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Minimization of Airtime in Machining Process Using Non-Conventional Method

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Abstract: Machining airtime is a process that movement of the cutting tool before cutting the workpiece. This paper discussed on how Ant Colony Optimization method will help to reduce the airtime in machining process. Ant Colony Optimization is one of the methods that use Artificial Intelligence (AI) to minimize the machining airtime to increase the efficiency of machining process. MATLAB software will be used to generate the optimized toolpath and the data will be transferred to MasterCAM software in order to run the machining simulation. To prove this theory, the results of machining time that use toolpath generated by ACO method is compared with the machining time that use toolpaths generated by conventional methods. It can be concluded that in this study, the ACO method is on average, by 83% better than the conventional methods in reducing the machining time.

Keywords: Airtime, Ant Colony Optimization, Artificial Intelligence

1. Introduction

Machining now has become very important in the manufacturing industry. It is a process of removing unwanted material from workpiece to get a new shape of product that we already designed. The standard approach to planning parts for conventional machining is to define the "features" on the part, and match these features and tolerances to a set of processes that can create the required geometry to the specified accuracy [1]. There are several types of machining processes such as turning, drilling and milling. Plain milling is one of the essential machining operations and it is used for planning the top surface of component to achieve the high accuracy with good surface finish [2]. Due to the high tolerances in milling process, it usually used to make holes, slots, pockets and three-dimensional surface contours as in the process of pocket milling.

Pocket milling is one of the commonly used types of cutting operations. It is a process of removing material of workpiece in a closed boundary flat surface at a certain fixed depth. Tool path for machining of pockets has great significance because together with the process parameters determine productivity [3]. A different path chosen for the pocket milling process will affect the machining time. It is important to decide on the most efficient tool path so that the machining time can be reduced.

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Without considering the impact of cutter path selection with adequate consideration of the machining outcome such as machining time, tool wear, tool life, dimensional accuracy and workpiece surface integrity, the result can lead to catastrophic cutter failure and therefore lead to unnecessary waste of time, cost and poor surface quality [4]. The process of pocket milling is usually controlled by using Mastercam software.

MasterCAM is a computer-aided manufacturing (CAM) software program that offers CAD/CAM software tools for translating computer-aided design (CAD) so that the computer aided manufacturing (CAM) can read the data of the design and create a model for the machining process. Aiming for increasing performance of robot-based machining processes, the conventional CAD-CAM process planning chain was extended with simulation-based analyzation and optimization methods [5]. CAM software allows us to check first if there any geometry errors that can affect the manufacturing process before the real process begin. To ensure the efficiency of the machining process, the CAM software also enable us to create the toolpath for the machining process and setting the parameters of the machine such as the cutting speed, voltage, and the cutting height. The parameter selection when using a CAM software, lies on the operator's experience and it is not always known which of these are the most influencing ones for a machining process [6]. Although this method did minimize the machining time, but it did not minimize it to the lowest machining time possible. That is why the study on Ant Colony algorithm in minimize the machining airtime is being conducted to compare the result with the conventional method.

An ant colony optimization (ACO) approach has been developed to deal with process planning problem by simultaneously considering activities such as sequencing operations, selecting manufacturing resources, and determining setup plans to achieve the optimal process plan [7]. This algorithm idea come from observation of the behavior of an ant in seeking a shortest path between their colony to reach the food source. It is found that the Ant Colony Optimization method produces a non-productive tool path length that is approximately 60% shorter than the conventional method [8].

2. Materials and Methods

The research methodology is important to ensure the result of the data collected and the results of the study are accurate. The simulation in this research is to determine the machining time of the toolpaths generated by using ant colony algorithm method and the conventional CAD/CAM method. The result for both methods compared to find the method that produced the shortest machining time by minimizing the machining airtime.

2.1 Development model of sugar-cane crusher

The Solidworks software used to design the model of sugar-cane crusher. The dimensions of the crusher drawn precisely by using this software. It is important to make sure the dimension is correct and the design is machinable because this drawing will be the guidance used to do the simulation of the machining process. In order to have the outcome that same as expected, the design must be correct. Figure 1 shows the 2D drawing of Sugar-cane crusher and Figure 2 is the 3D design of the sugar-cane crusher.

