

The Use of Taguchi Method in Design of Dies Propeller Production Using CNC Machine

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(Received: 01 August 2019 / Revised: 24 November 2019 / Accepted: 28 November 2019)

Abstract—propeller is a rounded blade that rotates in a circle, helping to move a vehicle by pushing against water or air. A speed boat's propeller moves it forward by spinning against the water. Propellers use the laws of physics to propel, or drive forward, an aircraft or a boat. The basic structure of a propeller is a spinning or rotating shaft with wide, curved blades attached to it. The very simplest propellers were first used in ancient Greece, where the inventor Archimedes invented a "screw propeller" that moved water for irrigating crops. A method for making propeller is to use a casting method with sand mold. In operating, the sand mold can only be used for one use, and in the molding process must be reconstructed, which of course, requires cost and additional time, so it is less efficient. Therefore, making a propeller with a permanent mold is the right solution. In this study, the design of the dies propeller production process with CNC (Computerized Numerical Control) machine was designed using the MasterCam software simulation method. In addition, variations in machining parameters feed rate, retract rate, and depth of cut were also carried out using the Taguchi method. The research has known the step of dies propeller production process and the time for cutting that used to calculate the most efficient variable variation. Based on the simulation that has been done, for making dies propeller requires ten steps of processing, there are facing, pocket, contour (top die), rough surface pocket, surface finish contour (top die), surface finish parallel, contour (bottom die), and surface finish contour (bottom die). From a series of work processes designed, the total processing time was produced for top die 729,17 minutes, and cutting power was 9,734 kWh, and for the bottom, die is about 1329,65 minutes, and cutting power was 14,543 kWh.

Keywords—CNC machines, machining parameters, mastercam, permanent mold, propeller, simulation, taguchi method.

I. INTRODUCTION

Manufacturing industry activities often deal with increasing customer demand. Manufacturing activities are required to develop production methods continue to be more competitive in making products such as sustainable change and increasing the flexibility of the production system. These developments have the main goal of getting a shorter production time, cheaper products, and the best performance of the product. An example of the manufacturing industry is the metal casting industry, and the products produced are propeller.

In the process of casting metal, there are several kinds of molds. Molds are often used are permanent mold (metal molds) and non-permanent mold (sand molds). In general, the metal casting industry uses sand mold (sand casting). In operating sand molds are made manually so that the dimensions are less precise and can only be used for one use and in the moulding process must be reconstructed which of course, requires cost and extra time[1].

Permanent mold (metal mold) is a type of mold that can be used repeatedly, and this mold is usually made of metal material. Using metal molds will produce cast products that are more economical both in quality and quantity. With this permanent mold, even though the initial investment is relatively more expensive, for more production, the use of metal molds will be profitable, and this mold can be used repeatedly. The technology that can be used to produce permanent molds for the

propeller is CNC (Computerized Numerical Control) machines [2].

Software used for CNC programming is the MasterCam software. By using MasterCam software, a programmer only needs to draw an object image and plan the machining parameters to be used. After that, the instructions for the process of working the object will be made by the software. These commands will be converted into the numerical language (G-Code), which can be understood by CNC machines and then transferred to CNC machines for execution. But before executing the command directly on a CNC machine, MasterCam software can execute the command in the form of a simulation aluminum so that if there are errors, it can be identified. The simulation aims to reduce the risk of errors and work accidents when the G-code command is executed directly on a CNC machine [3].

Production costs are accumulated costs that occur during the production process of a material. Production cost are influenced by material costs, production processes, and other indirect costs that occur during the production process. This production cost calculation is used in the manufacturing industry to find out the true cost of making a machine component product so that it can be estimated how much profit will be obtained [4].

II. METHOD

A. Permanent Die Casting

Permanent die casting is the manufacture of metals with molds combined with hydrostatic pressure. This method is not practical for large casting and when using high boiling metals. Non-steel metals such as aluminium, zinc, tin, magnesium, bronze if made in this way the results are good. This mold consists of two or more parts

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combined with screws, clamps, plates or other removable tools after the product has hardened. In general, permanent molds are made from close-grain and clamped to one another. This mold is usually coated with heat-resisting wet mixture and soot, which will keep the mold from sticking and reduce the effect of cold on the metal [5].

B. Propeller

Propeller is a rounded blade that rotates in a circle, helping to move a vehicle by pushing against water or air. A speed boat's propeller moves it forward by spinning against the water. Propellers use the laws of physics to propel, or drive forward, an aircraft or a boat. The basic structure of a propeller is a spinning or rotating shaft with wide, curved blades attached to it. The very simplest propellers were first used in ancient Greece, where the inventor Archimedes invented a "screw propeller" that moved water for irrigating crops [6].

