Time Optimization Analysis Using Hybrid Simulated Annealing and Genetics Algorithm For CNC Punching Machine

Lukman Selvi¹*, Endra Joelianto² and Edi Leksono³

¹Master Program of Engineering Physics, Faculty of Industrial Technology, Institut Teknologi Bandung, Jl. Ganesha No.10, Bandung, Indonesia
²Instrumentation and Control Research Group, Faculty of Industrial Technology, Institut Teknologi Bandung, Jl. Ganesha No.10, Bandung, Indonesia
³Engineering Physics Research Group, Faculty of Industrial Technology, Institut Teknologi Bandung, Jl. Ganesha No.10, Bandung, Indonesia

Email: lukmansylvia88@gmail.com*

Abstract. This research describes the method of manufacturing process planning of hole manufacturing, which in every machining process consists of several individual operations with various types of punching blades. The process of setting the trajectory is one of the problems of holes manufacturing process because this process takes a long machining time and often it obtains undirected sequence path that sometimes causes stress material and the damaged of punching blades. The aim of optimization process is to minimize the processing time of holes manufacturing so the time function which is obtained can be converted in the form of energy consumption that helps manufacturers to predict the machining time. Dynamic Directed Graph is applied where each node represents a machining operation. The time function is obtained by studying the shortest path of a directed graph where the structure of objectivity studied is similar to the Traveling Salesman Problem (TSP). The mathematical model is used to solve the hole optimization problem of the graph structure by proposing the combination of both to solve the optimization problem. The Algorithm realization will be applied in real time CAD / CAM programming by using TOPS300 which is used for TRUMPF TC200 Punching Machine. There are 2 kinds of blade operations in this research which are single stroke operation and multi strokes operation. Both produce different time function. By a. Finally, some conclusions are given from examples that show the hybrid algorithm of Simulated Annealing and Genetic Algorithms is effective in reaching higher optimization performance and less energy consumption, which 26.02 seconds for single stroke operation and 126.02 seconds for multi strokes operation with the acquisition of logical path results with the absence of intersecting trajectories.

1. Introduction

Mostly manufacturing industrial need hole manufacturing in their industrial process. CNC Punching is the process of making holes on the surface of the sheet metal using turrets that are pressed with great strength. Equipped by the computer programming, the perforation position on the sheet metal is ensured to be precise with the correct hole size. The common CNC
punching machine runs with a special program, and its tasks are handled by a CAD/CAM drafter [3]. During manufacturing process, some small diameter holes can be processed directly into their final shape, but some geometric shapes require a piercing blade with a variety of diameter shapes. However, distortion due to stress material cannot be avoided. According to merchant’s survey, tooling path operation takes most of times in a manufacturing process [1].

The shortest path problem of the hole making process is based on the Traveling Salesman Problem (TSP) which is an optimization problem that can be applied to various activities such as routing. The problem of TSP optimization is well known and has become the standard for figuring out computational algorithms. The main problem of the TSP is a salesman must visit number of cities and those cities must only be visited once. The problem is how the salesman can set the most optimized route as the best minimum distance [3]. The shortest path problem is a classic problem that is often encountered in everyday life such as vehicle routes in the transport system, traffic routing, communication networks and path planning in robotic systems though there are several algorithms that can be used in solving the shortest path problem [2][4], in this paper the hybrid Simulated Annealing (SA) and Genetics Algorithm (GA) are used to solve the shortest path of from one hole to another. Simulated Annealing is an algorithm based on the process of cooling metal fluid. The working principle is briefly explained as high temperatures fluid molecules which have high energy levels are relatively easy to move against other molecules then the temperature is slowly lowered to obtain a steady state condition with minimum energy level. Decreasing the temperature slowly is called the annealing process. Annealing is a metallurgical technique that applies the science of cooling process scheduling to produce efficiency in energy usage and optimization. The uniqueness of the SA method is allowing the cost, mileage and travel times of new routes greater than the current route [2][5].

