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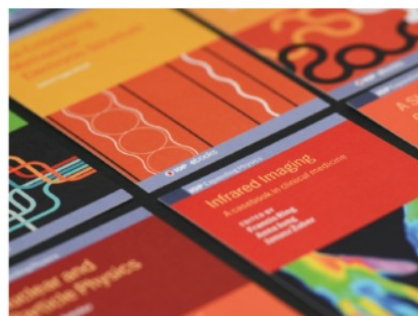
Optimizing machining time for CAD / CAM milling programming using the Taguchi method

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Abstract. The CNC milling machining process is a very important process in manufacturing products because it affects the profitability of the production process. CAD / CAM programming software tools speed up the process and predict the production process time. This study uses CAD / CAM simulation of HSM operations and uses the Taguchi method which is a method that can optimize process variables to get a good response. Process variables chosen are Speed, feed rate, depth of cut, step over, stay on surface and radius link. The type of tool used is an end mill with a diameter of 20 mm SECO Jabro-Solid-JS554 standard. The results of the study stated that the HSM machining simulation process that had a greater influence on machining time was feeding 680 mm / minute and 5 mm depth of cut. The experimental results confirm the ideal time produced is 34.25 minutes.

1. Introduction

Computer Aided Design (CAD) is one of the computer (or workstations) uses which has a function for assisting the creation, modification, analysis, or optimization of designs [1]. The CAD software is used to increase design productivity, improve design quality, improve communication through documentation, and to create databases for manufacturing [2]. Normally, CAD output is in the form of electronic files for printing, machining, or other manufacturing operations. Computer Aided Manufacturing (CAM) is the use of computer software to control machine tools or other machine parts related to machining processes. CAM is a process after modeling using Computer Aided Design (CAD) or also Computer Aided Engineering (CAE). CAM can also refer to the use of computers to assist in all plant operations, including planning, management, transportation, and storage [3,4].

The Taguchi design method was developed by Dr. Genichi Taguchi and is a set of methodologies in which the variability of the characteristics of the manufacturing process can be considered during the design phase itself [5]. The uniqueness of the Taguchi design methodology is that it can examine processes for a number of factors at once. In addition, it also considers the influence of noise factors other than the factors controlled. Julie Z. Zhang et al. [6] have examined optimizations to optimize surface roughness in milling operations using the Taguchi design and concluded that the Taguchi design is an efficient methodology for optimizing machining parameters [7].

JA. Ghani et al. [8] have studied the optimization of end milling parameters on hardened steel and also analyzed the effect of parameter interactions using the Taguchi design. W.H. Yang and YS. Tarng has used the Taguchi method to optimize cutting parameters in the replacement of S45C steel with tungsten carbide tools and together with the use of ANOVA to identify significant factors that affect operations [9]. Tsann-Rong Lin has carried out an experimental design to optimize cutting parameters from face grinding operations with TiN-coated devices [10].

Bagci Eyup and Şeref Aykut have identified optimal end surfaces in face surface grinding operations of cobalt-based alloys by optimizing milling parameters such as feed rate, cutting speed, and cutting depth [11]. CAD / CAM programming CNC (Computer Numerical Control) machines are used to make G-Code. CAD / CAM milling simulates the actual machining process. To produce minimal machining times, machining variables that affect the machining process can be set. The Taguchi experimental design method is used to obtain optimal machining times [12].

2. Method

The Taguchi method is a statistical method developed by Genichi Taguchi to improve the quality of manufacturing, engineering, biotechnology, marketing and advertising production. The advantage of the experimental design of the Taguchi method is getting an overview of how parameters affect process performance [5]. There are two main measuring tools in the Taguchi design method, namely:

- Size of quality during design / development. In order to obtain a good individual indicator and can be used to evaluate due to changes in a parameter design, especially in product performance, the Signal-to-noise ratio (SNR) model is used.
- Efficient experiments to find information about the design of simultaneous parameters. From the experiments carried out must be able to obtain interrelated information so that design changes during the manufacture and use of customers can be avoided, and the information must be obtained in the minimum time and material. To perform an efficient experiment, the Orthogonal Matrix was used [13].

The following steps are performed to apply the Taguchi parameter design approach:

- Determine the quality parameters to be optimized.
- Select significant controlled parameters and different levels for research.
- Select the appropriate orthogonal array.
- Do the number of experiments needed, simulate CNC milling programs from each level so that you get a response in the form of machining time.
- Analysis of the results obtained from the experiment and determine the optimal level of the controlled parameters, calculation of the S / N ratio and the resulting graph.
- The characteristics of the S / N ratio used are the smaller the better (Smaller is Better) where the equations are as follows [5]:
- $S/NR - 10\log\left[\frac{1}{n}\sum_{i=1}^{n} y_i^2\right]$ ....(1)
- Predict optimized parameter performance.
- Confirm to get the actual results.

The main objective of this research paper is to apply the Taguchi parameter design to predict the main factors that influence the counter country milling operation and to optimize machining times.