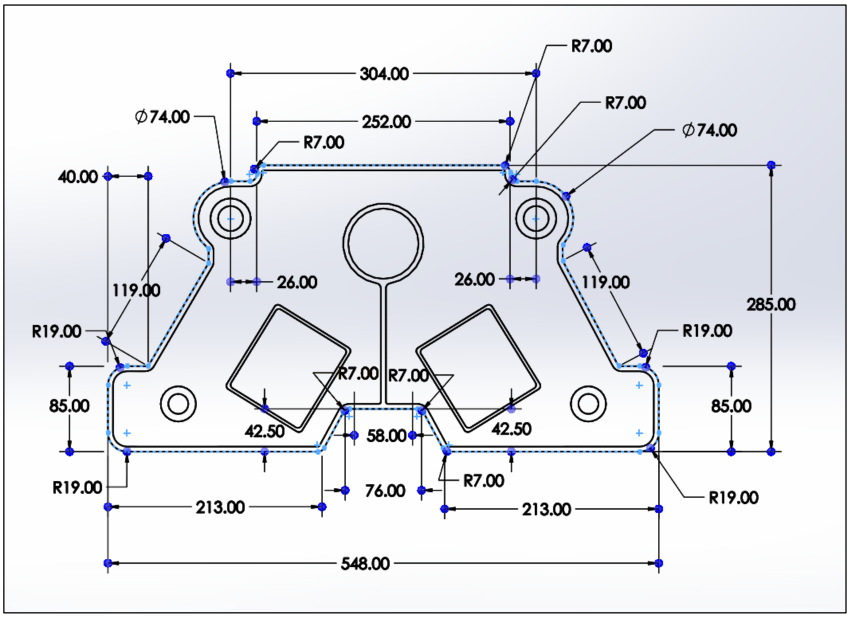

Figure 1: 2D Drawing of Sugar-Cane crusher

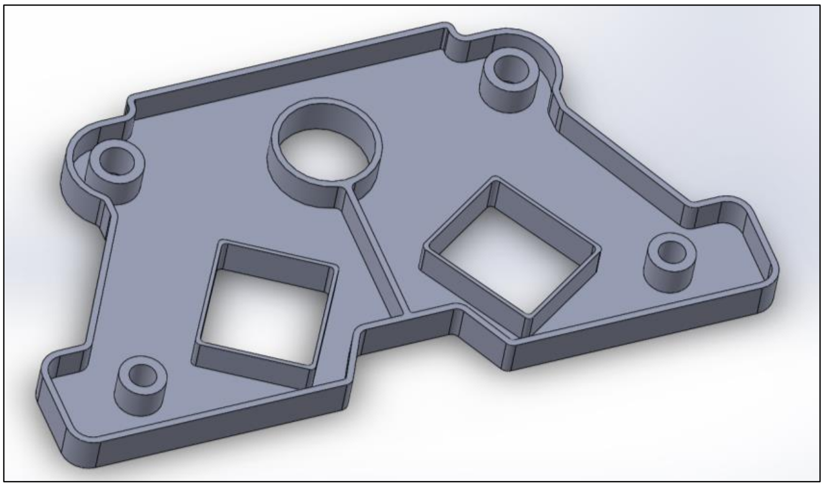

Figure 2: 3D Design of Sugar-Cane crusher

2.2 Simulations in CAD/CAM software

The data from Solidworks software need to be transferred into MasterCAM software in order to run the simulation. There are 3 types of machining processes involved in this simulation which is pocket milling, hole drilling (Counterbore), and dynamic milling (Drill/Counterbore).

2.3 Ant Colony Algorithm

Do the optimization of toolpath by applying the ACO method. Use Solidworks software to determine every center point coordinates for every part in the design. Place the ant on the first node. Next, determine the movement of the ant by using MATLAB to develop coding for ant colony optimization. Then, key in all the coordinates into the coding. Save and run the coding to generate a toolpath with a minimized airtime. The generated toolpath will determine the sequence of the machining process. This sequence will be used when running the simulation in MasterCAM. The simulation will show the total length of the machining time which is airtime plus productive time. The formula below is used to calculate the rapid length of ACO method:

$$(MATLAB\ ACO\ toolpath\ Length + (2\ \mathrm{X}\ Retract\ Value)\ ) = Rapid\ Lengt \qquad \text{Eq.1}$$

The percentage of time saved by using combination of ACO and conventional method can be calculated using the Equation 2:

$$\frac{ACO\ method\ machining\ time}{Conventional\ method\ maching\ time}\ X\ 100\% \qquad \text{Eq. 2}$$

3. Results and Discussion

An analysis on the toolpath that are used in the process has been done. This method was performed by running the simulation of the tool path using MasterCAM software. Then, the result from this simulation is being compared to the results that used conventional method.

