JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 2, 2022, p. 20-30
https://publishoa.com
ISSN: 1309-3452

Automation For Feed Motion of Flat Grinding Machine Improve Accuracy and Productivity Machine

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ABSTRACT

In the manufacturing industry, the suface for high quality and gloss are often processed by semi – finishing and finishing on the grinding machine after roughing or heat treatment. To improve machining accuracy, to increase labour productivity and product quality, it depends very much on the opertiong status and accuracy of the machine. Therefore, the article has introduced the solution for automation feed motion on a flat grinding machine base on mechanical system of machine, that can automatically control the machining process and integrated of programming to process gringding details with complex frofiles, improve the accuracy of the machine. The research results are carried out on the active real flat grinding products, high quality surface grinding, reducing pocessing time and improving effect opertating of the machine

Keyword: Flat grinding machine, programing for grind products, accuracy of grind machine; Box – Hunter method

1 Introduction

The flat grinding machines are used to rough and smooth the surface of various parts with the cylindrical surface or the face of the grinding wheel. Following the pieces depending on the material, shape or size can be fixed on either a workpiece or magnetic table. The workpiece table can straight movement, round – trip or circular oscillation. Depending on the position of the grinding wheel spindle, flat grinders can be divided into three main categories:

- Flat grinding machine for vertical spindle
- Special flat grinder
- Horizontal spindle plane grinding machine.

On the basis of structure and operating principle of the grinder, the application of numerical control for main movements need a firm grasp of the structure and operating principle of each cluster of machine design [2]. The automated flat griding machine is in use in normal operation, called NICCO – NSG 550B designation which is a horizontal spindle flat grinder with high machining accuracy. The basic movement of a flat grinder consists of the main rotation of the grinding wheel (The movement that produces the cutting speed) and the linear traversing and vertical feed motion). The main flat grinding movements are shown in figure 1.1

Fig. 1.1. The machining on the flat griding machine tool

Specifications of the NICCO - NSG 550B flat grinder include:

- Worktable size: 380 × 110 [m]
- Travel table X: 560 [mm]
- Travel table Y: 150 [mm]
- Travel table Z: 200 [mm]
- Max of diameter of grinding Wheel: 180 [mm]
- Number of rotation of Wheel (max): 2000 [rpm]
- Spindle motor power: 0.75 [kW]
- Ability with a thickness of part: 8 ÷ 32 [mm]
- Dimension (Length x Width x Height): 1.1 x 1.0 x 1.8 [m].

The amount of the toolpath X,Y,Z: Sx = 45 [mm/s]; Sy = 16.5 [mm/s]; Sz = 3.5 [mm/s]
Minimum travel : X-axis, Y-axis: 0.07 [mm], Z-axis: 0.001[mm]
Diagram of dynamic structure and the whole machine shape is shown in figure 1.2

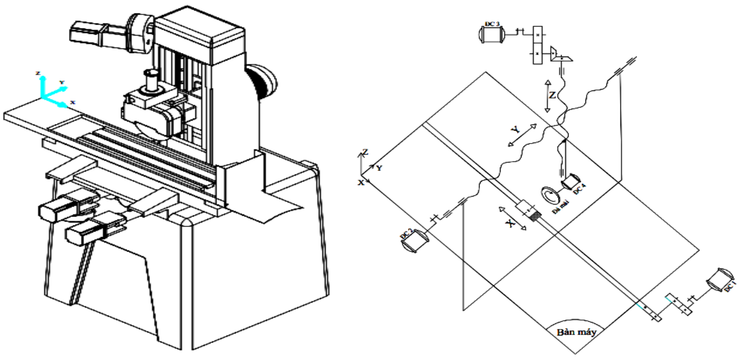

Fig. 1.2. Machine image and dynamic structure diagram

2. Mechanical analysis of the feed motion

The NICCO - NSG 550B flat grinder has a cylindrical grinding wheel in included: linear , horizontal and vertical feed motion. Linear feed motion of the reciprocating machine table carrying the workpiece in the X direction, the traverse movement is the movement of the machine table in the direction perpendicular to the workpiece axis in the Y direction, the vertical feed motion is the movement of the grinding wheel in the Z direction eating up the depth of cut [3]. The feed movement on a flat grinder machine consists of two main movements in the X and Y directions. Mechanical structure of the movement of the machine. The X-axis cluster includes sliding table X, chip shield, a size 25x25[mm] square guide and a slider on the guide. The machine table moves in the X axis using a toothed rack shown in Figure 2.1.

