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Study of Machining Time in Drilling process using Ant Colony Algorithm and CAM software

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Abstract: Optimization of machining time in the CNC machining process is important for improving the productivity of the machining process. In this present study, a non-conventional method called Ant Colony Optimisation (ACO) was applied in order to reduce the amount of time required for the machining process by shortening the length of the tool path taken during the drilling process. The workpiece that had 36 holes was designed in the SolidWorks software in order to study the overall length of the tool path based on the drilling process. Matlab software was used to develop an ACO algorithm to figure out the best length for the tool path in drilling. The model was then transferred to Mastercam software for tool path simulation in order to compare the tool path length and machining time between the ACO approach and the default Mastercam method. There are five types of drilling tool path has been implemented in Mastercam. The ACO results show that the optimization procedure can shorten the tool path length in the drilling process with a percentage difference of 8% when compared to the machining time generated by Mastercam software.

Keywords: Machining time, Ant Colony Optimization, Drilling, CNC, Mastercam

1. Introduction

In the last decade, increased demand in various industries, such as aircraft, spacecraft, and automotives in the manufacturing process, has stimulated the rapidly growing development of drilling processes. Drilling is important in every manufacturing industry, including the aeronautics industry since it is used to fasten holes in aircraft [1]. Drilling is a material removal technique that involves utilizing a rotating cutting device called a drill bit to create a circular hole in the workpiece [2]. Numerous research investigations have been conducted on the hole making process, which have enhanced the development and optimization progress in the drilling process. The optimization of the drilling process is critical for the manufacturing business in order to increase the overall productivity of all activity.

Based on past research, numerous optimization models have been successfully used to discover the best drilling technique. There are several techniques of artificial intelligence (AI) or hybrid optimization, such as genetic algorithms (GA) [3,4], particle swarm optimization (PSO) [5], traveling

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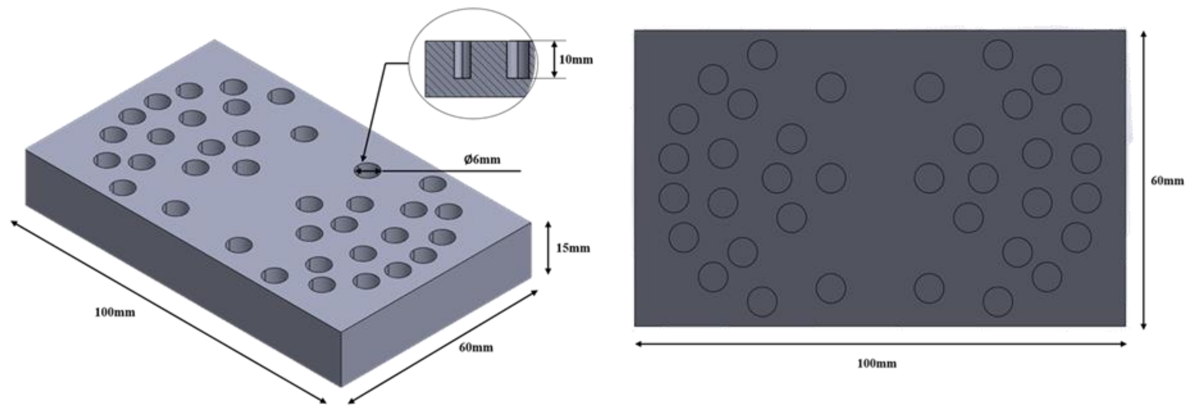
salesman problem (TSP) [6] and ant colony optimization (ACO) [6,7] that have been applied by researchers in their study. Kadim et al. [4] has utilized Genetic Algorithm (GA) and Traveling Salesman Problem (TSP) to reduce machining time for CNC drilling. The results showed that the machining time was cut by about 50%, which meant that less machining power and money were used. The ACO and GA approaches were also applied to the PCB model in order to compare which method, between GA and ACO, has the best tool path and shortest length for the drilling operation [7]. The result is that the ACO method works better than GA at finding the shortest distance tool path.

Furthermore, the study by Abbas et al. [8] and Liu et al. [9] has implemented customized ACO algorithms to find the best drilling route for a workpiece with a lot of holes. This was done in an effort to cut down on the total machining time required for the drilling operation, including the time taken by the machine to change tools. The overall tool travel distances were significantly reduced when using the conventional ACO algorithm method. Abbas used a combination of an ACO and a genetic algorithm to minimise the overall route length in the machining operation of products with a high number of holes placed in spiral patterns [10].