Genetic Algorithm is an algorithm based on modeling a population which is describes as a collection of individuals within the population with limited values. The solution is modeled like a chromosome living things. In Genetic algorithm, important terms such as genes, chromosomes and recombination are observed. Genes are the entity modeling of the issue. In TSP, the gene modeled a city to be visited. Chromosomes are a set of genes that are candidates for the solution. In TSP, chromosomes modeled as the city tour. Then, recombination is used as a method to get the value and modify a gene presence on a chromosome. The Recombination process such as cross over and mutation is applied when two individuals are reproduced.

In this study, the time function which is obtained from the combination of the Simulated Annealing and Genetics algorithm are converted into energy units to predict the energy consumption in hole manufacturing process [3]. There are two kinds of machining process are the single stroke operation and multiple strokes operation. The type of tool that is applied is a tool that is a precise tool with geometry is called single stroke operation which diameter is 20 mm and another tool that is smaller which diameter is 6 mm called multiple strokes. Both are uses to process the same hole diameter but with different time results. By applying Hybrid Simulated and Genetic Algorithm, the most optimize time function and no intersection path is obtained.

2. Methodology
Since The Traveling Salesman Problem (TSP) is an optimization problem that can be applied to various activities and has become the standard for figuring computational algorithms.Rules for TSP are stated as the journey must begin and end in the same city as the basis of where the salesman is departed. Cities must be visited without being missed and exactly once with a minimum total distance. The TSP can be written as the following integer linear optimization:

\[
\text{Min } \sum_{i=1}^{n} \sum_{j=1, j \neq i}^{n} c_{ij} x_{ij} \quad (1)
\]

Subject to:
\[ \sum_{i=1, i \neq 1}^{n} X_{ij} = 1, \text{ with } X_{ij} = \begin{cases} 1 \\ 0 \end{cases} \]  

where \( i = 1, 2, \ldots, n \) and \( j = 1, 2, \ldots, n \).

Equation (1) is the total minimization function for city \( i \) to city \( j \), whereas \( C_{ij} \) and \( X_{ij} \) describe as weighting value and distance from city \( i \) to city \( j \) respectively. The value 1 of \( X_{ij} \) in equation (2) indicated the path from city \( i \) to city \( j \) and the value 0 indicated the absence of path.

For single stroke operation in machining process, the formula is modified as follows:

\[ \sum_{i=1}^{n} \sum_{j=1, j \neq i}^{n} t_{ij} X_{ij} + \bar{\ell} \]  

where \( t_{ij} \) denotes time function for machining process and \( \bar{\ell} \) indicates the sum nibbling operation time and taking the appropriate blade from the tool station.

For multiple strokes operation, the formula is presented in the following equation

\[ \sum_{i=1}^{n} \sum_{j=1, j \neq i}^{n} t_{ij} X_{ij} + 10\bar{\ell} \]  

which means time consuming in seconds to complete a machining operation process in a circle form, to illustrate, as shown in below figure.

![Figure 1. Modelling Perforating Grid Holes.](image)

Herewith, the steps for combining the Simulated Annealing and Genetics Algorithm are described in short. Since GA is also later being applied, it is obliged that the route function of Genetic Algorithm defined in the beginning.

\[ F(R) = \frac{1}{f(r)} \text{ whereas } r = \text{route} \]  

Those are the following steps in combining the two algorithms represented in the following flowchart.
In the SA and GA combination graph, it is difficult to achieve long convergence because the first population has already contained minimum routes from the iteration results of SA as much as 100 x samplings, but it does not matter because the minimum route graph in the SA method to GA does not change significantly.
3. Result and Discussion
After applying Hybrid SA+GA algorithm using mathlab for single stroke and multiple strokes operation, it is shown the absence of intersection trajectory with different time function which is 26.02 seconds for single stroke operation and 126.02 for multiple strokes operation.