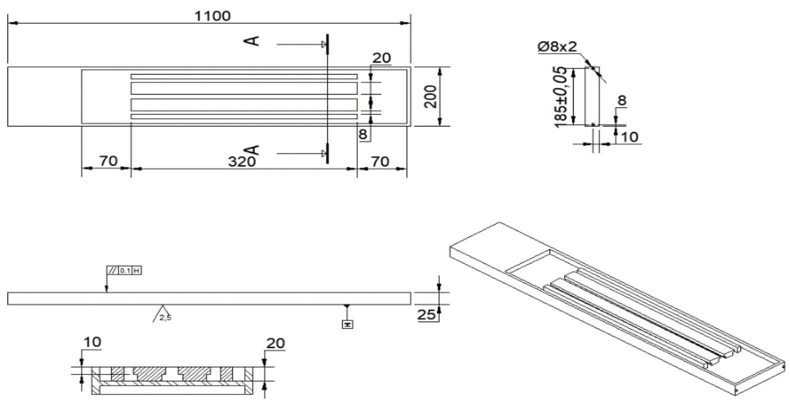

Fig 2.1. X axis assembly

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The Y-axis assembly consists of a square guide, driven in the Y direction by a nut lead screw axis. Figure 2.2 shows structure of Y-axis cluster

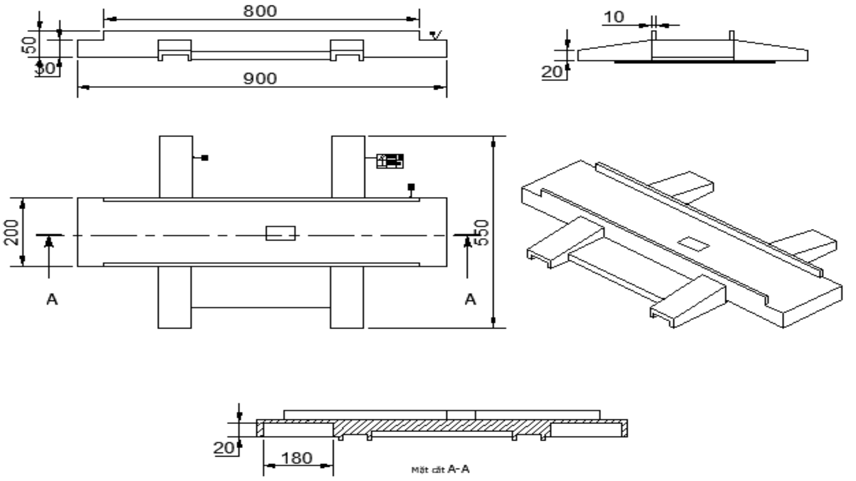

Fig 2.2. Y axis assembly

For machines already and in use, the process control includes: Collect and store information about the required process technology, study the first information about the tasks and characteristics of the process control, gain insight into the incompatibility of given parameters with real process parameters, analyze and transform information to decide on appropriate control commands, thereby affecting the engine. control actuators to achieve the desired results [4]. From analyzing the mechanical structure, the parts on the X, Y cluster can design the plan to automate the tooling movement, combine the X, Y motion and improve the machining ability of the parts, reducing outwork time increases labor productivity and automates the machines in use, improve working conditions and effectively solve problems.

3. Design of the control system for the feed motion of flat grinder

3.1. Design of the control system

With a flat mechanical structure as analyzed above, it is a hand-crank mechanical control, to integrate automatic control of the X, Y, Z axis cluster using open-cycle control is appropriate. On the basis of the mechanical structure of the grinder and the driving force for the movement of the table, to be controlled, it is necessary to design and replace the controllable dynamic source and the corresponding control elements to ensure parameters of flat grinder [5].