Therefore, this study proposed an effective methodology to decrease the machining time in order to enhance the optimization of the machining process. In this method, ACO has been implement to generate the tool path method of drilling process. This tool path will be used in CAM software to generate the total tool path length and machining time. Then, comparison of machining time between tool path default by CAM softawarehas been done to observe the effectiveness of the ACO approach in decreasing machining time

2. Materials and Methods

In this study, a rectangular workpiece was used which is shown in Figure 1a & 1b. The Solidwork 2022 software is used to create a basic rectangular with holes of the same radius but different coordinates with measurements of 60 millimetres x 100 millimetres x 15 millimetres. The workpiece consists of 36 holes which the arrangement pattern of holes is proposed by [11]. The diameter of the holes, which need to be drilled, is 6 mm, and the depth is 1 cm. The type of workpiece that was used in the experiment is Aluminium 6061. This workpiece was chosen for experimental studies due to its widespread use in engineering applications.



(a) (b)

Figure 1: (a) Three-dimensional model of workpiece, (b) Top view of workpiece

2.1 Ant Colony Optimization in Drilling Process

Ant Colony Optimization (ACO) is a method of minimization that was inspired by the way ants look for food and find the shortest way back to their nest. This method of finding the closest path is applied to identify the tool point's movement that can completely cut the excess area at the minimum distance. In this study, holes will be drilled in accordance with the coordinates that are produced by the Ant Colony Algorithm (ACO). When these points are joined to one another, the resulting set of coordinates will represent one complete path that can be used for the drilling process. In most cases, the ACO is carried out with the use of Matlab software. The total distance travelled by this drilling route begins at the reference point and ends at the final hole. The total number of holes is 36, and they must be drilled in accordance with the path routes defined by the ACO simulation in Matlab programme.

A complete cutting tool path is produced when the ant moves from the first point of the excess area to the last point of the excess area. The path taken by the ant from the first point to the second point can be obtained based on Equation 1 which is also known as called the rule arbitrary probability.

$$P_{i,j}^{k}(t) = \begin{cases} \dfrac{[\tau_{i,j(t)}]^{\alpha}[\eta_{i,j}(t)]^{\beta}}{\sum_{t\epsilon N_i^k}[\tau_{ij}(t)]^{\alpha}[\eta_{ij}(t)]^{\beta}} & j \epsilon N_i^k \\ 0\ if\ j\ has\ been\ passed \end{cases} \qquad \text{Eq.1}$$

2.2 Comparison of Machining Time based on ACO and Mastercam

The amount of time spent during the experiment will be compared to the amount of time spent by the ACO. The main objective of the comparison is to determine which method will produce the lowest machining time and find the percentage difference. The percentage difference can be determined using Equation 3.1 below. If ACO brings efficiency in machining time, the objectives of the study will be achieved.

$$Percentage\ differences\ \% = \frac{Machining\ Time\ ACO - Machining\ time\ Exp}{Machining\ time\ Exp} \qquad \text{Eq. 2}$$

3. Results and Discussion

An investigation of the toolpaths that are implemented during the process has been conducted. This analysis covers the time generated by the tool route length in the Mastercam x9 software using the sort approach and ACO method. The results of these two methods will be compared to find the shortest machining time and tool path length. Next, the obtained optimization results were verified through the actual machining process.

3.1 Result of Simulation based on Mastercam

In this study, the tool path length was compared with various sorting methods that are already existing in the software function in order to observe the effectiveness of the ACO approaches. The drilling operation was simulated with the Mastercam program in order to determine the optimal length for the cutting tool. For the drilling process in Mastercam, different methods were used to determine the route length for the cutting tool. There were 5 different tool paths used in Mastercam, which are X ZIG+ Y+, X+ Y+, Y ZIG+ X+, CW R-, and CW Z-. The overall results of the simulation based on Mastercam are shown in Table 1 below.