C. CNC (Computerized Numerical Control)

Computer Numerical Control, abbreviated as CNC is a machine tool automation system operated by abstractly programmed and stored commands on storage media, this is in contrast to a previous habit in which machine tools are usually controlled by hand spin or simple automation using cam[7]. The word NC itself is an English abbreviation of the word Numerical Control which means "numerical control". The first NC machines were first invented in the 1940s and 1950s, by modifying ordinary machine tools. In this case, ordinary machine tools are added with motors that will move the control wheels include the points entered into the system by the paper recorder. The blend of motor and mechanical servo was soon replaced by analog systems and then digital computers, creating a modern Machine Tool called the CNC Machine (computer numerical control) which later revolutionized the design process. Currently, CNC machines have a very close relationship with the CAD program. CNC machines are built to address the challenges in the modern manufacturing world. With a

CNC machine, the accuracy of a product can be guaranteed up to 1/100 mm more, mass product workmanship with exact same results molding and fast machining time [8].

D. CAD/CAM Programming

Computer-Aided Manufacturing (CAM) is a function of computer software to control the machine and its equipment in the work process of the object. CAM aims to make the production process faster, with more precise and consistent dimensions. CAM software is used in computer systems to facilitate programmers in producing complex contour and surface forms (machining of artistic products) without using complicated mathematical formula calculations. In the manufacturing process, a product generally begins with the design concept of the product, then proceeds with making a 3D model using a Computer-Aided Design (CAD) system. After modeling using a CAD system, the product model is transferred to the CAM system [9]. With the CAM system, a path will be made that the cutter (toolpath strategy) will pass through the 3D product that we made. The cutter path in the CAM system will later be used as a cutter path in the actual machining process in a CNC machine with the help of NC; post-processing is done on the cutter location (Cutter Location / CL data) where it defines the cutter path. With a post-processor, the CL data can be converted into a G-Code that can be read by CNC machines [10].

E. Taguchi Method

Taguchi method used in offline quality control activities at the design process stage of production, what is meant by offline quality control, is quality control activities in product design. In the Taguchi method, a matrix called orthogonal array is used to determine the number of minimal experiments that can give information as much as possible of all factors that influence the parameters. The most important part of orthogonal arrays lies in the selection of combinations level of input variables for each experiment[11].

TABLE 1.
 ORTHOGONAL ARRAY 4 FACTORS WITH 3 LEVELS

Experiment no.	Factor A	Factor B	Factor C	Factor D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

F. Analysis of Variance (ANOVA)

Analysis of variance or ANOVA is a multivariate analysis technique that serves to differentiate the mean of more than two groups of data by comparing the variance. Analysis of variance is included in the statistical

parametric category. As a parametric statistical tool, to be able to use the ANOVA formula must first be tested for assumptions including normality, heterogeneity and random sampling [13].

Analysis of variance can be used to analyze data from various types and research designs. Analysis of variance is widely used in many studies involving comparative testing, namely testing the dependent variable by comparing it to the independent sample groups observed [14].

III. RESULT AND DISCUSSION

In doing this thesis, a process must be prepared. There must be planning in the work so that it feels more focused and easier. In the discussion of this research will be discussed step by step, which will be carried out in the execution of the thesis.

A. Model Design

Making dies propeller models using existing data propeller. Modeling is done using SolidWorks software, which is then simulated using the Mastercam software to determine the total production time and cutting power requirement.

B. Machining Process Design (CAM) and Simulation

It was selecting and calculating CNC machining parameters needed, such as toolpath, tools, spindle

speed, feed rate, and depth of cut for the production of Dies Propeller. After determining the machining parameters of the process, a simulation (running) the MasterCam program is performed. It aims to look at the work results in each groove on each toolpath.

C. Calculation of Total Time & Power Requirement

The total time of the production process is the overall processing time on the variations of the tool with the most optimal results and also the time of non-productive machinery. After obtaining the optimal time, we calculated also the power requirement for the work of the object.

D. Analysis of Variance (ANOVA)

Analysis of variance (ANOVA) statistics used to determine the effect of each factor variable (feed rate, re-track rate, and depth of cut) on the response variable (machining process power). The variances analysis process uses Minitab software 18.

A. Model Design

Workpieces that will be processed by CNC milling are dies propeller models. Below is the model of the dies propeller:

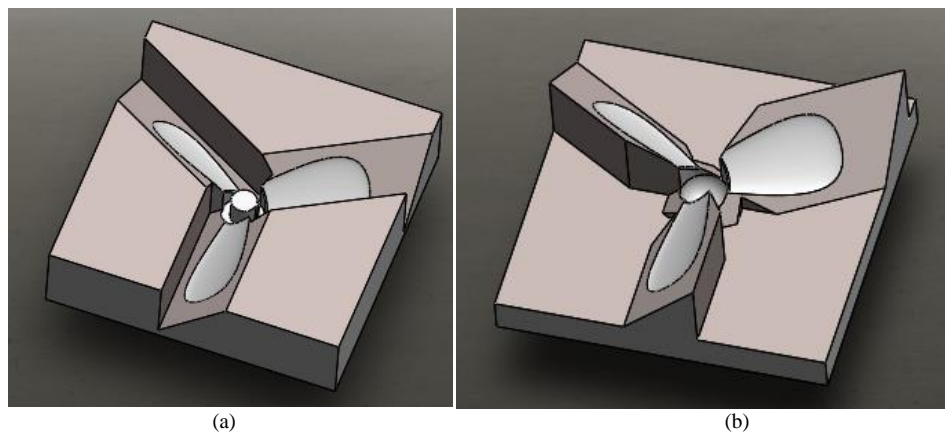


Figure 1. (a) Top Die (b) Bottom Die

B. Mastercam Design Process

The design of the machining process at MasterCam is the stage for determining the type of machining, the selection of boundaries or working area boundaries, and the selection of the right type of work for making dies propeller. In the MasterCam software, each type of work is called the toolpath. For dies propeller production process there are ten tool paths that is facing, pocket, contour (top die), rough surface pocket, surface finish contour (top die), multiaxis roughing, surface finish parallel, contour (bottom die), high-speed surface waterline, and surface finish contour (bottom die).

C. Determination of Machining Parameters

All machining parameters are calculated to get the engine optimization in the form of smoother finishes, more durable tools, and more optimal processing time and power. Machining parameters that need to be determined include:

- a. Material type and tool diameter
- b. Cutting speed

- c. Spindle speed
- d. Feed rate and depth of cut

The formula for calculation machining parameters includes:

$$CS = \frac{\pi DN}{1000}, N = \frac{1000CS}{\pi D}$$

Where:

- CS = Cutting Speed, m/min
- D = Diameter tool, mm
- N = Spindle speed, rpm

$$F = f_z \times N$$

Where:

- F = Feed rate, mm/min
- f_z = Cutting feed, mm/rev

$$f_z = f_t \times Z$$

Where:

f_t = Cutting feed, mm/rev
 Z = Number of teeth/cutting edge

The results of setting machining parameters can be seen in Table 2 to Table 5.

TABLE 2.
 TOOLS SELECTION

No	Tools	Diameter (mm)	Material
1	Face End Mill	75	Carbida
2	Flat End Mill	20	Carbida
3	Flat End Mill	25	Carbida
4	Sphere End Mill	8	Carbida
5	Sphere End Mill	20	Carbida

TABLE 3.
 SPINDLE SPEED CALCULATION

No	Tools	Diameter (mm)	Spindle Speed (Rpm)
1	Face End Mill	75	389
2	Flat End Mill	20	1457
3	Flat End Mill	25	1457
4	Sphere End Mill	8	3643
5	Sphere End Mill	20	1457

TABLE 4.
 FEED RATE CALCULATION

No	Tools	Diameter (mm)	Feed Rate (mm/minute)		
			Level I	Level II	Level III
1	Face End Mill	75	395	592	379
2	Flat End Mill	20	592	1184	1776
3	Flat End Mill	25	592	1184	1776
4	Sphere End Mill	8	1110	2220	3331
5	Sphere End Mill	20	592	1184	1776

TABLE 5.
 DEPTH OF CUT CALCULATION

No	Process	Axial Depth of Cut (mm)			Radial Depth of Cut (mm)
		Level I	Level II	Level III	
1	Facing	1	1.5	2	45
2	Contour	1	2	3	0.5
3	Surface Rough Pocket	1	2	3	12
4	Surface Finish Contour	0.5	0.75	1	0.5
5	Surface Finish Parallel	1	2	3	12

D. Calculation of Total Time & Power Requirement

The calculation of time and power uses the Taguchi method with a variation of three-parameter combinations that is feed rate, retrack rate and depth of cut with three different levels then simulated in the Mastercam software to analyze the combination that produces the most optimum power response which is then used as a guideline for planning machining parameters.

TABLE 6.
 PARAMETER VALUE OF FACING

Factor Name	Code	Level I	Level II	Level II	Unit
Feed Rate	F	395	592	790	mm/min
Retrack Rate	Cr	5000	7500	10000	mm/min
Depth of Cut	a	1	1.5	2	mm

TABLE 7.
 POWER RESPONSES OF FACING

No	Parameter Combination			Time (min)	MRR mm ³ /min	HPc kW	HPm kW	kWh
	F	Vr	a					
1	395	5000	1	60.3	17775	0.809	1.349	1.3553
2	395	7500	1.5	56.03	26662.5	1.214	2.023	1.889
3	395	10000	2	30.02	35550	1.618	2.697	1.3495
4	592	5000	1.5	40.26	39960	1.819	3.032	2.0343
5	592	7500	2	20	53280	2.425	4.042	1.3474
6	592	10000	1	40.25	26640	1.213	2.021	1.3558
7	790	5000	2	15.12	71100	3.237	5.394	1.3593
8	790	7500	1	30.23	35550	1.618	2.697	1.3589
9	790	10000	1.5	28.43	53325	2.427	4.046	1.917

Table 6 shows the parameter value of the facing process. From table 7 it can be concluded that the optimal power response value in the facing process is in the 5th combination with feed rate value of 592

mm/minute (level II), re-track rate 7500 mm/minute (level II), and depth of cut 2 mm (level III) with power response value 3,474 Wh and time 20 minutes.

