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Optimization of Machining Parameters in CNC Milling Machine through Genetic Algorithm

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Abstract - *Reducing the amount of time required for each operation's machining in order to keep costs down and maintain a high profit margin without sacrificing component quality is a major challenge in many manufacturing businesses. Operating CNC machines efficiently is economically vital in order to obtain the required return on investment, given the significant capital and machining costs involved. Determining the ideal values prior to starting production is essential because machining parameters on CNC machines have an impact on machining costs. The goal of this project is to create a simulation model that takes into account the particular tools and machining settings to determine how long each operation will take to complete. Reducing the amount of time spent machining is the main goal. A Genetic Algorithm is suggested to maximise machining parameters (feed and speed) while respecting limitations (maximum machine power, cutting force, and surface polish requirements). MASTER CAM software is used in the simulation to simulate CNC milling machine operations. The goal of the optimisation is to minimise the amount of time spent machining. The Genetic Algorithm's output is contrasted and examined with that of other optimisation techniques, such as Tabu search, Ant colony algorithm, and particle swarm optimisation. The goal of the study is to create a workable strategy for raising machining efficiency.*

Keywords: (CNC), Genetic Algorithm (GA)

I. Introduction

Even with the abundance of tools and methods developed specifically for the manufacturing sector, real-world difficulties arise when trying to simulate intricate operational procedures or make adjustments to settings that already exist. Simulation shows itself as a useful technique to save needless costs and give advance insight into the possible efficacy of systems. Bennett describes simulation as "a technique or a set of techniques whereby the development of models helps one to understand the behaviour of a system, real or hypothetical." Simulation is a commonly used tool for possibility exploration, system behaviour evaluation through external and internal changes, and support for process optimisation and organisational improvements. Simulation provides a number of advantages, including the ability to analyse manufacturing processes without interfering with the actual system, the avoidance of the high implementation costs, the facilitation of training and learning opportunities.

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The validation of analytical solutions derived from mathematical models, the resolution of questions regarding the causes and mechanisms of phenomena, and the evaluation of the effects of minor modifications on the manufacturing system as a whole. Production efficiency can be increased by effective simulation, giving businesses where production planning and implementation are strategically important a major competitive edge. Reliability of input data and appropriate variable analysis are prerequisites for the accuracy of information produced by simulation models. Additionally, accurately analysing output data requires a solid grasp of statistics. Because high-speed computers are becoming more accessible and affordable, optimisation algorithms are becoming more and more prevalent in engineering applications. When solving engineering challenges, these algorithms are frequently employed to maximise or minimise particular objectives. In chemical engineering, examples include developing mechanical components to achieve either minimum manufacturing cost or highest production rate, and in aeronautical engineering, minimising overall weight through optimal process plant design or operation. Optimising an existing process that satisfies all imposed limits and constraints while meeting specified goals is the ultimate goal of optimisation; this process is known as the optimum process

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Speed, feed, and depth of cut are a few examples of machining factors that are crucial in forming the workpiece. These variables have a big influence on the machining process, therefore it's crucial to optimise them to get the results you want. Traditionally, the choice of machining parameters has been made based on the knowledge of planners or machinists, who frequently use accessible handbooks and catalogues. However, because planners differ in their expertise and judgement, manual selection presents difficulties. When production incorporates expensive Numerical Control (NC) machines, there is an increased focus on making the most use of these resources by selecting the right machining parameters.