Table 1: The result of the total time and length of the tool path in the Mastercam simulation

No.	Sort Method	Feed Path Length (mm)	Total Cycle Time (min)	Rapid Path Length
1	X ZIG+ Y+	432	7m 38s	1646.678
2	X+ Y+	432	7m 33s	1309.724
3	**Y ZIG+ X+**	**432**	**7m 17s**	**1092.832**
4	CW R-	432	7m 24s	1198.694

5	CW Z-	432	7m 29s	1272.622

According to the result, the shortest machining time was 7 minutes and 17 seconds, which was obtained by using the method Y ZIG+X+. This sorting method also resulted in the shortest tool path length, which was 1092.832mm. Based on the previous study by Abdullah et al. [12], they found that X ZIG+ Y+ technique produces the smallest tool path length, which differs from this result. This occurs because of the different design of the workpiece, which may have an effect on the result of the Mastercam simulation. The workpiece's complexity will also have a direct effect on the machining process and the time it takes to do the machining [13]. Figure 2 shows the shortest tool path length created by using Y ZIG+ X+ method

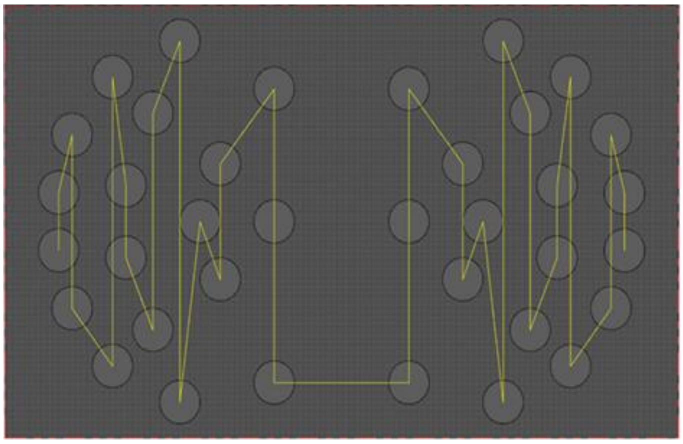


Figure 2: Sorting tool path by Y ZIG+ X+ method in Mastercam

3.2 Result of Simulation Mastercam based on Ant Colony Optimization (ACO)

The tool path for drilling holes is obtained by the tool path generated by ACO. The objective of this study is to identify the machining time of the ACO approach when using the Mastercam simulation. Figure 3 below shows the tool path length of the ACO that was simulated in Mastercam.

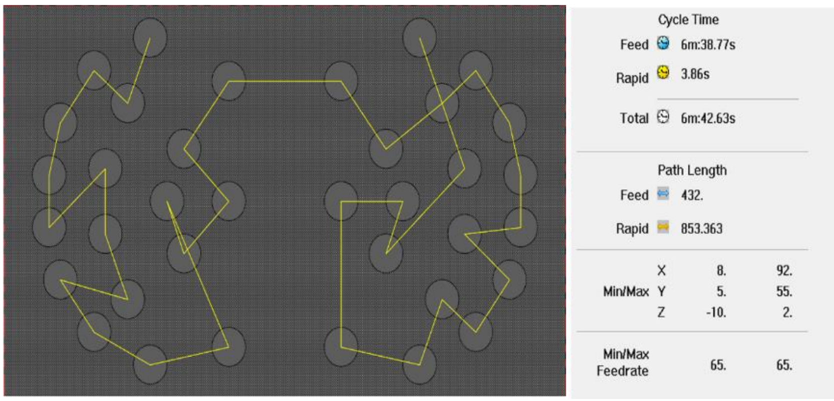


Figure 3: The tool path ACO in Mastercam

According to the simulation, the amount of time required for machining based on ACO was determined to be 6 minutes and 42 seconds. This demonstrates that the ACO has the capability to optimise tool path length and produce results that are shorter compared to the sorting approach.

3.3 Comparison of time machining between default Mastercam and ACO

A comparison of the machining time (T_{mk}) has been done between the result obtained from ACO and the sorting method from Mastercam software. This comparison was carried out with the purpose of determining how effective the ACO algorithm is in reducing T_{mk}. The results show that the ACO approach resulted in the shortest machining time which is 6 minutes and 42 seconds when compared to Mastercam's sorting method. The results were comparable to those achieved by Abdullah et al. [7], in which ACO optimised the tool path length by offering the lowest machining time.

4. Conclusion

In this paper, it can be concluded that the objective of the study the comparison of machining time based on ACO and has been achieved. The Ant Colony Optimization approach is proposed to optimize the tool path length in a drilling operation in order to reduce the machining time. Matlab software was used to develop the ACO algorithm, and the simulation was used to test the tool path length that was generated based on this optimization in order to find the shortest machining time. A comparison of the amount of time required for machining while using ACO with the amount of time required for sorting methods has also been carried out in order to determine which approach is capable of reducing the machining time required for machining. It was found that ACO is capable to reduce the tool path length and machining time.

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