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A Review Paper on Milling Process Parameters

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Abstract—
The research looks at ways to increase tool life by using the proper process factors, geometry parameters, and machining parameters. The design of experiment was used to look at the influence of major milling parameters including feed rate, cutting speed, and depth of cut on tool life. Two limiting criteria to consider are face milling area and slot depth. The Taylor Tool Life Equation is used to create a tool life relational equation, which is then utilised to calculate the tool life. To investigate the impact of these variables on surface roughness, Response Surface Methodology must be employed (RSM).

Keywords – Response surface Methodology, Optimization, depth of cut, cutting speed, Too Life, feed rate,

I. Introduction

Milling is the process of removing metal from a surface. A revolving multipoint cutter mounted on the milling machine's arbour removes metal during milling operations. Milling machines take away superfluous material from an item to provide a variety of characteristics. The column, saddle, base, table, knee, arbour, over-arm, and spindle are the major components of a milling machine. Certain components of the milling process, such as the work piece, fixture, and cutter required by the milling machine, play a critical role. The work is held in a fixture that is connected to a milling machine table. In milling machines, three table motions are allowed: transverse, vertical, and longitudinal, although in certain situations, rotational or swivel movement is also possible with regard to the table. The quality of the surface plays a critical role in optimising the milling process. A good surface improves fatigue strength, corrosion resistance, and creep life. Surface roughness has an impact on a variety of functional characteristics of components, including friction between two contacting parts, parts wear, heat reflection, lubricant distribution, load bearing capacity, coating or fatigue resistance, and so on. As a result, the procedures used should be appropriate during the operation, and the intended final surface should be defined. Taguchi technique may be used to improve the process parameter for optimal surface roughness. 0020 In order to get a product that meets machining criteria, efficient control of process parameters throughout machining operations is critical. Furthermore, selecting the best potential combinations of process parameters can result in a successful process design that enhances manufacturing economics in terms of cost and production time. The geometry of cutting tools, as well as the process design of the production process, frequently affects their performance and usable life. This has an impact on production throughput as well as overall production and maintenance costs, which is a function of long-term viability and profitability. One of the most widely used production methods for accurate machining of components is milling. It is an operation in which the multi-point cutting tool's spinning edge contacts the work item fed in a direction that is perpendicular to the tool. Because it is a complicated procedure that necessitates machining of geometrical and sophisticated shapes, relying on the machinist's knowledge in selecting process parameters may be insufficient or unreliable, necessitating the use of suitable process design. Over the years, researchers have created a number of models and algorithms that utilise both numerical and physical experimental designs to anticipate the optimum values of process parameters in order to construct a cost-effective process.

Wang, Wenjie, et al., (2020) investigated that Selecting a set of acceptable CNC milling settings is critical for lowering energy consumption and increasing processing productivity. Existing research, on the other hand, pays little attention to optimising energy-conscious milling settings. This study provides a dual-objective optimization model for milling parameter selection that minimises power consumption and process time. An enhanced artificial bee colony (ABC) intelligence method is utilised to handle the suggested dual-objective optimization model, which has various constraints of milling processing conditions. Our revised method performs well when compared to the non-dominated sorting genetic algorithm (NSGA-II).

Kumar, SP Leo (2019) examined the impact of cutting parameters such as spindle speed (n), feed rate (f), and depth of cut (ap) on Arithmetic Average Surface Roughness (Ra) and Material Removal Rate (MRR) in micro turning operations. The work and tool materials are C360 Copper alloy and Tungsten Carbide insert, respectively. Experiments based on the Taguchi L27 Orthogonal Array were used, and a micro pin with a diameter of 800 m was produced using a micromachining tool. The accuracy of the measured findings was confirmed using Type-'A' uncertainty analysis, with a standard deviation of 0.007 m. It has been discovered that combining a lesser range of process variables (within the specified range) results in a fine surface finish, whereas combining a greater range of variables results in a maximum MRR but a bad surface finish. Using analysis of variance, it was discovered that "ap" had a substantial impact on Ra and MRR. It was also discovered that a greater 'f' has an effect on surface quality due to the marking phenomena. The Genetic Algorithm was used to optimise the parameters (GA). Ra and MRR optimum values were determined to be 0.031 m and 0.0768 mm3/s, respectively, with process parameters of n = 1686 rev/min, f = 10.6242 m/rev, and ap = 99.45 m. Finally, confirmation experiments were used to verify the correctness of GA results.