Modern enterprises use both NC and conventional machines, thus it becomes necessary to have automated processes to choose the best machining parameters. When selecting machining parameters automatically, computer-aided processes have shown to be dependable in terms of speed, accuracy, and consistency when compared to human approaches. For a given operation, the best machining settings can be found using a variety of optimisation approaches. A CNC simulation programme called MASTERCAM makes it easier to simulate machining parts on a computer before they are really cut. This allows for the removal of mistakes that could endanger the part, break cutting tools, damage fixtures, or cause machine crashes. Furthermore, MASTERCAM ensures error-free and effective programmes by optimising the cutting process. The identification of collisions and near-misses between all machine tool components—such as axis slides, heads, turrets, rotary tables, spindles, tool changers, fixtures, workpieces, and cutting tools—depends heavily on Machine Simulation in MASTERCAM. Establishing "near-miss zones" around components allows users to look for near misses and identify over-travel issues. By lowering the possibility of machine crashes—which can be costly and interfere with production schedules—this feature provides an effective means of preventing errors and validating programmes.

II. Problem Statement

The objective is to determine the optimum machining time for completing the part illustrated in Figure 1 on a CNC milling machine. The workpiece involves five machining operations: face milling, corner milling, pocket milling, and two slot milling operations. As different tools are selected for machining these features, the challenge becomes maximizing the profit rate for a multi-tool operation. The aim is to establish cutting conditions for each feature to minimize the machining time, thereby maximizing the profit rate. The solution to this problem is achieved through the use of a Genetic Algorithm.

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Specifically, the corner milling operation can be integrated with the pocketing operation, considering that the corner radius is 5mm and the tool's pocket milling diameter is 10mm. This integration eliminates one operation, contributing to a reduction in machining time. Furthermore, based on the tables, it is evident that a 12mm diameter tool is chosen for slot milling (1), and the width of the slot is also 12mm according to the figure provided. In practical terms, the choice of a tool with the same diameter as the slot width is a logical selection.

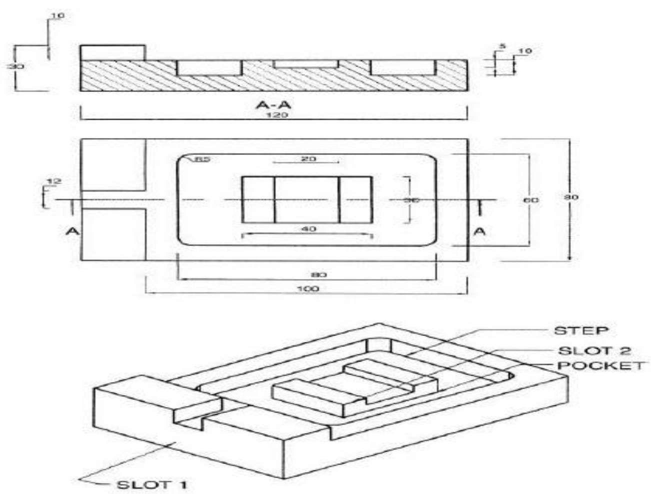

Figure 1. Geometry Problem

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II. Matlab Optimization Model

In a wide range of applied mathematics applications, Matlab is widely used in academic contexts for research and teaching at universities as well as in a variety of companies. The software is specifically designed to manipulate matrices and vectors; the term Matlab is derived from MATRIX LABORATORY. Because of this feature, the software is especially useful for jobs involving linear algebra. Beyond this, Matlab is an effective tool for numerical integration and the solution of algebraic and differential equations. Interestingly, it is one of the easiest languages to learn for creating mathematical programs because it can also be used as a programming language, much like C.Toolboxes are a collection of add-on solutions for Matlab that are intended for specific uses. These toolkits make learning and using particular technologies easier. They consist of a large set of Matlab routines designed to handle various problem classes. Numerous disciplines are covered by the available toolboxes, such as simulation, wavelets, fuzzy logic, neural networks, control systems, and signal processing, among many others.