TABLE 8.
 PARAMETER VALUE OF SURFACE ROUGH POCKET

Factor Name	Code	Level I	Level II	Level II	Unit
Feed Rate	F	592	1184	1776	mm/min
Retrack Rate	Vr	5000	7500	10000	mm/min
Depth of Cut	a	1	2	3	mm

TABLE 9.
 POWER RESPONSES OF SURFACE ROUGH POCKET

No	Parameter Combination			Time (min)	MRR mm ³ /min	HPc kW	HPm kW	kWh
	F	Vr	a					
1	592	5000	1	1043.18	7104	0.323	0.539	9.3707
2	592	7500	2	527.52	14208	0.647	1.078	9.4772
3	592	10000	3	366.8	21312	0.97	1.617	9.8847
4	1184	5000	2	274.35	28416	1.294	2.156	9.8577
5	1184	7500	3	190.6	42624	1.94	3.234	10.2727
6	1184	10000	1	440.92	14208	0.647	1.078	7.9214
7	1776	5000	3	131.65	63936	2.91	4.851	10.6433
8	1776	7500	1	354.22	21312	0.97	1.617	9.5457
9	1776	10000	2	180.3	42624	1.94	3.234	9.7176

Table 8 shows the parameter value of the rough surface pocket. From table 9 it can be concluded that the optimal power response value in the surface rough pocket process is in the 6th combination with feed rate value 1184 mm/minute (level II), re-track rate 10000

mm/minute(level III), and depth of cut 1 mm (level I) with power response value 7,9214 kWh and processing time 440,92 minutes.

TABLE 10.
 PARAMETER VALUE OF CONTOUR

Factor Name	Code	Level I	Level II	Level II	Unit
Feed Rate	F	592	1184	1776	mm/min
Retrack Rate	Vr	5000	7500	10000	mm/min
Depth of Cut	a	1	2	3	mm

TABLE 11.
 POWER RESPONSES OF CONTOUR

No	Parameter Combination			Time (min)	MRR mm3/min	HPc kW	HPm kW	kWh
	F	Vr	a					
1	592	5000	1	459.08	296	0.013	0.022	0.1718
2	592	7500	2	2229.26	592	0.027	0.045	0.1716
3	592	10000	3	151.65	888	0.04	0.067	0.1703
4	1184	5000	2	119.65	1184	0.54	0.09	0.1791
5	1184	7500	3	75.56	1776	0.081	0.135	0.1697
6	1184	10000	1	236.2	592	0.027	0.045	0.1768
7	1776	5000	3	51.55	2664	0.121	0.202	0.1736
8	1776	7500	1	155.95	888	0.04	0.067	0.1751
9	1776	10000	2	77.28	1776	0.081	0.135	0.1735

Table 10 shows the parameter value of the contour process. From table 11 it can be concluded that the optimal power response value in the contour process is in the 5th combination with feed rate value 1184 mm /minute

(level II), re-track rate 7500 mm/minute (level II), and depth of cut 3 mm (level III) with power response value 0,1697 kWh and time 75,56 minutes.

TABLE 12.
 PARAMETER VALUE OF SURFACE FINISH CONTOUR

Factor Name	Code	Level I	Level II	Level II	Unit
Feed Rate	F	1110	2220	331	mm/min
Retrack Rate	Vr	5000	7500	10000	mm/min
Depth of Cut	a	1	2	3	mm

TABLE 13.
 POWER RESPONSES OF SURFACE ROUGH POCKET

No	Parameter Combination			Time (min)	MRR mm3/min	HPc kW	HPm kW	kWh
	F	Vr	a					
1	1110	5000	0.5	536.55	277.5	0.013	0.021	0.01883
2	1110	7500	0.75	236.02	416.25	0.019	0.032	0.1242
3	1110	10000	1	175.66	555	0.025	0.042	0.1233
4	2220	5000	0.75	182.15	832.5	0.038	0.063	0.1917
5	2220	7500	1	120.33	1110	0.051	0.084	0.1689
6	2220	10000	0.5	369.2	555	0.025	0.042	0.2591
7	3331	5000	1	102.53	1665.5	0.076	0.126	0.2159
8	3331	7500	0.5	315.8	832.75	0.038	0.063	0.3325
9	3331	10000	0.75	152.86	1249.125	0.057	0.095	0.2414

Table 12 shows the parameter value of the surface finish contour process. From table 13 it can be concluded that the optimal power response value in the surface finish contour process in the 3rd combination with feed rate

value 1110 mm/minute (level I), re-track rate 10000 mm/minute (level III), and depth of cut 1 mm (level I).