The first problem is that the driving force for the X, Y translational movements is designed, chosen as a 12Nm 86BYGH450C stepper motor to convert DC pulses into discrete mechanical rotations corresponding to small displacement. of the machine table, small and medium capacity. The rotation angle and rotation speed are proportional to the number of pulses and pulse frequency supplied to the motor. Main parameters of the motor: 6A load capacity, 12Nm torque, 4 wire, 4.2kg weight with step angle: 1.8 ° ± 5%; Insulation resistance: 500V DC 100MΩ Min - Strong dielectric: 50Hz / ph; 500V / ph; Ambient temperature: 20 ℃ ~ + 50 ℃ - Maximum temperature is 80 ℃. The stepper motor is selected due to the step angle corresponding to the number of control signal pulses, easy to perform gradual, indirect, continuous movements with micro-stepping angles.

Mach3 control software is integrated into the control system for machines capable of multi-axis machining, many control modules are optimized with friendly LPT interface.

The diagram of the machine's open control system is shown in figure 3.1 below

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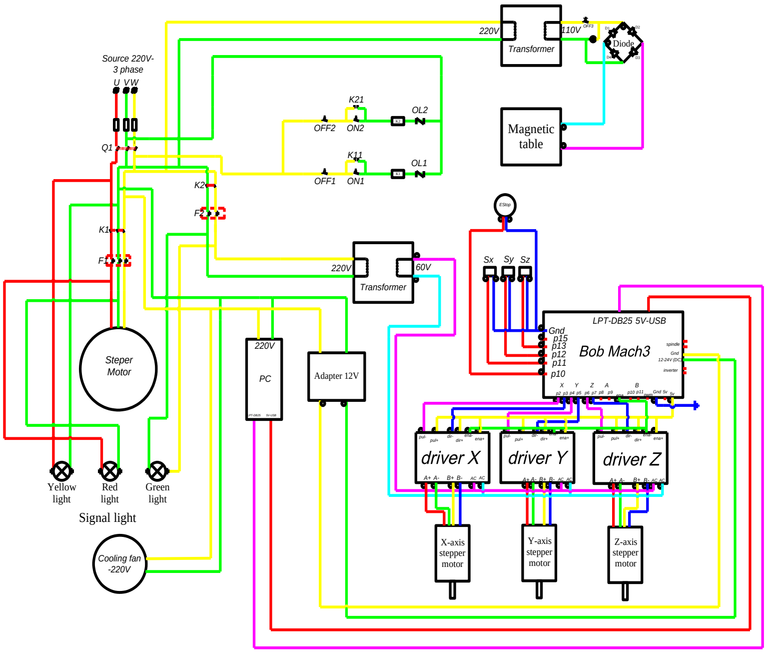

Notes:
OFF1, OFF2: OFF switch
OFF3: Maintenace switch
ON1, ON2: ON switch
F1,F2: Thermal relay
OL1, OL2: Thermal relay contact
K1,K2: Contactor
K11,K21: Point of contactor
Q1: Aptomat
S_x, S_y, S_z: Switch of axis X, Y,Z
Estop: Emergency stop

Fig 3.1. Control circuit diagram of a flat grinder

3.2 Evaluate the stability of the system

To test the stability of the control system of the X, Y axes, when working, it can be unstable, reversed, caused by inertial force [6].