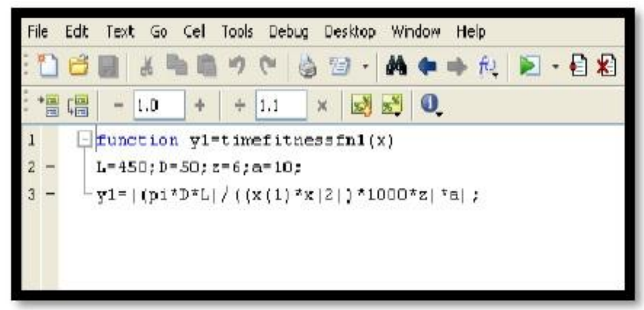

Figure 2. Objective Function

IV. Matlab Optimization Model

The part requires four milling operations to be completed: face, pocket, and two slot milling operations. First, as the picture shows, a thorough 3D solid model needs to be created. The necessary tool, depth of cut, speed, and feed must all be precisely specified in the tool path for each operation. The modern industrial environment is increasingly dependent on sophisticated machine tools, which highlights the necessity of precise and timely assessment of critical production parameters. Cutting parameters are usually selected in traditional machining processes based on operator experience or manuals. To avoid cutting failure, these limits are frequently conservative. This makes changes difficult even with offline optimization methods because of things like heat generation, tool wear, and other disruptions.

Real-time optimization and control of cutting parameters during machine tool operation are necessary to ensure the quality of machined components, lower cutting costs, and increase cutting efficiency. For these factors to satisfy the best cutting criterion, they must be dynamically changed.

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There are many different machining techniques, including sawing, reaming, tapping, planing, broaching, boring, and threading, but the most common ones are milling and turning. It is advised to use unconventional methods based on distinguishing characteristics to optimize cutting circumstances within predetermined bounds. While these methods have benefits, there are drawbacks that should be taken into account while optimizing machining procedures.

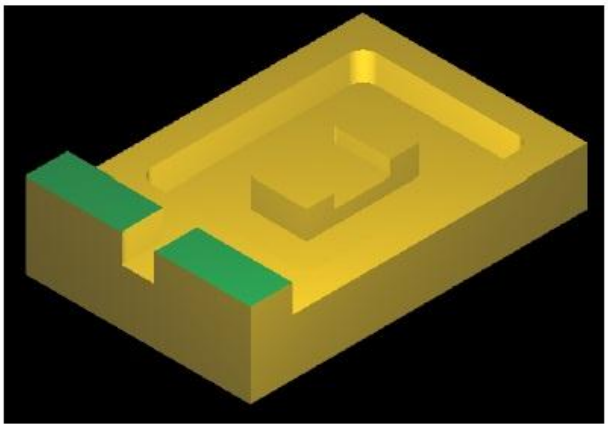

Figure 3. 3D Solid Model

V. Non Conventional Technique

Among the most effective intelligent algorithms is the Genetic Algorithm (GA), which includes important elements including chromosome coding, first population generation, fitness function assessment, gene editing, next generation selection, and algorithm termination. Genetic operations are carried out prior to the selection phase in order to increase the generational variability for inheritance. There are an infinite number of Pareto solutions since the goal functions are continuous. In practice, the scale of each generation varies dynamically during the algorithm to support a wider range of Pare to solutions. The chromosome is made up of the kind of distributed sources and the produced active and reactive power, stored in a real matrix, assuming the initial population size is NP. Buses 1, 2, and 3 in a 7-bus system are coded as DG buses, and their chromosomes reflect this designation. Crossover and mutation are two aspects of gene modification.

Both resulting chromosomes are handed on to the following generation once two randomly chosen cutting sites are selected. The cutting point must appear between non-zero elements in order to cut effectively. The disruption of both active and reactive power is a component of mutation. The worldwide search capability is represented by a mutation probability of 10% and a crossover probability of 95%. Throughout the iteration process, this probability can be changed to speed up convergence and accomplish a certain level of self-adaptation. The subsequent generation, which includes new NP chromosomes, is lawful and exemptfromregulation. There are two steps to the selection strategy: finding Pareto solutions and using proportional selection to create more chromosomes. NSGA-II [26] is the source of inspiration for the Pareto solution extraction procedure. A global Pareto solution saver is initiated with NPi chromosomes in generation I. One option is saved first, and then the other solutions are contrasted. An external solution is either included to the saver or ignored depending on whether it is non-inferior, superior, or replaces the internal solution. As ηk drops with increasing iteration time k, accelerating the convergence rate, the small parameter improves the inheritance probability of the poorest chromosome, gradually diversifying genes in the following generation.

