Precession of Surface Roughness by CNC End Milling

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Abstract - *Surface finish produced on machined surface plays an important role in production. The surface roughness has a vital influence on most important functional properties like wear resistance, fatigue strength, corrosion resistance and power losses due to friction. Poor surface roughness will lead to the rupture of oil films on the packs of micro irregularities which lead to a state approaching dry friction and results in decisive wear of rubbing surfaces therefore finishing process are employed in machining the surface of many critical components to obtain a very high surface finish. Process variables surface roughness in milling depends on spindle speed, feed, number of flutes, and depth of cut and plan approach angle. Mainly surface finish depends on spindle rpm, feed rate and depth of cut).*

Key Words: surface roughness, fatigue strength ,corrosion, wear resistance

1. INTRODUCTION

Surface roughness has received serious attention for many years. It has been an important design feature and quality measure in many situations such as parts subjected to fatigue loads, precision fits and fasteners. The experiment was conducted to analyse surface roughness on 6081 aluminium alloy using various machining variables such as spindle speed, feed rate, depth of cut and number of flutes. This data was used to develop surface roughness prediction models: as a function of spindle speed, feed rate, depth of cut, number of flutes for this material. Purpose of this study is to develop a technique to predict a surface roughness of part to be machined according to cutting parameters. This project focuses on developing a first-order, second-order and third-order regression equation for surface roughness in cnc milling process. In developing these, the most familiar milling parameters such as spindle speed, feed rate, depth of cut and number of flutes are considered. Surface roughness of machined components corresponding to these conditions is the output of this technique. The trained regression equations were used in predicting surface roughness for cutting conditions and tested using test data. The above technique is applied for generating first, second and third order regression equations for calculating the surface roughness. The plots were drawn between experimental and predicted values of surface roughness for various regression techniques and percentage accuracy is calculated. Finally, comparison is made between surface roughness values of first-order, second-order and third-order regression models with experimental values. From graphs, it is observed that second order model gives accurate results of surface roughness. The experimental results show, regression technique can be successfully used for predicting surface roughness.

2. REGRESSION TECHNIQUE

In statistics, regression analysis includes any technique for modeling and analyzing several variables, when the focus is on the relationship between a dependant variable and one more independent variables. More specifically, regression analysis helps us understand how the typical value of the dependent variable changes when any one of the independent variables is varied, while the other independent variables are held fixed. Regression analysis is widely used for prediction and forecasting. Regression analysis is also used to understand which among the independent variables are related to the dependent variable, and to explore the forms of these relationships. A large body of technique for carrying out regression analysis has been developed. Familiar methods such as linear regression and ordinary least squares regression are parametric, in that the regression are parametric, in that the regression function is defined in terms of a finite number of unknown parameters that are estimated from the data. Nonparametric regression refers to techniques that allow the regression function to le in a specified set of function, which may be infinite-dimensional.

1.1 Regression models:

Regression models involve the following variables:

- The unknown parameters denoted as β: this may be a scalar or vector of length *k*.

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- The independent variable, X.
- The dependent variable, Y.

A regression model relates Y to a function of X and β.

$$Y \approx f(X,\beta)$$

To carry out regression analysis, the form of the function f must be specified. Sometimes the form of this function is based on knowledge about the relationship between Y and X that does not rely on the data. If no such knowledge is available, a flexible or convenient form for *f* is chosen.

Assume now that the vector of unknown parameters β is of length *k.*

In order to perform a regression analysis the user must provide information about the dependent variable Y.

*If N data points of the form (Y,X) are observed, where *N<k*, most classical approaches to regression analysis cannot be performed: since the system of equations defining the regression model is underdetermined, there is not enough data to recover β.

*If exactly *N=k* data points are observed, and the function f is linear, the equation Y=*f*(X,β) can be solved exactly rather than approximately. This reduces to solving a set of N equations with N unknowns (the elements of β), which has a unique solution as long as the X are linearly independent. If *f* is nonlinear, a solution may not exist, or many solutions may exist.

*The most common situation is where *N> k* data points are observed. In this case, there is enough information in the data to estimate a unique value for β that best fits the data in some sense, and the regression model when applied to the data can be viewed as an over determined system in β.