Model of constructing transfer function for X axis is shown in figure 3.2

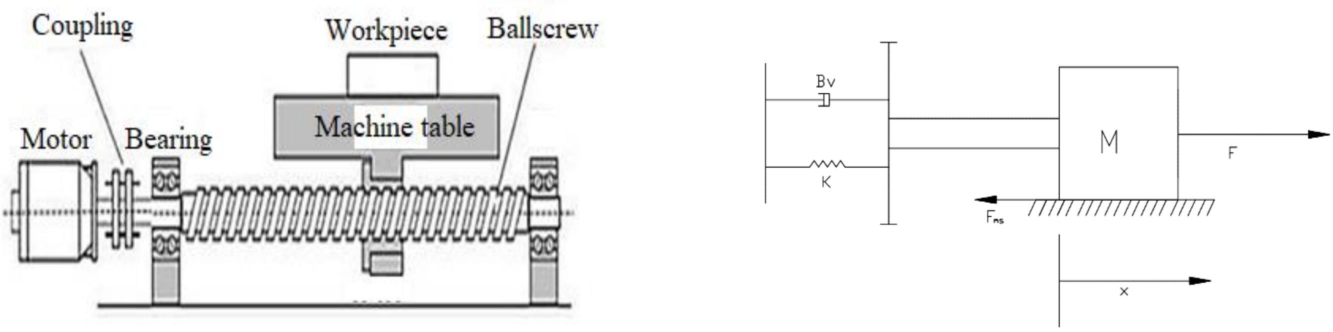

Fig 3.2. Modeling of X-axis drive

In which: M- Mass of machine table and workpiece; K - Hardness coefficient of lead screw, ball bearing, shaft connection, guide rail; B – Friction on system ; *F* - The forces acting; *x*- linear displacement of the worktable.
According to Newton's second law:

$$\mathrm{M}\ddot{x}(\mathrm{t})+\mathrm{B}\dot{x}(\mathrm{t})+\mathrm{Kx}=F_{\mathrm{dc}}=K\theta(t)\frac{1}{2\pi} \qquad (1)$$

The Laplace transform of the equations of motion can be written as

$$\mathrm{M}s^2\mathrm{X(s)} + \mathrm{BsX(s)} + \mathrm{KX(s)} + \mu M g_{SX}(s) = K\theta(s)\frac{1}{2\pi} \quad (2)$$

⇨ $$\left[\mathrm{M}s^2 + (\mathrm{B} + \mu Mg)s + K\right]X(s) = K\theta(s)\frac{1}{2\pi} \quad (3)$$

⇨ From this, the transfer funtion is:

$$G(s) = \frac{X(s)}{\theta(s)} = \frac{K\frac{1}{2\pi}}{Ms^2 + (B + \mu Mg)s + K} \quad (4)$$

To test relative stability with transfer function

$$G(s) = \frac{X(s)}{\theta(s)} = \frac{290}{200s^2 + 5204,3s + 1,82 \cdot 10^5}$$

Given the characteristic equation of system as

$$A(s) = 200s^2 + 5204,3s + 1,82 \cdot 10^5 = 0 \quad (5)$$

If all the solutions of the characteristic equation are to the left of the imaginary axis or then A (s) is called the Hurwitz polynomial, use the roots A (s) command Matlab to get the roots and Bode graphs shown in Fig 3.3, given by [7]