3. Results and discussion
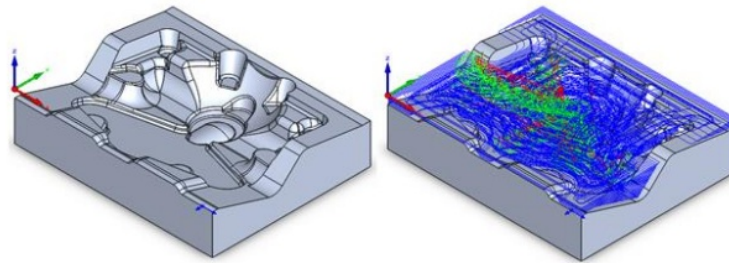
3.1. CAD and CAM research models

Figure 1. CAD and CAM design.

Drawing research models in the form of CAD (Computer Aided Design) using SolidWorks 2014 software, the CAD design model was taken from the solidcam 2017. database the research model was converted into a CAM (Computer Aided Manufacture) so that it can be simulated using SolidCAM 2017. CAD and CAM can be seen in Figure 1.

3.2. Determining research factors and levels
The following are the factors and levels of research adapted to the Milling catalog (Jabro-Solid-JS554 SECO).

Table 1. Factors and level of research.

Factor	Parameter	Level				
		(1)	(2)	(3)	(4)	(5)
A	Speed (rpm)	800	1200	1600	2000	2400
B	Feeding (m/min)	130	260	390	520	680
C	ap (mm)	1	2	3	4	5
D	ae (mm)	8	10	12	14	16
E	Stay on Surface (mm)	10	20	30	40	50
F	Link Radius (mm)	2	2.5	3	3.5	4

3.3. Determine the orthogonal matrix

Table 2. Orthogonal matrix design.

Experiment	Factor						Response	
	Speed (N)	Feed (f)	Depth of cut (ap)	Step over (ae)	Stay on surface (SoS)	Link radius (Lr)	Time (t)	S/N Rasio
	rpm	mm/min	mm	mm	mm	mm	min	db
1	800	130	1	8	10	2	545	-54.73
2	800	260	2	10	20	2.5	102	-40.17
3	800	390	3	12	30	3	57	-35.12
4	800	520	4	14	40	3.5	43	-32.67
5	800	680	5	16	50	4	34	-30.63
6	1200	130	2	12	40	4	176	-44.91
7	1200	260	3	14	50	2	77	-37.73
8	1200	390	4	16	10	2.5	82	-38.28

Table 2. Cont.

9	1200	520	5	8	20	3	51	-34.15
10	1200	680	1	10	30	3.5	96	-39.65
11	1600	130	3	16	20	3.5	143	-43.11
12	1600	260	4	8	30	4	89	-38.99
13	1600	390	5	10	40	2	55	-34.81
14	1600	520	1	12	50	2.5	108	-40.67
15	1600	680	2	14	10	3	82	-38.28
16	2000	130	4	10	50	3	138	-42.80
17	2000	260	5	12	10	3.5	109	-40.75
18	2000	390	1	14	20	4	155	-43.81
19	2000	520	2	16	30	2	49	-33.80
20	2000	680	3	8	40	2.5	46	-33.26
21	2400	130	5	14	30	2.5	122	-41.73
22	2400	260	1	16	40	3	179	-45.06
23	2400	390	2	8	50	3.5	84	-38.49
24	2400	520	3	10	10	4	103	-40.26
25	2400	680	4	12	20	2	35	-30.88

Orthogonal matrix is a matrix whose elements are arranged according to rows and columns (5). The selected factors are 6, namely speed, feed, depth of cut (ap), step over (ae), Stay on surface (SoS) and lead radius (Lr), while the research level is 5, then the orthogonal matrix L25 is chosen (56). The form of variations in levels can be seen in Table 2.

3.4. Data collection and S / N calculation of HSM ratio

There are two stages of data retrieval: The first stage of the CNC Milling HSM simulation process, from CNC Milling simulation experiments can the data be in the form of machining time. The second stage of machining time derived from the CNC Milling HSM simulation is calculated by S / N ratio using Minitab software 18. Calculating the S / N ratio in the first experiment uses the equation smaller the better.

$$S/NR = -10\log\left[\frac{1}{1}\sum_{i=1}^{n} 545^2\right]$$
$$S/NR = -10\log 2.97025 \times 10^5$$
$$S/NR = -54.73 \text{ db}$$

Then the above calculation results are averaged to determine the effect of the level on each research factor. Calculation of the effect of the level of each factor on the timing of machining of HSM. Calculation of S / N values the machining time ratio through a combination of levels of each factor, the following is how to calculate the response table.

$$N_1 = \frac{(-54.73)+(-40.17)+(-35.12)+(-32.66)+(-30.63)}{5}$$
$$N_1 = -38.66 \text{ dB}$$

Table 3. S / N response machining time ratio from the influence of the high-speed machining factor.