In the last case, the regression analysis provides the tools for:

**Finding a solution for unknown parameters β that will, for example, minimize the distance between the measured and predicted values of the dependent variable *Y* (also known as method of least squares).

**Under certain statistical assumptions, the regression analysis uses the surplus of information to provide statistical information about the unknown parameters β and predicted values of the dependent variable *Y.*

1.2 Linear regression:

In linear regression, the model specification is that the dependent variable, y_i is a linear combination of the parameters (but need not be linear in the independent variables. For example, in simple linear regression for modelling n data points there is one independent variable: xi and two parameters, β_0 and β_1:

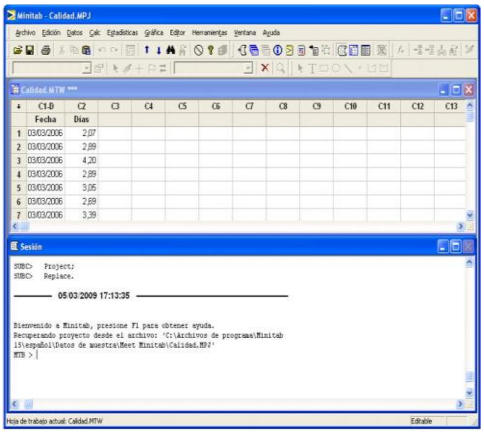
Straight line: $y_i = \beta_0 + \beta_1 x_i + \varepsilon_i$, $i=1,2,\ldots,n$.

In multiple linear regressions there are several independent variables or functions of independent variables. For example, adding a term in x_i2 to the preceding regression gives:

Parabola: $y_i = \beta_0 + \beta_1 x_i + \beta_2 x_i^2 + \varepsilon_i$, $i=1,2,\ldots,n$.

This is still regression; although the expression on right hand side of its quadratic in the independent variable xi, it is linear in the parameters β_0, β_1 and β_2.

MINITAB



General view of Minitab window

Minitab is statistical analysis software. It can be used for learning about statistics as well as statistical research. Statistical analysis computer applications have the advantage of being accurate, reliable, and generally faster than computing statistics and drawing graphs by hand. *Minitab* is relatively easy to use once you know a few fundamentals.

In this project Minitab is used to develop regression equations of first order, second order and third order equations from the training data and these are used to test the equations using testing data.

In order to develop regression equations the table of data is entered in the work sheet of Minitab and then regression option is selected from the popup menu in the tool bar, the required equation is displayed on session sheet.

2. EXPERIMENTAL SETUPS

INTRODUCTION TO CNC:

Definition: The abbreviation CNC stands for "COMPUTER NUMERICAL CONTROL" and refers specifically to a computer "controller" that reads G-code instructions and drives a machine tool, a powered mechanical device typically used to fabricate components by the selective removal of material.

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Specifications:

Specifications of CNC lathe

Machine model	VML-800
Axis-	x-800mm y-500mm z-500mm
Table size	500×1000
ATC	20 Tools
Control	fanuc 01MB
Spindle speed	60-6000rpm
Accuracy	0.005mm
Baudrate	4800bps
load capacity	700kgs
Supply voltage	415 v
Phase	3p
Supply Frequency	50-60 Hz

Specifications:

2.1 Basic concept of programming:

Part programming contains geometric data about the part and motion information of the cutting tool with respect to the work piece. Basically, the machine receives the information as a sequence of blocks containing commands to set machine parameters like speed, feed, depth of cut and other relevant information. When running a part program interprets one command line at a time until all lines are completed. A block contains a line of codes in a part program which begin with a series of letters and ends with a numerical value. For example, consider the block given below

N135 G01 X1.0 Y1.0 Z0.125 T01 F5.0
N135 - block number
G01 -G-code
X1.0, Y1.0, Z0.125 –Coordinates
T01 -Tool number
F5.0 -Special function

2.1 Cnc milling machine :

Computer numerical control (CNC) milling is the most common form of CNC. CNC mills can perform the functions of drilling and often turning. CNC machines are often classified as the number of axes that they possess. Axes are classified as x and y for horizontal movement and z for vertical movement. A standard Lokesh made VML-800 machine is has the following manufacturing data

CNC milling operation using VML-800.