X_1 = -10,7953 + 28,1685i

X_2 = -10,7953 – 28,1685i

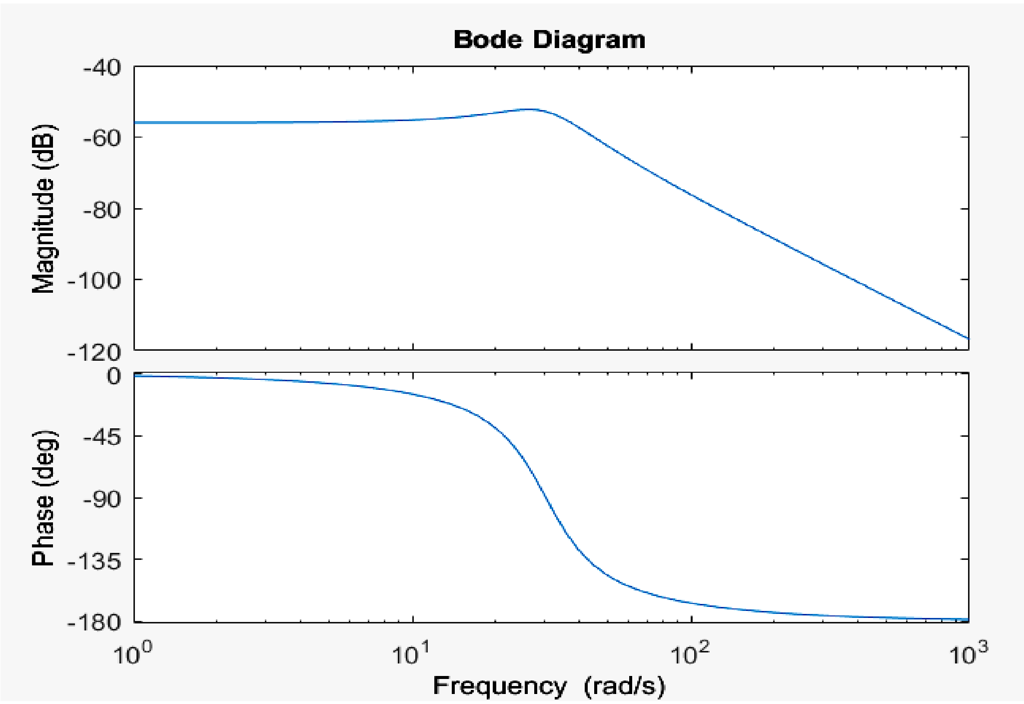

Fig 3.3. Bode graph of X-axis transmission function

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Model of constructing transfer function for Y axis is shown in figure 3.4

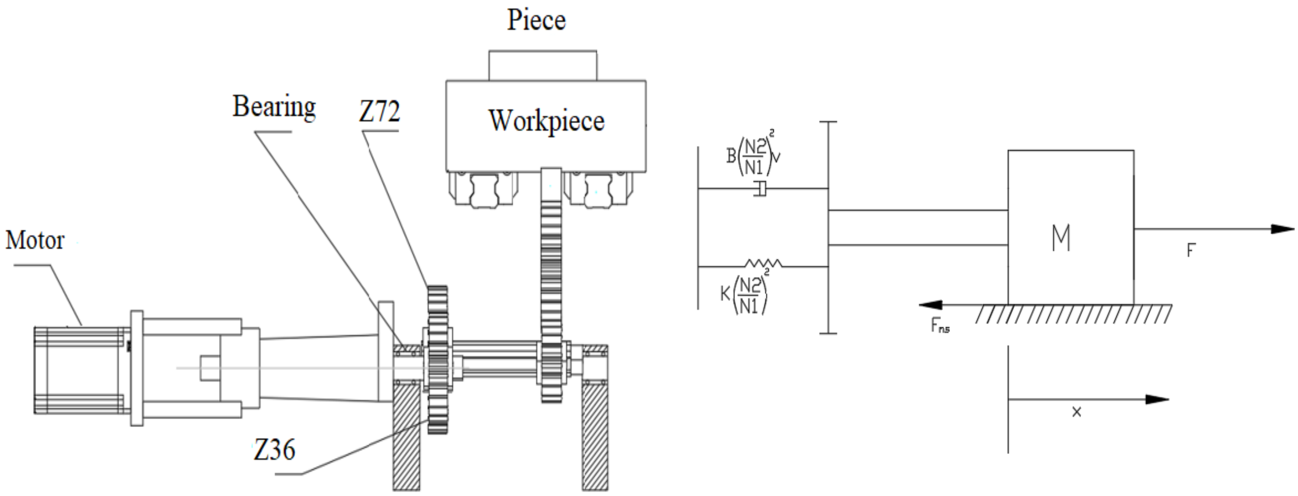

Fig 3.4. Modeling of Y - axis drive

Inside: M - Mass of machine table and workpiece; K- Hardness coefficient of lead screw, ball bearing, shaft connection, guide rail; B: Damper coefficient; x: linear displacement of the worktable.