TABLE 14.
 PARAMETER VALUE OF SURFACE FINISH PARALLEL

Factor Name	Code	Level I	Level II	Level II	Unit
Feed Rate	F	529	1184	1776	mm/min
Retrack Rate	Vr	5000	7500	10000	mm/min
Depth of Cut	a	1	2	3	mm

TABLE 15.
 POWER RESPONSES OF SURFACE FINISH PARALLEL

No	Parameter Combination			Time (min)	MRR mm3/min	HPc kW	HPm kW	kWh
	F	Vr	a					
1	355	5000	1	35.96	4260	0.194	0.323	0.1937
2	355	7500	2	18.2	8520	0.388	0.646	0.19607
3	355	10000	3	12.18	12780	0.582	0.97	0.19683
4	711	5000	2	17.96	17064	0.777	1.295	0.38752
5	711	7500	3	9.08	25596	1.165	1.942	0.29388
6	711	10000	1	16.03	8532	0.388	0.647	0.17294
7	1066	5000	3	4.1	38376	1.747	2.912	0.19895
8	1066	7500	1	12.05	12792	0.582	0.971	0.19491
9	1066	10000	2	6.08	25584	1.165	1.941	0.19669

Table 14 shows the parameter value of the surface to finish the parallel process. From table 15 it can be concluded that the optimal power response value in the surface finish parallel process is in the 6th combination

with feed rate value of 711 mm/minute (level II), re-track rate 10000 mm/minute (level III), and depth of cut 1 mm (level II) with a power response value of 0,17294 kWh and processing time 16,03 minutes.

TABLE 16.
 PARAMETER VALUE OF FACING (BOTTOM)

Factor Name	Code	Level I	Level II	Level II	Unit
Feed Rate	F	395	592	790	mm/min
Retrack Rate	Vr	5000	7500	10000	mm/min
Depth of Cut	a	1	1.5	2	mm

TABLE 17.
 POWER RESPONSES OF FACING (BOTTOM)

No	Parameter Combination			Time (min)	MRR mm3/min	HPc kW	HPm kW	kWh
	F	Vr	a					
1	395	5000	1	91.02	4740	0.216	0.36	0.32732
2	395	7500	1.5	60.65	7110	0.324	0.539	0.32716
3	395	10000	2	53.25	9480	0.432	0.719	0.38299
4	592	5000	1.5	40.56	10656	0.485	0.808	0.32791
5	592	7500	2	36.42	14208	0.647	1.078	0.39258
6	592	10000	1	60.84	7104	0.323	0.539	0.32791
7	790	5000	2	30.46	18960	0.863	1.438	0.43816
8	790	7500	1	44.62	9480	0.432	0.719	0.32092
9	790	10000	1.5	34.23	14220	0.647	1.079	0.36929

Table 16 shows the parameter value of the facing process. From table 17 it can be concluded that the optimal power response value in the facing process is in the 8th combination with feed rate value 790 mm/minute (level III), re-track rate 7500 mm/minute (level II), and

depth of cut 1 mm (level I) with power response value 0,32092 kWh and processing time 44,62 minutes.

TABLE 18.
 PARAMETER VALUE OF CONTOUR (BOTTOM)

Factor Name	Code	Level I	Level II	Level II	Unit
Feed Rate	F	592	1184	1776	mm/min
Retrack Rate	Vr	5000	7500	10000	mm/min
Depth of Cut	a	1	2	3	mm

TABLE 19.
 POWER RESPONSES OF CONTOUR (BOTTOM)

No	Parameter Combination			Time (min)	MRR mm3/min	HPc kW	HPm kW	kWh
	F	Vr	a					
1	592	5000	1	475.63	296	0.013	0.022	0.10681
2	592	7500	2	238.16	592	0.027	0.045	0.10697
3	592	10000	3	162.36	888	0.04	0.067	0.10938
4	1184	5000	2	120.16	1184	0.054	0.09	0.10794
5	1184	7500	3	92.03	1776	0.081	0.135	0.124
6	1184	10000	1	239.62	592	0.027	0.045	0.10762
7	1776	5000	3	65.25	2664	0.121	0.202	0.13188
8	1776	7500	1	156.1	888	0.04	0.067	0.10517
9	1776	10000	2	90.83	1776	0.081	0.135	0.12239

Table 18 shows the parameter value of the contour process. From table 19 it can be concluded that the optimal power response value in contour process is in the 8th combination with feed rate value 1776 mm/minute

(level III), re-track rate 7500 mm/minute (level II), and depth of cut 1mm (level I) with power response value of 0,10517 kWh and processing time 156,1 minutes

TABLE 20.
 PARAMETER VALUE OF SURFACE ROUGH POCKET (BOTTOM)