2.2 DESCRIPTION:

Initially, the main program to be run is set to the incremental system. Then spindle is made to rotate in clockwise direction and is returned to reference point.
The values for X and Y direction travel distance and the spindle speed is fixed. Coolant is made to on. After the slot of given dimensions and of speed, feed and depth of cut is given spindle is made to off. Then by putting in program edit mode, sub program is called. In the sub program the values for depth of cut and feed are varied and returned to the main program. After the particular operation is completed, the tape is rewinded and the same procedure is repeated. For details regarding program refer Appendix
The above procedure is done using 2 tools of varying flute number. One is 4-flute and the other is 7-flute.

➢ Material used:

Aluminium 6081 is an aluminium alloy with magnesium and silicon as the alloying elements. It has generally good mechanical properties and is generally heat treatable and wieldable. It is similar to the British aluminium alloy HE9. It is strong, with strength comparable to many steels, and has good fatigue strength and average machinability; the alloy is readily welded by all of the conventional methods filler rod should be of same alloy or 4043 alloy. This is generally considered to be an extrusion alloy that is heat treatable for strengthening.

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Composition of 6081 Aluminum alloy

Composition	% Weight
Al	98.44-97.6
Si	0.7
Mg	0.6-0.1
Fe	0.5
Cu	0.1
Zn	0.2
Cr	0.1
Ti	0.15
Other	0.05

Properties of 6081 Aluminum alloy

Parameter	Value
Density	2.70 gm/cm^3
Poisson's Ratio	0.33
Elastic Modulus	69.5
Tensile Strength (MPa)	131
Yield Strength (MPa)	69
Elongation (%)	18
Shear Strength (MPa)	70
Thermal conductivity	200 W/m-k

6081 is mostly used in extruded shapes for architecture especially for window frames, door frames, roofs, and sign frames. It is typically fit for very smooth surfaces fit for anodizing. It is also used in rail transport, road transport, and extreme sports equipment. It is used where high surface finish, high corrosion resistance surfaces are needed.

- Surface roughness measuring instrument:

The surftest SJ-210 is a shop-floor type surface roughness measuring instrument, which traces the surfaces of various machine parts, calculates their surface roughness based on roughness standards, and displays the results. A pick up (herein after referred to "stylus") attached to the detector unit of the SJ-210 traces the minute irregularities of the work piece surface The vertical stylus displacement during the trace is converted into electrical fluctuations by the tracer head and these signals are magnified by the amplifier and digitally displayed on the liquid crystal display of the SJ210. The readings shown on the digital display indicates the average height of the surface roughness.

3. RESULTS AND DISCUSSIONS

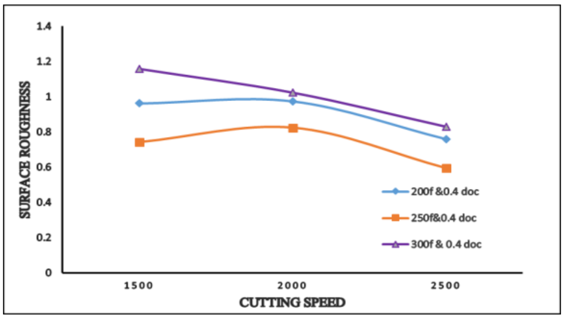

Fig1:Variation of spindle speed (rpm) vs. surface roughness (µm)

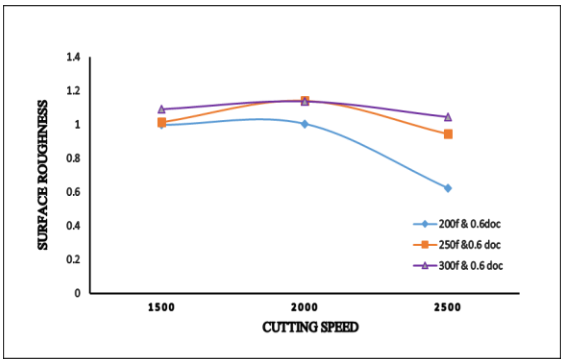

Fig2:Variation of spindle speed (rpm) vs. surface roughness (µm)