The total forces on this system

$$\sum F = F_{dc} + F_{ms} \tag{6}$$

With: F_{dc} - Force of motor; F_{ms} – Force friction of mechanic

We get

$$\frac{N2}{N1} = \frac{Z2}{Z1} = \frac{72}{36} = 2 \tag{7}$$

The equation of motion can be written as

$$\mathrm{M}\dot{x}(\mathrm{t}) + \mathrm{B}\left(\frac{N2}{N1}\right)^2 x(\mathrm{t}) + \mathrm{K}\left(\frac{N2}{N1}\right)^2 \mathrm{x} = K\theta(t)\frac{1}{2\pi} \tag{8}$$

The transfer funtion is

$$G(s) = \frac{X(s)}{\theta(s)} = \frac{12987}{100s^2 + 40678s + 8,2 \cdot 10^6} \tag{9}$$

To test relative stability with transfer function, If all the solutions of the characteristic equation are to the left of the imaginary axis or then A (s) is called the Hurwitz polynomial, use the roots A (s) command Matlab to get the roots and Bode graphs shown in Fig 3.5, given by

X_1 = -203,39 + 201,58i

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X_2 = -203,39 - 201,58i

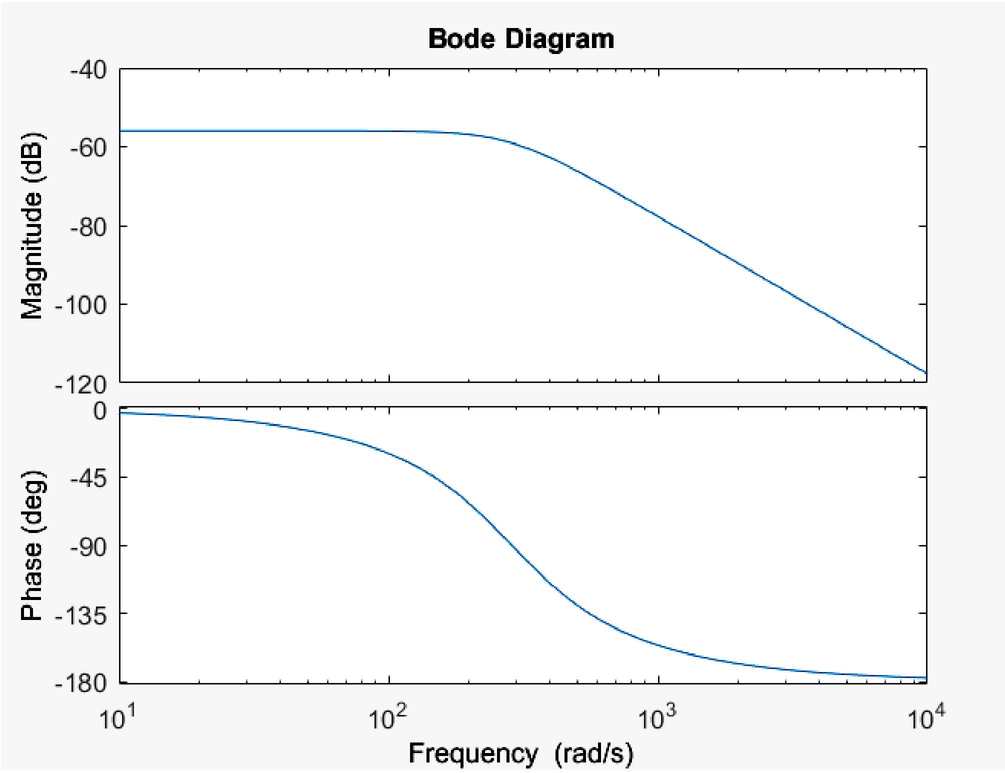

Fig 3.5. Bode graph of Y-axis transmission function

Through defining the transmission function and plotting the frequency response for the X-axis, Y compared with the experiment to check the stability of the system. From the Bode graph of the object transfer function, we can determine marginal reserve GM> 0 and phase reserve PM> 0 should have a stable system.