Factor Name	Code	Level I	Level II	Level II	Unit
Feed Rate	F	592	1184	1776	mm/min
Retrack Rate	Vr	5000	7500	10000	mm/min
Depth of Cut	a	1	2	3	mm

TABLE 21.
 POWER RESPONSES OF SURFACE ROUGH POCKET (BOTTOM)

No	Parameter Combination			Time (min)	MRR mm3/min	HPc kW	HPm kW	kWh
	F	Vr	a					
1	592	5000	1	2276.66	7104	0.323	0.539	12.2705
2	592	7500	2	1172.25	14208	0.647	1.078	12.6361
3	592	10000	3	816.46	21312	0.97	1.617	13.2014
4	1184	5000	2	582.26	28416	1.294	2.156	12.5528
5	1184	7500	3	409.2	42624	1.94	3.234	13.2327
6	1184	10000	1	1139.2	14208	0.647	1.078	12.2798
7	1776	5000	3	273.45	63936	2.91	4.851	13.2643
8	1776	7500	1	756.02	21312	0.97	1.617	12.2241
9	1776	10000	2	388.96	42624	1.94	3.234	12.5782

Table 20 shows the parameter value of the surface rough pocket process. From table 21 it can be concluded that the optimal power response value in the surface rough pocket process is in the 8th combination with feed

rate value 1776mm/minute (level III), re-track rate 7500 mm/minute (level II), and depth of cut 1 mm (level I) with power response value 12,2241 kWh and processing time 756,02 minutes.

TABLE 22.
 PARAMETER VALUE OF SURFACE FINISH CONTOUR

Factor Name	Code	Level I	Level II	Level II	Unit
Feed Rate	F	1110	2220	3331	mm/min
Retrack Rate	Vr	5000	7500	10000	mm/min
Depth of Cut	a	1	2	3	mm

TABLE 23.
 POWER RESPONSES OF SURFACE FINISH CONTOUR

No	Parameter Combination			Time (min)	MRR mm3/min	HPc kW	HPm kW	kWh
	F	Vr	a					
1	1110	5000	0.5	551.26	277.5	0.013	0.021	0.11606
2	1110	7500	0.75	276.05	416.25	0.019	0.032	0.08718
3	1110	10000	1	185.86	555	0.025	0.042	0.07826
4	2220	5000	0.75	190.42	832.5	0.038	0.063	0.12027
5	2220	7500	1	128.66	1110	0.051	0.084	0.10835
6	2220	10000	0.5	380.55	555	0.025	0.042	0.16024
7	3331	5000	1	109.6	1665.5	0.079	0.126	0.13849
8	3331	7500	0.5	323.6	832.75	0.038	0.063	0.20445
9	3331	10000	0.75	161.86	1249.125	0.057	0.095	0.15339

Table 22 shows the parameter value of the surface finish contour process. From table 23 it can be concluded that the optimal power response values in the process of surface finish contour are in the 3rd combination with

feed rate value of 1110 mm/minute (level I), re-track rate 10000 mm/minute (level III), and depth of cut 1 mm (level I) with power response value 0.07826 kWh and time 185,86 minutes.

TABLE 24.
 PARAMETER VALUE OF SURFACE FINISH PARALEL

Factor Name	Code	Level I	Level II	Level II	Unit
Feed Rate	F	592	1184	1776	mm/min
Retrack Rate	Vr	5000	7500	10000	mm/min
Depth of Cut	a	1	2	3	mm

TABLE 25.
 POWER RESPONSES OF SURFACE FINISH PARALLEL

No	Parameter Combination			Time (min)	MRR mm3/min	HPc kW	HPm kW	kWh
	F	Vr	a					
1	355	5000	1	563.26	4260	0.194	0.323	1.82045
2	355	7500	2	287.98	8520	0.388	0.646	1.86149
3	355	10000	3	189.7	12780	0.582	0.97	1.83932
4	711	5000	2	146.02	17064	0.777	1.295	1.8904
5	711	7500	3	102.2	25596	1.165	0.942	1.98464
6	711	10000	1	290.6	8532	0.388	0.647	1.88108
7	1066	5000	3	78.52	38376	1.747	0.2912	2.28612
8	1066	7500	1	187.05	12792	0.582	0.971	1.81533
9	1066	10000	2	112.03	25584	1.165	1.941	2.17452

Table 24 shows the parameter value of the surface finish the parallel process. From table 25 it can be concluded that the optimal power response value in the surface finish parallel process is in the 8th combination with

feedrate value 1066 mm/minute (level III), ret-rack rate 7500 mm/minute (level II), and depth of cut 1 mm (level I) with power response value 1,81533 kWh and processing time 187,05 minutes.