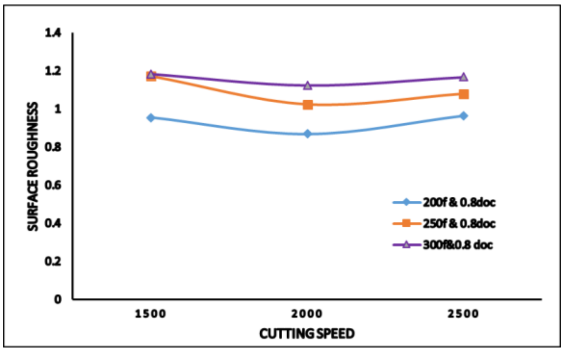

Fig3:Variation of spindle speed (rpm) vs. surface roughness (µm)

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Figures 1, 2 and 3represent the variation of surface roughness with Spindle speed for various feed rates. From these figures, it is observed that as the cutting speed increases the surface roughness decreases in all cases. It is also observed that surface roughness values are higher for feed rate 200 mm/min as compared to feed rates f=250 and
300 mm/min. Therefore surface roughness values increases with increase in feed rate.

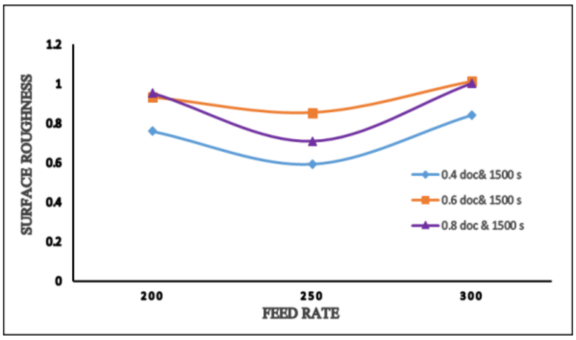

Fig4:Variation of feed rate (mm) vs. surface roughness (µm)

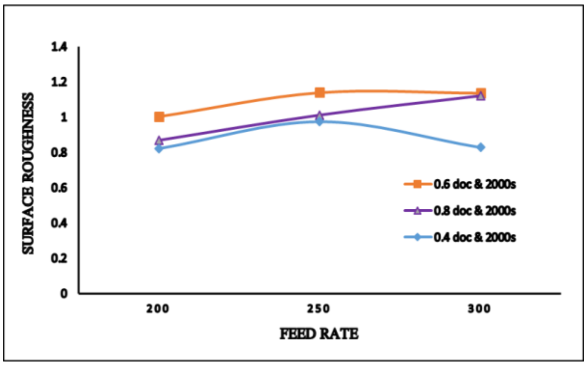

Fig5:Variation of feed rate (mm) vs. surface roughness (µm)

Figures 4 and 5 represent the variation of surface roughness with feed rates for various depth of cuts. From these figures, it is observed that as the feed rate increases the surface roughness increases in all cases. It is also observed that surface roughness values are higher for depth of cut 0.4 mm as compared to depth of cuts d=0.6 and 0.8 mm. Therefore surface roughness values decreases with increase in depth of cut.

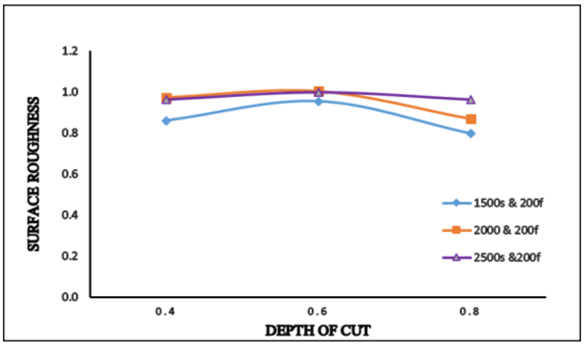

Fig6:Variation of depth of cut (mm) vs. surface roughness (µm)

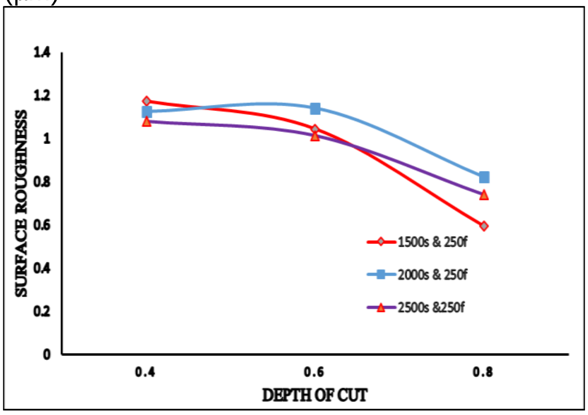

Fig7:Variation of depth of cut (mm) vs. surface roughness (µm)