Shi, K. N., et al (2019) every year, modern industrial firms consume a significant quantity of energy. Improving energy efficiency would not only assist businesses financially, but will also aid the globe in overcoming issues such as energy scarcity and pollution. An accurate energy consumption model is required to do this. The major goal of this work is to provide a more accurate cutting power-based energy consumption model for general end milling. Due to auxiliary components and spindle motion, the suggested model has an idle portion and an extra part for cutting workpiece materials. The first element is proportional to the cutting power, whereas the second is modelled as a function of spindle rotation speed. Experiments under various milling circumstances have shown that the suggested model is successful and efficient. The suggested model is more accurate than existing models, according to comparative research. The suggested model is appropriate for generic milling processes, despite being calibrated from slotting tests when cutting aluminium alloy. Experiments with partial-immersion milling demonstrate that the suggested model's prediction error is as low as 1.74 percent. When the substance of the workpiece is changed to titanium alloy which performance of titanium alloy is still good, with a prediction error of 2.81 percent. This demonstrates its ability to offer accurate estimates for various workpiece materials. As a result, it may be possible to forgo time-consuming model calibration, saving time, material, and energy. Finally, numerical experiments using the suggested model are used to assess the energy efficiency of the general end milling process. The suggested model might serve as an ideal platform for energy-efficient manufacturing/cleaner production by exposing the link between energy usage and various cutting factors.

Tlhabadira, I., et al (2019) investigated that the roughness of the surface Ra is a metric that is often used to indicate the degree of surface imperfections during machining. The goal of this study is to use the Taguchi technique to model the cutting process, correlate, and optimise the important process parameters during the milling operation of AISI P20 in order to decrease surface roughness. For modelling the stress, displacement, and thermal behaviour of the cutting tool and work piece under various cutting circumstances, Autodesk Fusion 360 (2.0.5357) was used. The experimental strategy was based on Taguchi's approach, which included a L9 orthogonal array with three factors and three levels for each variable, with each factor's contribution to surface roughness being investigated. The Taguchi technique was used to investigate the impact of process parameters and establish a link between cutting speed, feed, and depth of cut in connection to the most important machinability element, surface polish. The depth of cut (d), spindle speed (N), and cutting feed (fm) are the machining parameters investigated in this study, with surface roughness as the response factor. The physical studies were carried out on M200 TS material utilising carbide inserts on a DMC 635 V DMG ECOLINE, Deckel Maho Germany, Siemens 810D, 3-Axis, CNC vertical milling machine, and the surface roughness was assessed with a Mitutoyo SJ–201 surface roughness machine. The statistical analysis of both numerical and physical experiments resulted in the development of a mathematical model and optimum solutions for the evaluation of surface roughness during the milling process, which had a high degree of correlation with experimental values, thus validating the model.

Khalilpourazari, Soheyl, and Saman Khalilpourazary (2018) studied as Selecting appropriate settings for the process parameters is critical for minimising overall production time in the multi-pass milling process. The multi-pass milling process parameter optimization model is a Constrained Non-Linear Programming formulation. The mathematical model's nonlinearity and complexity need the development of novel solution techniques that can give efficient solutions. In order to reduce overall production time, an unique hybrid method called Sine–Cosine Whale Optimization Algorithm is developed in this work for parameter optimization issue of multi-pass milling process. To obtain superior results, the SCWOA employs the exploration and exploitation capabilities of the two main algorithms. An experimental research is carried out to demonstrate the effectiveness of the suggested algorithm, and the results of the proposed algorithm are compared to those in the literature. According to the findings, SCWOA offers potential solutions that result in considerably reduced manufacturing time.