4. Experiment and result

4.1. Experiment on surface grinding

In this study, using SKD11 steel grinding sample [8][9], detailed drawings as shown in figure 4.1

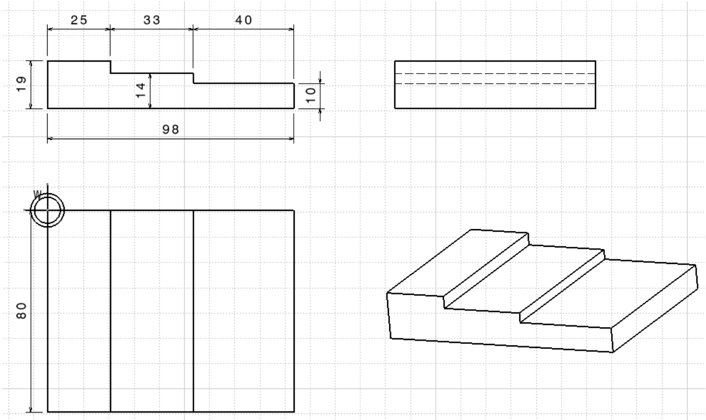

Fig 4.1. Detailed drawings of the step surface

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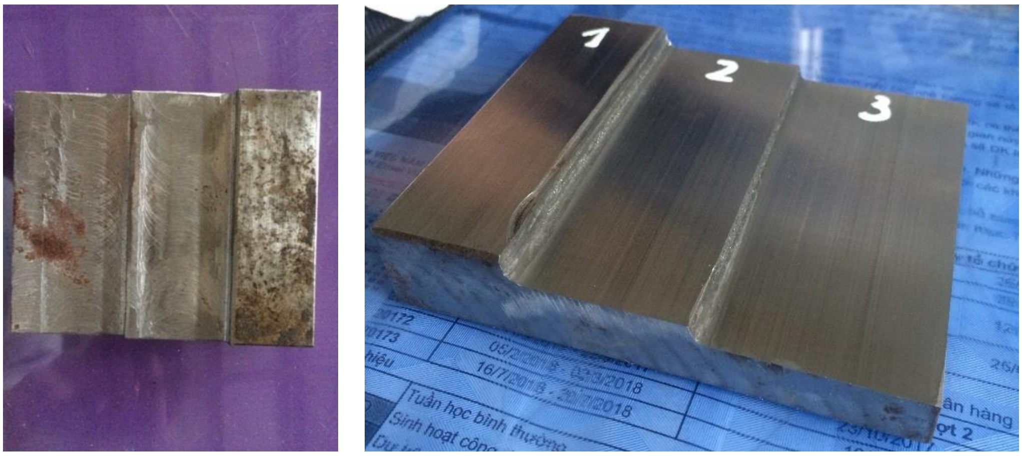
- Programming and machining details on simulation software to export G file - program code
- Assign the part on the machine, select the origin and set the zero base by X, Y, Z axes
- Set up the program into the NSG-550B flat grinder to run the machining program. The machining details are shown in

Figure 4.2.

Fig 4.2. Automatic grinding with the program loaded on the NSG-550B machine

Figure 4.3 is the result after gridding surface 1,2,3 and measured roughness is shown in table 4.1



a) b)

Fig 4.3. a. Surfaces before machining; b – Surfaces after automatic grinding

Table 4.1. Surface roughness value before and after machining

R_a ((µm)	**Flat 1**	**Flat 2**	**Flat 3**
R_a of Surface before	0.9	4.41	4.56
R_a of Surface after	0.19	0.18	0.16

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4.2. Optimizing technology parameters

Using experimental planning which is both orthogonal and rotational in the investigation area and optimized with three factors Vc - Speed of grinding wheel [m/ph]; t - Depth of cut [mm]; S - Feed motion [mm/vg]. Table 4.2 gives of parameter values of factor [4,12].

Table 4.2. Experimental factor value

Factor	**Units**	**Min**	**Max**	**-1 lever**	**1 lever**
Speed of Wheel (V_c)	m/ph	1700	2000	-1	1
Cutting depth (t)	m/ph	0.005	0.025	-1	1
Feed motion (S)	mm/s	2	6	-1	1

Process the surface grinding SKD11 in the order and obtained the test results according to Box - Behnken model shown in Table 4.3 [13].