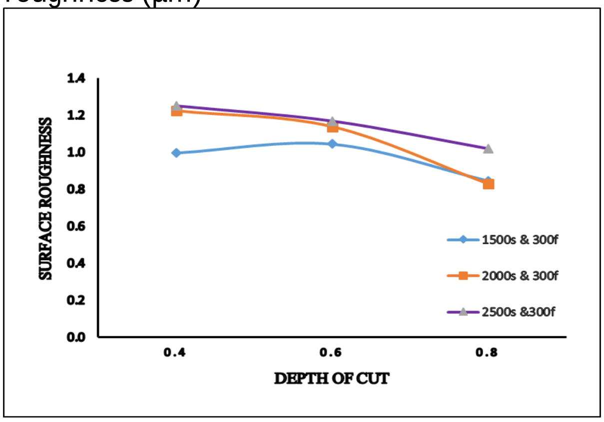

Fig8:Variation of depth of cut (mm) vs. surface roughness (µm)

Figures 6, 7 and 8 represent the variation of surface roughness with depth of cut for various spindle speeds. From these figures, it is observed that as the depth of cut increases surface roughness decreases. It is also observed that the surface roughness values are higher for spindle speeds 1500 rpm as compared to s=2000 and 2500 rpm.

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Predictor	Coef	SE Coef	T	P
Constant	0.507	0.1901	2.67	0.01
S	0.00004163	0.00004924	0.85	0.402
F	0.0006178	0.0004924	1.25	0.216
D	0.1936	0.1231	1.57	0.122
N	0..02732	0.0134	2.04	0.047

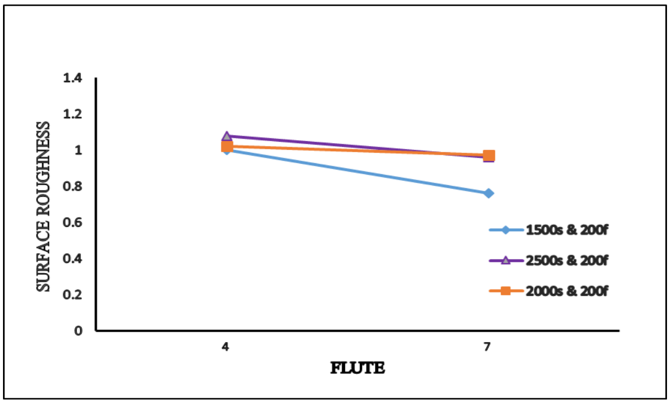

Fig9:Variation of surface roughness (µm) vs. number of flutes

Fig10:Variation of surface roughness (µm) vs. number of flutes

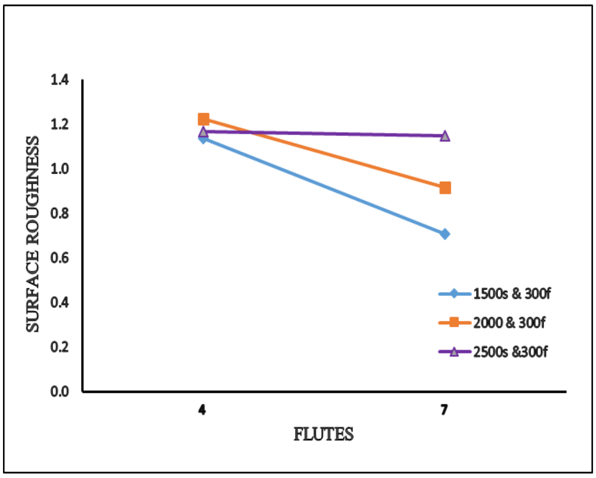

Fig11:Variation of surface roughness (µm) vs. number of flutes

Figures 9, 10 and 11 represent the variation of surface roughness with number of flutes and for various spindle speeds at constant feed rate f=300 mm/min. From the figures, it is observed that as the number of flutes increases surface roughness decreases in all cases. It is also observed that surface roughness values are higher for spindle speed 1500 rpm as compared to other spindle speeds