TABLE 26.
 TOTAL PROCESSING TIME AND POWER CUTTING REQUIREMENT

NO	Process	Time (minute)	Power (kWh)
1	Facing	20	1,3474
2	Contour	76,56	0,1697
3	Surface Rough Pocket	440,92	7,9214
4	Surface Finish Contour	175,66	0,1233
5	Surface Finish Parallel	16,03	0,17294
6	Facing	44,62	0,32092
7	Contour	156,1	0,10517
8	Surface Rough Pocket	756,02	12,2241
9	Surface Finish Contour	185,86	0,07826
10	Surface Finish Parallel	187,05	1,81533
Total		2058,82	24,2785

E. Analysis of Variance (ANOVA)

From the results of simulations that have been carried out then proceed with analysis using variance analysis according to parameter factors, level, and processing of data based on ANOVA statistics to determine the effect

of each factor variable (feed rate, re-track rate and depth of cut) on the response variable (machining process power). The variance analysis process software 18.

Results of Analysis of Variance:

TABLE 27.
 ANALYSIS OF VARIANCE FACING PROCESS

Source	DF	Adj SS	F-Value	P-Value
Feed Rate	2	898.02	41.81	0,023
Retrack Rate	2	48.25	2.25	0,308
Depth of Cut	2	877.23	40.85	0,024
Error	2	21.48	-	-
Total	8	1844.98	-	-

Based on Table 27, it can conclude several things. If the value of $P > 0.05$ means that there are no significant factors that influence the power response. In the facing feed rate process, and the depth of cut has a value of $P < 0.05$ means that it significantly affects the power response. In the facing process the greatest F value of the

three factors in the experiment is feed rate, which is 41,81 which means that feed rate has the greatest influence on the power response, then the second depth of cut with $F = 40,85$ and the last re-track rate with $F = 2,25$.

TABLE 28.
 ANALYSIS OF VARIANCE CONTOUR PROCESS

Source	DF	Adj SS	F-Value	P-Value
Feed Rate	2	55188	9.71	0,093
Retrack Rate	2	6225	1.09	0,477
Depth of Cut	2	58902	10.36	0,088
Error	2	5685	-	-
Total	8	126001	-	-

Based on Table 28 it can conclude several things. If the value of $P > 0.05$ means that there are no factors that most influence the power response. In the contour, all factors have a value of $P > 0.05$, which means there are no factors that significantly affect the power response. In

the contour process, the greatest F value of the three factors in the experiment is a depth of cut, which is 10.36, which means that depth of cut has the greatest influence on the power response, then the second is feed rate with $F = 9.71$ and the last re-track rate with $F = 1.09$.

TABLE 29.
 ANALYSIS OF SURFACE ROUGH POCKET

Source	DF	Adj SS	F-Value	P-Value
Feed Rate	2	304222	9,61	0,094
Retrack Rate	2	40199	1,27	0,441
Depth of Cut	2	237748	7,51	0,117
Error	2	31653	-	-
Total	8	613821	-	-

Based on table 29, it can conclude several things. If the value of $P > 0.05$ means that there are no significant factors that influence the power response. In the surface rough pocket process, all factors have a value of $P > 0.05$, which means there are no factors that significantly influence the power response. In the surface rough

pocket process the greatest F value of the three factors in the experiment is the feed rate which is 9.61 meaning that the feed rate has the greatest influence on the power response, then the second is the depth of cut with the value $F = 7.51$ and the last re-track rate with the value $F = 1.27$.

TABLE 30.
 ANALYSIS OF VARIANCE SURFACE FINISH CONTOUR

Source	DF	Adj SS	F-Value	P-Value
Feed Rate	2	25415	7,60	0,116
Retrack Rate	2	4237	1,27	0,441
Depth of Cut	2	125590	37,55	0,026
Error	2	3344	-	-
Total	8	158587	-	-

Based on Table 30 it can conclude several things. If the value of $P > 0.05$ means that there are no significant factors that influence the power response. In the surface finish contour process, the depth of cut has a value of $P < 0.05$ means that it significantly affects the power response. In the surface finish contour process, the

greatest F value of the three factors in the experiment is the depth of cut, which is 37,55 which means that depth of cut has the greatest influence on the power response, then the second feed rate with $F = 7,60$ and the last re-track rate with $F = 1,27$.

TABLE 31.
 ANALYSIS OF VARIANCE SURFACE FINISH PARALLEL

Source	DF	Adj SS	F-Value	P-Value
Feed Rate	2	324,61	11,31	0,081
Retrack Rate	2	104,20	3,63	0,216
Depth of Cut	2	250,70	8,74	0,103
Error	2	28,69	-	-
Total	8	708,21	-	-

Based on Table 31, it can conclude several things. If the value of $P > 0.05$ means that there are no significant factors that influence the power response. In the process of surface finish parallel feed rate has a value of $P < 0.05$, which means that it significantly affects the power response. In the process of surface finish parallel, the highest value of F from the three factors in the experiment is feed rate which is 11.31, meaning that feed rate has the greatest influence on power response, then

the second depth of cut with $F = 8.74$ and the last re-track rate with $F = 3.63$.