Medarević, Djordje, et al. (2018) focused on this research is to create carvedilol (CRV) nanosuspension using wet media milling. Critical formulation and process factors were identified as the concentration of polymeric stabiliser (hydroxypropyl cellulose-HPC-SL), milling speed, and milling bead size, and their influence on CRV particle size after 60 minutes of milling was examined using a Box-Behnken experimental design. Spray drying and freeze drying were used to solidify the optimised nanosuspension, which was then characterised in solid form. The best milling parameters were determined to be a low stabiliser concentration (10%), a low milling speed (300 rpm), and tiny milling beads (0.1 mm). Within CRV crystals, crystal lattice modelling indicated a possible slip zone where fractures are most likely to occur. Calculated mechanical characteristics of CRV crystal show that if applied in the correct direction, low energy stress is sufficient to begin fracture, explaining the benefit of employing smaller milling beads. Only spray dried nanosuspension returned to its original nanoparticles, but particle agglomeration after freeze drying hindered redispersion. Wet milling and spray drying did not cause polymorphic transition in CRV, but there was evidence of polymorphic transition during freeze drying, therefore spray drying is the preferable technique of solidification.

Huang, Tao, et al. (2018) demonstrated that the tool path created by commercial software in a five-axis milling operation seldom takes the dynamics of the machining process into account. Milling chatter, which causes overcut, rapid tool wear, and other issues, can damage the workpiece surface and decrease tool life if process dynamics are ignored. This encourages us to think about dynamic limitations while creating tool paths. Due to the variable tool-workpiece immersion area and cutting power, tool orientation variations in five-axis ball-end milling impact chatter stability and surface location error (SLE), which inversely offers us with a viable and flexible approach to reduce chatter and SLE. However, adjusting tool orientations to reduce noise and SLE can result in significant changes in tool orientations, which might impair surface quality. The goal is to create a compromise between smooth tool orientations and chatter and SLE suppression. This study proposes a minimax optimization technique for designing tool orientations to address the problem. With chatter-free and SLE threshold constraints, the optimization goal is to produce smooth tool orientations by reducing the greatest variance of rotational angles between consecutive cutter sites. To validate the suggested method, a specific designed ball-end milling experiment is carried out. The research adds to our understanding of tool path creation for ball-end milling of sculptural surfaces, as well as decision-making for process parameter optimization in shop-floor complicated component milling processes.

Kaushik, V. S et al., (2018) demonstrated as In metal cutting, measuring temperature and estimating heat dispersion is critical since it affects tool deflection, tool life, cutting force and vibration, as well as the quality of the machined item. A statistical model has been developed in this article to estimate temperature rise in terms of design factors such as cutting tool helix angle, radial rake angle, and machining parameters such as cutting speed, feed rate, and axial depth of cut under dry conditions. Experiments were carried out using response surface technique and experimental design. Aluminum Al 7068 was used as the work piece material, and the tool was a high-speed steel end mill cutter with variable tool shape. A pyrometer was used to measure the temperature rise. For calculating a temperature rise, a second order mathematical model in terms of machining parameters was developed. The model's competency was determined through the use of ANOVA. The direct and interaction effects of process parameters on temperature increase were investigated, assisting in the selection of process parameters to maintain temperature rise at a low, indicating the immobility of the final milling process. With a 95 percent confidence interval, the prediction models in this work are expected to generate temperature rise values that are near to those measured experimentally. The optimization was carried by using a Matlab Genetic Algorithm Solver.

Aslantas, K., et al., (2018) examined in the micro milling of Ti-6Al-4V alloy, the effects of cutting settings on surface quality and burr width were studied. The control factors are the spindle speed, feed per tooth, and cut depth. The cutting parameters for minimal burr width (for up and down milling operations) and surface roughness were optimized using Taguchi-based gray relational analysis (Ra). Analysis of variance was used to establish the contribution percentages of the control variables (ANOVA). The feed rate value for the optimum surface quality was determined to be 0.25 m/tooth based on the collected findings. Ploughing occurs at lower feed rate levels, and the surface quality deteriorates. To generate minimum Ra, however, it was discovered that values of ap of 0.1 mm and n of 10,000 rev/min are more acceptable. On the down milling side, the burr width is greater than on the up milling side. Burr width increases when the feed rate is reduced and the cut depth is increased. Furthermore, because to fast tool wear, greater spindle speeds increased burr width.