Level	Speed	Feed	ap	ae	Stay on Surface	Link Radius
1	-38.66	-45.45	-44.78	-39.92	-42.46	-38.39
2	-38.94	-40.54	-39.13	-39.54	-38.42	-38.82
3	-39.17	-38.10	-37.89	-38.47	-37.86	-39.08
4	-38.88	-36.31	-36.72	-38.84	-38.14	-38.93
5	-39.28	-34.54	-36.41	-38.17	-38.06	-39.72
Delta	0.62	10.92	8.37	1.75	4.60	1.33
Rank	6	1	2	4	3	5

In Figure 2 it can be seen that the highest delta value is feed speed and feed depth (ap) so that it can be concluded that the two factors most influence the machining time. While the Smaller is Better target value is the average value of the S / N ratio close to zero which results in each factor. Then the variations in levels that produce machining processes with ideal time are: Speed (N_1) 800 rpm, Feed (f_5) 680 mm / minute, Feed depth (ap_5) 5 mm, Step over (ae_5) 16 mm, Stay on surface (SoS_3) 30 mm, Link radius (Lr_1) 2 mm.

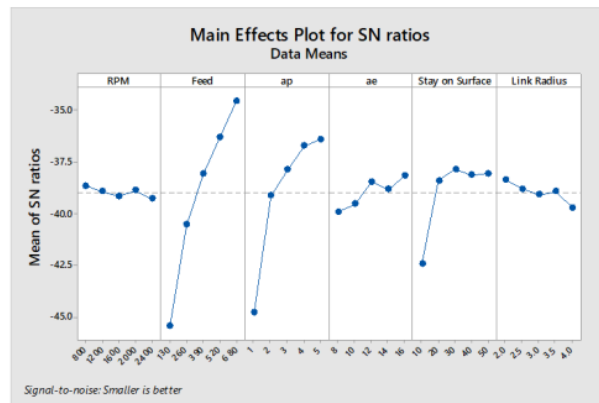From Table 3. in graphical form as shown in figure 2 below.

Figure 2. Graph of S / N values ratio to machining time high speed machining.

3.5. Confirmation trial

Table 4 below is the confirmation of the HSM operational machining simulation time. Number 1 and 2 are two variations of the optimum machining time level while number 3 is confirmation of the optimum machining time for 34.25 minutes.

Table 4. Confirmation value of operational variables HSM.

No	N	f	ap	ae	SoS	Lr	t
	(rpm)	(mm/min)	(mm)	(mm)	(mm)	(mm)	(minute)
1	2400	680	4	12	20	2	35
2	800	680	5	16	50	4	34.5
3	800	680	5	16	30	2	34.25

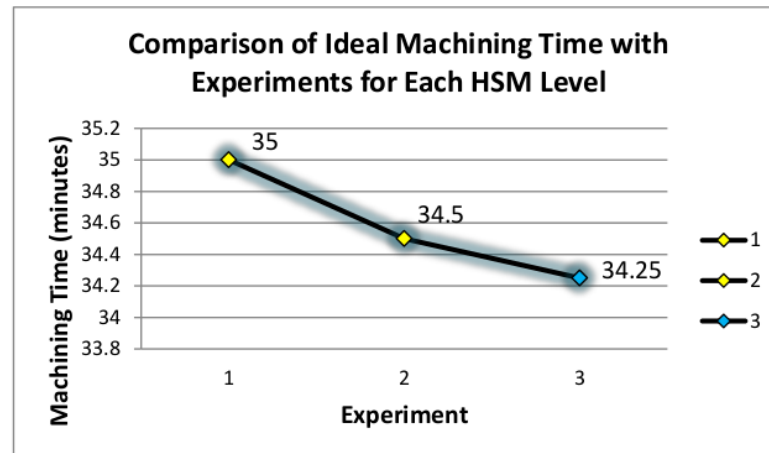From Table 4. in graphical form in figure 3. the following.

Figure 3. Confirmation value of operational HSM.

3.6. Discussion
CAD/CAM programming simulation strategies can be made convenient for design and manufacturing problems, and provide an easier way to solve complex manufacturing problems. This reduces the time needed to apply to new CNC machines. Simulation can prevent the danger faced when dealing with CAM steps and CNC machines have accidents and near misses, which may occur at an early stage.

4. Conclusion
From the results of this study of machining parameters for machining time on CAD / CAM programming, HSM Milling can be concluded as follows:

- In the machining simulation process with operational CAD / CAM software HSM the main factors that have greater influence are feeding and depth of cut, while Speed, stay on surface and radius links are less influential. Then the ideal combination of machining simulation parameters is: Speed (N1) 800 rpm, Feed (f5) 680 mm / minute, Feed depth (ap5) 5 mm, Step over (ae5) 16 mm, Stay on the surface (SoS3) 30 mm, Link radius (Lr1) 2 mm.
- The results of the confirmation experiment produce the ideal machining simulation time by comparing the S / N ratio of the HSM machining simulation process. We could obtain the ideal time for 34.25 minutes.

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