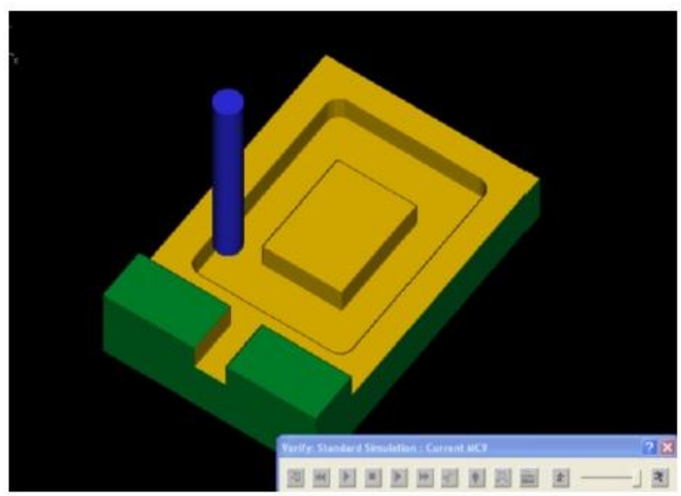

Figure 4: Slot Milling

VI. Genetic Design

Since its initial introduction by John Holland in 1975, the Genetic Algorithm (GA) technology has demonstrated its strength as an optimization algorithm, emulating the natural process of evolution in order to approach ideal solutions [6]. The algorithm starts with a population, which is a random collection of configurations. Each population member is represented by a string of symbols, usually a binary bit string that denotes an optimization problem solution. Every generation, or iteration, that makes up the present population is evaluated according to its fitness. Fitter people are more likely to be chosen to become parents. To produce children with mixed traits, genetic operators such as crossover, mutation, and inversion are applied to the parents. This procedure is carried out over several generations, choosing parents and children to establish a new generation. The derivative-free approach of the GA optimization technique for near-optimal point search, its adaptability to both discrete and continuous variables, and its suitability for near-optimal conditions when an accurate solution is not necessary are some of its advantages. In addition to handling objective functions of arbitrary complexity, GAs may find nonlinear connections, complement models with additional input parameters, and perform quick and easy optimization [2, 8, 9]. The GA optimization method is not without restrictions, though. There's no guarantee of convergence, and there's no standard method for choosing algorithm parameters. The outcomes of GAs may not be repeatable, and their execution may take a long period. Repeatability is not assured, training parameters might take a lot of time, and algorithm creation requires knowledge [2, 9]. Applications of GA that are successful depend on variables like population size and variety. GA may prematurely converge to a local optimum if it can't sustain diversity before reaching the global optimum [10]. GA-based methods have been used by researchers to optimize cutting process parameters. Examples of GA uses in different machining processes.

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VII. Conclusion

A model found in the literature review was used in the simulation process to find the minimal machining time in a CNC milling machine, and the findings were acceptable. A three-dimensional model had to be created and then put through five milling operations: facing, cornering, pocketing, and two slot milling procedures. Important machining parameters were set, including feed, speed, and depth of cut. Corner milling was found to be one milling operation that might be avoided during the toolpath definition process. The pocketing process might effectively replace the corner milling operation, saving machining time, as the pocketing tool is 10mm and the corner radius is 5mm. In order to minimize potential damage to the item and align with the 12mm width of the slot, a 10mm tool diameter was selected for slot milling (1) as opposed to a 12mm one. When the findings were compared to those of other techniques, the genetic algorithm produced the best results.

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