Saini, Abhineet, et al. (2018) investigated that the Titanium alloy Ti6Al4V is a remarkable material with a number of desired characteristics, including high specific strength, corrosion resistance, and heat resistance, making it a viable candidate in a variety of demanding applications. However, because of its low heat conductivity, strong chemical reactivity with the tool, and spring action during cutting, it has poor machinability. Due of these characteristics, tool life is reduced during machining, limiting its use despite its outstanding mechanical qualities. As a result, in this study, the experimental optimization of process parameters utilising response surface approach in face milling of Ti6Al4V alloy with uncoated carbide tools was explored. The goal of this paper is to establish a mathematical relationship between input variables and response parameters, namely surface roughness (Ra), tool wear (Tw), and tool vibration (Tv). The machining settings are adjusted to get the lowest Ra, Tw, and Tv values possible. The ideal settings were tested in the lab and found to be in good agreement with the expected outcomes. The feed rate was determined to be the most important factor in determining Ra and Tv, whereas cutting speed had the greatest impact on Tw.

Pereira, Robson Bruno Dutra, et al (2017) investigated that When opposed to traditional drilling, helical milling is an alternate hole-making machining method that offers numerous benefits. The tool follows a helical route while rotating around its own axis in the helical milling process. Low cutting forces, tool wear, and increased borehole quality may be obtained because to its adaptable kinematics. A review of the helical milling technique is presented in this publication. The latest studies on the helical milling process were compiled as a first article aimed at describing the present state of the art of this method and pointing out potential directions in this sector. Initially, the benefits of helical milling were discussed in comparison to traditional milling. The kinematics of the operation were then provided in order to standardise the nomenclature and offer information on the motions and characteristics of helical milling. The feed velocity decomposition in frontal and peripheral directions was established. The ratio between the cutting volumes removed by frontal and peripheral cuts was proven to be dependent only on the borehole and tool diameters, and undeformed chip and cutting volumes of frontal and peripheral cuts were characterised. Cutting forces and temperature investigations were also reported, confirming that helical milling produces a smooth hole. After that, tool life and wear experiments in helical milling were described, demonstrating that tool wear can be tracked in both frontal and peripheral cutting edges, with frontal cutting edges determining tool life in most situations. On helical milling, some statistical and soft computing applications were also mentioned. To offer preliminary suggestions for using helical milling, a review of the existing literature was conducted, which summarised the equipment and cooling procedures utilised, as well as the levels of helix milling cutting conditions used for hole-making in various materials. The quality of helical milled boreholes was evaluated in terms of dimensions, geometrical, and micro-geometrical deviations, as well as burr and delamination levels, demonstrating that completed boreholes may be produced. Future study opportunities on helical milling were mentioned in the findings. This overview of helical milling can be used as a synopsis of current experimental and theoretical findings, as well as to identify future research requirements and possibilities.

Bhirud, N. L., and R. R. Gawande (2017) demonstrated that Heat is created during machining operations as a result of metal plastic deformation and friction along the tool–chip and tool–work piece interfaces. A substantial portion of the heat is absorbed by the work piece in materials with high thermal conductivity, such as aluminium alloys. As a result, the temperature of the work piece rises, potentially causing dimensional errors, surface damage, and deformation. As a result, it is necessary to keep the temperature of the work piece under control. The measurement, analysis, and prediction of work piece temperature rise during the dry end milling operation of Al 6063 are the subject of this article. The number of flutes, spindle speed, depth of cut, and feed rate were all utilised as experimental controls. The Taguchi technique was used to plan the experiment, and the L18 orthogonal array was chosen. A K-type thermocouple implanted in the work piece was used to measure the temperature rise of the work piece. The lower the quality attributes, the better the signal to noise (S/N) ratio analysis. The most important element impacting the work piece temperature rise was found to be the depth of cut, followed by spindle speed. The major parameters impacting the work piece temperature rise were determined using analysis of variance (ANOVA). The results of the ANOVA were found to be consistent with the S/N ratio study. The empirical temperature increase equation was developed using regression analysis. Using the regression equation, the temperature rise of the work piece was estimated and found to be in excellent agreement with the observed values. Finally, confirmation tests were performed to ensure that the results obtained were accurate. The Taguchi technique was shown to be an efficient way for determining optimised settings for minimising work piece temperature during the confirmation test.