![Figure 4. Trajectory after optimization using SA+GA.](image)

![Figure 5. Energy Consumption for Single Stroke Operation.](image)
4. Conclusions
In this paper, it was shown that the expected results of the Hybrid Simulated Annealing and Genetics can be applied for figuring out the shortest path in the hole of manufacturing processes and were proposed to be translated in G-Code form either manually or by using software generator. Hence, the machining works in 2-dimensional field can be done precisely in order to reduce the distortion caused by the stress material issue.

References
[1] Thanh-Tan Nguyen, Huy-Tuan Pham, and Thi Hong-Minh Nguyen Tool Path Optimization in CNC Punching Machine for Sheet Metal Manufacturing in International Conference on System Science and Engineering (ICSSE) 2017 p 381-386
[2] Lijun Zhang, Xiaoyi Luo, Shizhao Xing Application of Modern Optimization Algorithms in Holes Machining Path Planning in 3rd International Conference on Information Science and Control Engineering 2016 p 867-870
[3] Danijela P Efficiency of Tool Path Optimization Using Genetic Algorithm in Relation to the Optimization Achieved with the CAM Software in International Conference on Manufacturing
[4] Alexander A. Petunin, Chrysostomos Stylios Optimization Models of Tool Path Problem for CNC Sheet Metal Cutting Machines in IFAC (International Federation of Automatic Control) 2016 p 023-028
[5] XiaoXia Li, Qinggang Wang, Jun Chang and JianXiao Liu Tool Path Optimization for Energy Efficient Machining Using Exhaustive and Simulated Annealing in 6th International Conference on Information Science and Technology p 362-365
[6] Anton Dietmair; Alexander Very Energy Consumption Modelling and Optimization for production in 2008 IEEE International Conference on Sustainable Technology
[7] Andrea Cataldo, Marco Taisch, Bojan Stahl Modelling, Simulation and Evaluation Energy Consumptions for a Manufacturing Production Line in 39th Annual Conference of the IEEE Industrial Electronics Society
[8] ZeYi Sun, Dong Wei, LingYun Wang, Lin Li Simulation Based Production Scheduling With Optimization of Electricity Consumption and Cost in Smart Manufacturing Systems in 2015 IEEE Conference on Automation Science and Engineering (CASE)
[9] Jaber E. Abu Queideiri, Al-Momani Raid, Mohammed Anouar Jamali, Hiddehiko Yamamoto Optimization Hole Cutting Operations Sequence in CNC Machine Tools
Using GA 2016 International Conference on Service System and Service Management

[10] Nan Yang Shen, Zi Meng Quo, Jing Li, Lian Tong, Kai Zhu A Practical Method of Improving Hole Position Accuracy in the Robotic Drilling Process in The International Journal of Advanced Manufacturing Technology

[11] Mike Mills A Totally Integrated System Approach and Manufacturing at Mc.Donnel Douglas Corporation in 18th Design Automation Conference.

[12] R.S. Lin and Y. Koren Efficient tool-path planning for machining free-form surfaces. Journal of engineering for industry 1996 118(1) p 20-28

[13] S.H. Yang and S.G. Lee CNC tool-path planning for high-speed high-resolution machining using a new tool-path calculation algorithm The International Journal of Advanced Manufacturing Technology 2002 20(5) p 326-333

[14] K.C.R. D’Souza and P. K. Wright Tool-path optimization for minimizing airtime during machining. Journal of Manufacturing Systems 2003 (22) p 173-180

[15] Cherif Ahrikencheikh and Ali A. Seireg Optimized-motion planning: theory and implementation. John Wiley & Sons, Inc. 1994

Acknowledgments

E. Joelianto was partially supported by the Ministry of Research, Technology and Higher Education of the Republic of Indonesia under the Applied Higher Education Excellent Research University, Bandung Institute of Technology, Bandung, Indonesia 2018.