Table 4.3. Experimental results

Exp. No	**Vc** (m/ph)	**T** (m/ph)	**S** (mm/s)	**Ra** (µm)
1	1850	0.015	4	0.16
2	2000	0.015	2	0.16
3	2000	0.025	4	0.43
4	1850	0.005	6	0.16
5	1850	0.015	4	0.17
6	1700	0.005	4	0.21
7	1850	0.025	6	0.32
8	2000	0.015	6	0.32
9	1700	0.025	4	0.32
10	1700	0.015	6	0.26
11	2000	0.005	4	0.12
12	1850	0.025	2	0.22
13	1850	0.005	2	0.18
14	1850	0.015	4	0.15
15	1700	0.015	2	0.28

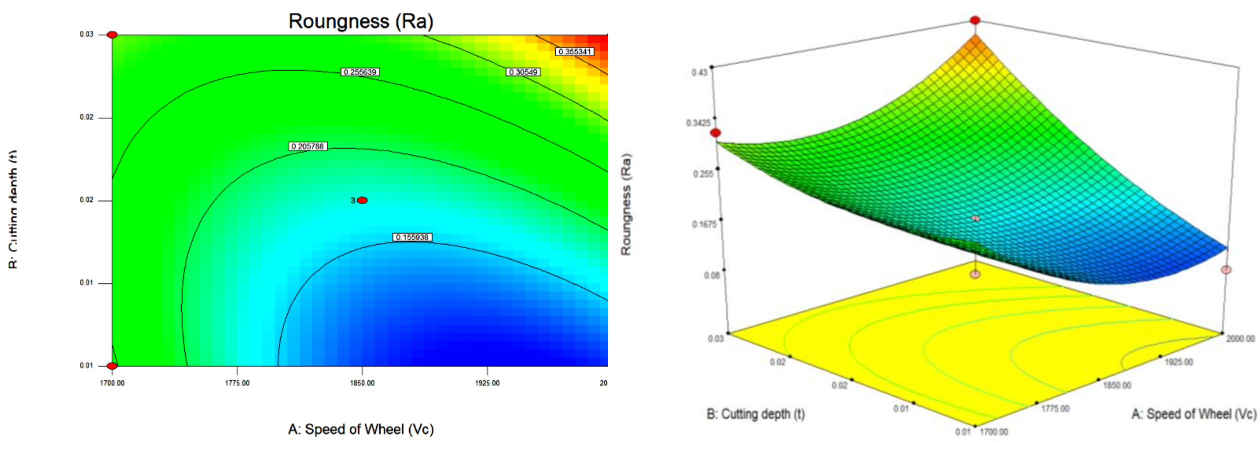

Fig 4.4. Roungness results for different of V_c, t, S

Using a software designer to process the data, the graph is shown in Figure 4.4 and define the target function that can perform the relationship between the surfaces with the parameters Vc, t, S as follows

$$Ra = 0.18 - 0.01V_c + 0.082t + 0.028S + 0.06V_c{*}t + 0.045V_c{*}S + 0.03S{*}t + 0.065V_c^2 + 0.03t \quad (10)$$

From the data analysis, it is possible to choose the optimal processed pine fish to achieve high surface gloss, for reference value Vc = 1970 [m / ph]; t = 0.01 [mm]; S = 2.06 [mm / s], Ra can reach value as 0.079 [µm]

5. Conclusions

The NSG-550B flat grinder has adopted a stable oscillation motion automation feature. The results of machining testing show flexibility and response to machining quality based on the automation of the machine in use.
The integration of the controller for the tooling movement shows good quality machining, stable assessment system, so it is possible to improve grinding and grinding of more complex parts. combined with stone repair, improve productivity.
Pre-grinding toolpath simulation and programming on this flat grinder can reduce the machining time of parts by 20% - 50% and improve productivity with computational analysis. optimal parameters for the best machining quality.

Acknowledgments
The authors thank Hanoi University of Science and Technology for supporting the budget of this research. The results of this research are carried out in University project No T2018 – PC-217

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