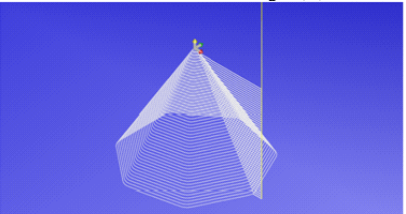
Type	Parameters
Pyramid polygon and frustum (with fillet at every corner)	1. Number of Corner 2. Radius of fillet (rf) 3. Height (H)
	

TABLE V
RESULT OF HEMISPHERE AND FRUSTUM HEMISPHERE


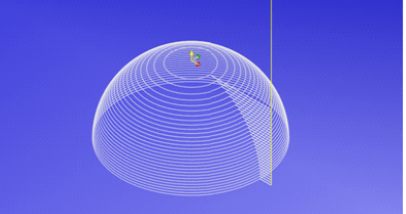
Type	Parameters
Hemisphere and frustum hemisphere	1. Base radius (rb) 2. Top radius (rt)
	

TABLE VI
RESULT OF POLYGON WITH FILLET

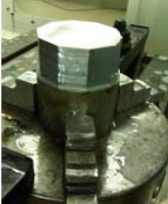
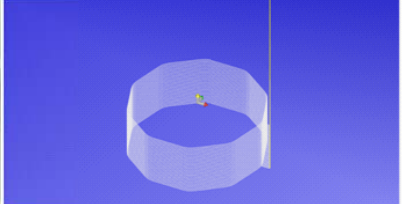
Type	Parameters
Polygon (with fillet at every corner)	1. Number of Corner 2. Radius of fillet (rf)
	

TABLE VII
RESULT OF TRAPEZOID

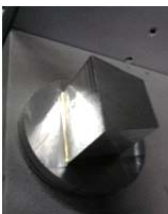
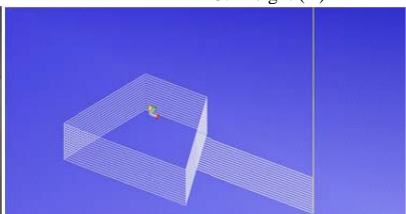
Type	Parameters
Trapezoid	1. Top length 2. Bottom length 3. Height (H)
	

TABLE VIII
RESULT OF PYRAMID TRAPEZOID AND FRUSTUM

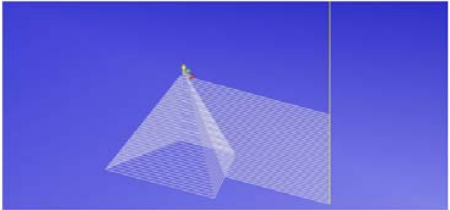
Type	Parameters
Pyramid trapezoid and frustum	1. Top length
	2. Bottom length
	3. Bottom length of top layer
	4. Height (H)
	

TABLE IX
RESULT OF ELLIPSE

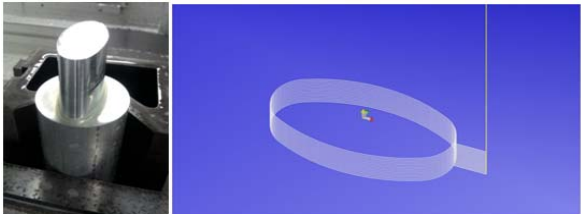

Type	Parameters
Ellipse	1. Length of "a"
	2. Length of "b"
	3. Height (H)
	

TABLE X
RESULT OF COMBINED SHAPES

Type	Parameters
Combined shapes	Feature selection
	

VI. DISCUSSIONS

This research focuses on how to reduce the times and redundant steps of CNC-machining process. The proposed technique can help to eliminate some redundant activities for redesigning the minor changes. The proposed technique can be considered as the new alternative channel to generate a set of G-code without using CAD and CAM program for re-modifying virtual model. The simple shapes (e.g., rectangle, triangle and polygon) are the first target that had been done for demonstrating the proposed approach.

The simple questions will be provided for the user to easily input the parameters which have the direct effects on the cutting parameters. After obtaining all geometric parameters, the developed program starts to calculate, converting, and writing the G-code. For these reasons, the user does not perform back-and-forth process to recreate model or regenerate the toolpaths where the applications of CAD and CAM are not required. However, this proposed technique is

available only for cylindrical billets and the basic geometric shapes.

The important steps of the process are setting cutting parameters, and operating CNC machine. Sometimes, the errors were occurred during the process such as applying the incorrect contour paths and spindle directions. This research may be used and applied in the real production line which the minor changes always be occurred and the time is very important issue.

VII. CONCLUSIONS

Times spent for changing, modifying the virtual model, and generating code from CAM are the key components of this research and they need to be reduced for enhancing the performance of machining process to be more effective and robust. Using the simple commands (G-codes) for CNC-milling machine can be quickly written by the developed program which is implemented on MATLAB platform. The program can generate the toolpaths and commands automatically by analyzing the geometric parameters of the part which is being machined.

For the contribution of this research, to produce complex shapes or features (e.g., cone, frustum, hemisphere, pyramid, trapezoid and ellipse), the combination calculations among the proposed standard geometric shapes has been applied. The minor changes can be considered as re-sizing or re-shaping, for example, the plastic bottles (as shown in Fig. 6) that contain different in sizes.



Fig. 6 The examples of plastic bottles [21]

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