Zhang, Hua, et al (2017) optimized as The connections between processing time, power energy consumption, and carbon emissions with milling process parameters were investigated during dry milling operations in response to the present urgent demand for low carbon and high efficiency production. The parameters of electricity usage and carbon emissions were also investigated. Low energy, high efficiency (minimal processing time), and low carbon emission functions were all built independently. Then, to attain high efficiency, low energy consumption, and low carbon emissions, a multi-objective optimization model was built. With the addition of weight coefficients, the multi-objective optimization model was reduced to a single goal. On the basis of experimental data, the technique for identifying the empirical model function coefficients was constructed using principal component analysis and regression analysis. The operational flow chart was supplied to solve the optimization model using the genetic algorithm, taking into account processing limitations from machine equipment performance and machining quality. A realistic example was used to demonstrate the viability of the process parameter optimization approach for balancing three responses (low processing time, low energy consumption, and low carbon emissions). Wide feed rates and large cut width can benefit three responses, according to the findings, assuming the constraints are satisfied. The optimal performance of the machine tool with the cutter was aided by the optimised solution and programme of cutting parameters, which helped to achieve sustainable production. The balance of efficiency, energy consumption, and carbon emissions can assist businesses in developing cutting parameters while reducing environmental effect.

Deng, Zhaohui, et al (2017) optimized as The process parameters were adjusted using the optimization model with the cutting specific energy consumption (CSEC) and the processing time in order to minimise the energy consumption of the machine tool. The energy consumption module of a numerical control (NC) machine tool was investigated based on its energy consumption characteristics. The cutting process parameters were supplied to CSEC together with the power composition of the machining process, which was based on the energy consumption module. The process characteristics were used to create an optimization model for the minimal cutting specific energy consumption and processing time under actual constraint situations in the production process. By incorporating subjective and objective comprehensive weights, the multi-objective optimization model was converted into a single-objective optimization model, which was then solved using the quantum genetic algorithm. When the goal of the optimization was to trade off processing time and CSEC to reduce energy consumption, selecting milling parameters should take into account the complex effect if the constraints could be met. For example, if the milling process constraints could be met, a large feed speed and a large milling depth could benefit. When compared to recommended process parameters, the processing energy consumption of improved process parameters was lowered by 27.21 percent, while CSEC was cut by 32.07 percent and processing time was reduced by 34.11 percent. The technique suggested in this study provided an effective solution for reducing the environmental impact of energy use and achieving sustainable manufacturing.

Jarosz, Krzysztof, et al (2017) analysed that the usage of computer software is an essential component in the design of technical processes in today's machining industry. This paper attempts to show how commercial software built specifically for milling operations may be used to optimise milling processes. This research used a face milling procedure on an aluminium flange. The outcomes of several different optimization techniques were displayed, analysed, and debated. In milling processes, the effect of variable radial depth of cut on cutting force values was investigated. In addition, it was suggested that future study include a comparison of experiment findings with simulation results. It was demonstrated that using the right optimization technique may cut machining time for the investigated face milling operation by 37% while staying within the process parameter restrictions.

Kalita, Kanak, et al., (2017) demonstrated that the Laser micro-marking is a cost-effective method for permanently branding and printing logos on materials. This research examines how to choose the best parametric combination for laser micro-marking. Markings on Gallium Nitride (GaN) were carried out in this study with different degrees of marking characteristics. Current (A), pulse frequency (Hz), and scanning speed (mm/sec) are the parameters addressed in this study. The response surface approach was used to construct this experiment, which used a "central composite design." The output response was defined as the mark intensity, which is a major reaction in laser marking. Analysis of variance (ANOVA) and mathematical modelling between the input parameters were used to understand the findings. The link and importance of input-output variation must be determined. The influence of various input factors interacting on mark intensity was also investigated. Finally, the best choices of input constraints were predicted using two techniques: genetic algorithm (GA) and particle swarm optimization (PSO).