TABLE 32.
 ANALYSIS OF VARIANCE FACING (BOTTOM)

Source	DF	Adj SS	F-Value	P-Value
Feed Rate	2	324,61	11,31	0,081
Retrack Rate	2	104,20	3,63	0,216
Depth of Cut	2	250,70	8,74	0,103
Error	2	28,69	-	-
Total	8	708,21	-	-

Based on Table 32, it can conclude several things. If the value of $P > 0.05$ means that there are no factors that most influence the power response. In the facing, all factors have a value of $P > 0.05$, which means there are no factors that significantly affect the power response. In

the facing process, the greatest F value of the three factors in the experiment is feed rate, which is 11.31, which means that feed rate has the greatest influence on the power response, then the second is a depth of cut with $F = 8.74$ and the last re-track rate with $F = 3.63$.

TABLE 33.
 ANALYSIS OF VARIANCE CONTOUR

Source	DF	Adj SS	F-Value	P-Value
Feed Rate	2	57514	7,13	0,123
Retrack Rate	2	6542	0,81	0,552
Depth of Cut	2	55490	6,88	0,127
Error	2	8064	-	-
Total	8	127610	-	-

Based on Table 33, it can conclude several of things. If the value of $P > 0.05$ means that there are no significant factors that influence the power response. In the contour process, all factors have a value of $P > 0.05$, which means there are no factors that significantly affect the power response. In the contour process, the highest value of the three factors in the experiment is the feed rate, which is 7.13. It means that feed rate has the most influence on the power response, then the second depth of cut with $F = 6.88$ and the last re-track rate with $F = 0.81$.

factors that influence the power response. In the surface rough pocket process, all factors have a value of $P > 0.05$, which means there are no factors that significantly influence the power response. In the surface rough pocket process, the highest F value of the three factors in the experiment is feed rate, which is 10.36, which means that feed rate has the most influence on the power response, then the second depth of cut with $F = 9.18$ and the last re-track rate with $F = 0.98$.

Based on Table 34, it can conclude several of things. If the value of $P > 0.05$ means that there are no significant

TABLE 34.
 ANALYSIS OF SURFACE ROUGH POCKET

Source	DF	Adj SS	F-Value	P-Value
Feed Rate	2	1463258	10,36	0,088
Retrack Rate	2	139163	0,98	0,504
Depth of Cut	2	1297038	9,18	0,098
Error	2	141290	-	-
Total	8	3040750	-	-

TABLE 35.
 ANALYSIS OF VARIANCE SURFACE FINISH CONTOUR

Source	DF	Adj SS	F-Value	P-Value
Feed Rate	2	31562	9,39	0,096
Retrack Rate	2	3361	1,00	0,500
Depth of Cut	2	125108	37,23	0,026
Error	2	3361	-	-
Total	8	163392	-	-

Based on Table 35 it can conclude several of things. If the value of $P > 0.05$ means that there are no significant factors that influence the power response. In the process of surface finish contour depth of cut has a value of $P < 0.05$ which means that it significantly affects the power response. In the process of surface finish contour, the highest value of F from the three factors in the

experiment is depth of cut which is 37.23, meaning that depth of cut has the greatest influence on power response, then the second feed rate with $F = 9.39$ and the last re-track rate with $F = 1.00$.

TABLE 36.
 ANALYSIS OF VARIANCE SURFACE FINISH PARALLEL

Source	DF	Adj SS	F-Value	P-Value
Feed Rate	2	79793	7,37	0,119
Retrack Rate	2	9197	0,85	0,541
Depth of Cut	2	80589	7,45	0,118
Error	2	10825	-	-
Total	8	180404	-	-

Based on Table 36, it can conclude a number of things. If the value of $P > 0.05$ means that there are no significant factors that influence the power response. In the process of surface finish parallel, all factors have a value of $P > 0.05$, meaning that there are no factors that significantly affect the power response. In the surface finish parallel process, the highest F value of the three factors in the experiment is the depth of cut, which is 7.45. It means that the depth of cut has the greatest influence on the power response, then the second is feed rate with the value $F = 7.37$ and re-track rate with $F = 0.85$.

- From the simulation results that have been carried out, the total production time of dies propeller is obtained, which is 729,17 minutes with power consumption 9.734 kWh for top dies and 1329,65 minutes with power consumption 14,54 kWh for bottom dies.

IV. CONCLUSION

A. Conclusion

Based on the simulation results of the production of dies propeller in the MasterCam software with several combinations of machining parameters, obtained several conclusions to answer the formulation of the problem on this paper, as follows:

- In the dies propeller production simulation, five steps are performed; there are facing, contour, rough surface pocket, surface finish contour and, surface finish parallel. That 5 processes are used for both top and bottom dies.

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