Regression analysis results:
First order regression Modelling:
The First-order regression equation is

Ra=0.507 + 0.000042 s + 0.000618 f + 0.194 d + 0.0273 n

Table 7: Regression analysis with first order variables

S = 0.147732 R-Sq = 15.4% R-Sq (adj) = 8 .5%

Table 8: Analysis of Variance:

Source	DF	SS	MS	F	P
Regression	4	0.19459	0.04865	2.23	0.079
Residual Error	49	1.06942	0.02182		
Total	53	1.26401			

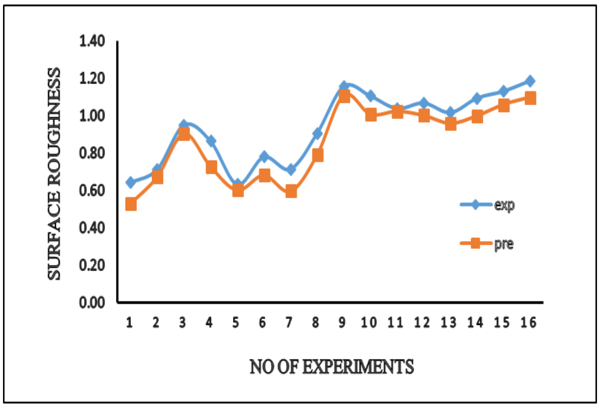

Fig12:Experiment-first order Regression roughness data

From Figure 12, it is observed that predicted surface roughness values from the first order regression equation follow the experiment surface roughness values. But predicted values deviates from experimental surface roughness values.

CONCLUSION AND SCOPE FOR FUTURE WORK

CONCLUSIONS:

From the results of the project it is observed that the graphs of the performed work indicate feed is the most influential factor in machining operations. The graphs show that as feed increases surface roughness increases. The minimum surface roughness can be achieved by

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setting the feed as low as possible. As spindle speed increase the surface roughness value decreases. As the depth of cut increases, the surface roughness first increase and then decreases. Surface roughness decreases with increase in number of flutes.
The proposed methodology has been validated by means of experimental data on milling and is found to be quite effective. In this technique, the equations are developed by using training data; further these are tested by using test data to predict the accuracy of developed model. The predicted values of surface roughness from the model are compared with experimental values of test data. Regression model gives better prediction , with an accuracy 91.33% in first order, 94.91% in second order and 82.4% in third order. The higher prediction accuracy of surface roughness values is second order regression model followed by first–order and then third-order regression model. So we can extend this project to other process variables in order to develop precession models.

SCOPE FOR FUTURE WORK:

This regression model can be effectively used to predict the surface roughness in milling operations, and can also be used to predict the roughness in various machining operations such as turning, drilling and other related operations.in this model prediction of surface roughness is done by considering three parameters namely spindle speed, feed rate, and depth of cut and no. of flutes. It is possible to introduce other parameters in the regression model which influence the roughness such as tool angle, tool vibrations and using different materials.

APPENDIX

PROGRAM FOR SLOTTING IN AL-6081 WITH DIFFERENT SPEEDS FEEDS DEPTH OF CUT AND FLUTES

MAIN PROGRAM

```
O0001 ;
G91 G28 Z0.0 ;
G0 G90 G54 X120. Y0 M3 S1500 ;
G43 Z50. H01 ;
Z10. ;
Z0. ;
M98 P02 L2 ;
G0 Z50 ;
M09 ;
M05 ;
G91 G28 Z0.0 ;
G91 G28 Y0.0 ;
M30 ;
%
```

SUB PROGRAM

```
O0002 ;
G91 ;
G01 Z-.2 F150. ;
G90 ;
Y90 ;
M99 ;
%
```

CODES USED IN THE PROGRAM AND THEIR MEANING:

- G0 - Rapid transverse (not cutting)
- G28- Return to reference point
- G43-tool length compensation, positive
- G54
- G90- absolute dimension program
- G91- incremental dimensions
- X- x- axis designation
- Y-y-axis designation
- Z-z-axis designation
- S- spindle speed designation
- L2-loop counter
- H01
- M03- spindle on clockwise
- M05- spindle off
- M09- coolant off
- M30- end of tape (rewind)
- M98- subprogram call
- M99- return to main program(jump to instructions)

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