3.1 Comparison between MATLAB and MasterCAM Results

Table 1 shows the comparison between rapid length of toolpaths. For the combination of ACO and conventional method, the value of 20911.168 is from MasterCAM software, but the rapid length of this method is 901.9548 if calculated using rapid length formula. The difference between this value is because of there are some movements that cannot be avoided when running the simulation of the toolpath in MasterCAM software. Although there is some different between the value from the calculated results and MasterCAM simulation results, but still this method shows the lowest rapid length compared to the conventional method.

Table 1: Comparison Between Rapid Length of Toolpaths

The Relation between Toolpath Rapid Length and Different type of Toolpath	
Type	**Rapid Length**
Conventional Method	
Zig-Zag	71933.745
Constant Overlap Spiral	83012.517
Parallel Spiral	81408.094
Parallel Spiral, Clean Corner	81408.094
Morph Spiral	82613.821
High Speed	79777.965
One Way	1555106.651
True Spiral	79838.645
Combination of ACO and Conventional Method	**20911.168**

Table 2 shows the comparison of machining time using toolpath from conventional method and the toolpath gained from Ant Colony Optimization method. Based on Table 2, there is a tremendous difference between the machining time of conventional method and combination of ACO and conventional method. The combination of ACO and conventional method shows the shortest machining time which is 2 hours 28 minutes 12.69 seconds while the longest machining time is when using the Morph Spiral toolpath of conventional method which is 70 hours 23 minutes 27.15 seconds. The machining time for combination of ACO and conventional method is the result of running the machining simulation in MasterCAM by us using the toolpath generated from MATLAB.

Table 2: Comparison Between Rapid Length of Toolpaths

The Relation between Machining Time and Different type of Toolpath	
Type	**Machining Time**
Conventional Method	[redacted]
Zig-Zag	9h 59m 57.12s
Constant Overlap Spiral	10h 57m 17.8s
Parallel Spiral	10h 38m 23.72s
Parallel Spiral, Clean Corner	11h 47m 3.47s
Morph Spiral	70h 23m 27.15s
High Speed	10 8m 13.07s
One Way	14h 53m 41.71s
True Spiral	51h 13m 10.09s
Combination of ACO and Conventional Method	**2h 28m 12.69s**

Table 3 shows the result order from the longest to the shortest machining time and the percentage of time saved by using ACO method.

Table 3: Comparison Between Rapid Length of Toolpaths

Machining Time	Type of Toolpath	Percentage of Time Saving by Using ACO Method
Longest	Morph Spiral	96.5%
2nd	True Spiral	95.2%
3rd	One Way	83.4%
4th	Parallel Spiral (Clean Corner)	79%
5th	Constant Overlap Spiral	77.4%
6th	Parallel Spiral	76.8%
7th	High Speed	75.6%
8th	Zig-Zag	75.3%
Shortest	**Combination of ACO and Conventional Method**	-

Based on all the data above, it is proven that the toolpath generated using ACO method did reduce the machining airtime and overall machining time. Another study that support this result is the study by [9]. The result of her study shows that ACO method is approximately reduced the non-productive toolpath length by 20%. The study of [10] also confirm that the ACO method is more efficient compared to the other algorithms.

4. Conclusion

As a conclusion to this study, it can be seen that the result of this study clearly shows the machining simulation using Ant Colony Optimization method did give a tremendous outcome by reducing such a large amount of machining time compared to the simulation using conventional MasterCAM method. In the other hand, it must be kept in mind that ACO method is not the only aspect that control the machining time. All the machining parameters set on the MasterCAM software such as cutting speed, cutting rate and feed rate will also affect the total machining time.

All the objectives of these studies were achieved. The first objective is to minimize the airtime in machining process using Ant Colony Algorithm. This can be proven through the result of the study which shows the machining simulation using ACO method gives the shortest machining time. The second objective is to simulate the machining time of machining process using conventional method. This objective was achieved by conducting the simulation using MasterCAM software. The third objective is to compare the results of machining time based on Ant Colony Optimization which is 2 hours 28 minutes 12.69 seconds and the conventional methods.

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