Albertelli et al., (2016) optimized that A novel model for determining how much energy a machine tool uses to process a prismatic workpiece has been created. The energy consumed by various machine components such as auxiliary systems, axis, axes chiller, tool change system, chip conveyor, and spindle system is taken into consideration by the model. The relationships between each machine component's power absorption and the major cutting parameters were accurately modelled. The cutting energy was taken into account as well. The energy consumed by the machine during inactive phases (e.g. tool changeover) was also assessed since the tool wear was incorporated in the model. Each machine component model was optimally designed for the manufacturing phase in question. Experimental experiments on an actual machining centre with linear motors were used to identify some of the characteristics of the machine tool energy model. The cutting speed, feed, and radial depth of cut were used as the primary factors in a multivariable energy optimization. Exhaustive enumeration methods were used to achieve energy reduction. The findings were thoroughly examined and evaluated. The optimization study was also carried out again, this time simulating alternative machine tool setups and production circumstances.

Arokiadass et al., (2012) demonstrated that End milling was used to study the machining properties of the LM25 Al/SiCp composite. Through response surface methodology and relevant experimental data obtained through experimentation, a comprehensive mathematical model was developed for correlating the interactive and higher order influences of various process parameters on the dominant machining criteria, i.e. the tool flank wear phenomena A common response surface technique design known as a central composite design was used to carry out the experimental plan (CCD). The analysis of variance (ANOVA) findings show that the suggested mathematical model may properly represent performance within the parameters of the components investigated. To obtain the least tool flank wear, an optimal combination of these factors can be utilised.

Gao et al., (2012) analysed that the selection of machining parameters is critical in the milling process since these parameters influence processing time, quality, cost, and so on, especially with high-accuracy machine tools. The parameters optimization of a multi-pass milling process, on the other hand, is a nonlinear constrained optimization issues that standard optimization approaches struggle to handle. As a result, this study presents a unique parameter optimization approach based on cellular particle swarm optimization to successfully tackle this problem (CPSO). The suggested approach combines two constraint handling strategies, including the penalty function method and the PSO constraints handling strategy, to efficiently handle the constraints. The smart cell in the proposed CPSO builds its neighbourhood using self-adaptive functions and constraint management approaches, which assist unfeasible particles to migrate to viable regions and search for better solutions. To demonstrate the efficacy of the proposed CPSO method, a case is used and solved. The experiment study's findings are examined and compared to those of prior algorithms. The experimental findings demonstrate that the suggested technique outperforms previous algorithms and improves performance significantly.

Al-Zubaidi et al., (2011) investigated as in recent years, there has been a movement toward utilising artificial intelligence to simulate machining. In the modelling of nonlinear issues such as machining processes, ANN is regarded one of the most significant artificial intelligence approaches. When compared to traditional approaches, artificial neural networks are better at predicting and optimising machining operations. Given the relevance of artificial neural networks in machining, this study attempts to summarise past research and investigations into the use of artificial neural networks in the milling process during the last decade.

Periyanan, P. R et al., (2011) analysed as Micro-machining is a fundamental micro-engineering method for producing micro-sized parts and components. Microend milling is the most used micromachining method in the industrial industry because of its ability to produce intricate geometric surfaces with high precision and surface quality. Material removal rate is a crucial component of micro end milling that requires attention from industry professionals as well as research and development. One of the current trends in contemporary industry is to produce low-cost products in a short amount of time. MRR, which denotes the amount of time it takes to process a workpiece, is a critical element that has a significant impact on production rate and cost. MRR varies a lot depending on the cutting process factors. The taguchi approach is used in this work to optimise the maximum metal removal rate (MRR) in micro-end milling operations, using the spindle speed, feed rate, and depth of cut as cutting parameters. The influence of these milling settings is investigated using an orthogonal array, signal-to-noise (S/N) ratio, and Pareto analysis of variance (ANOVA). The results reveal that the best combination for a greater metal removal rate (MRR) is medium cutting speed and high feed rateOther major impacts, such as the interaction among milling settings, are also examined using the Taguchi technique for design of experiment (DOE). The study demonstrates that the Taguchi technique is appropriate for solving the situation at hand. According to the results of the verification experiment, the proportion of response mistake was lower.

Rao R et al., (2010) investigated that Effective machining process parameter optimization has a significant impact on the cost and production time of machined components, as well as the quality of the finished products. The optimization features of a multi-pass milling process are discussed in this article. The goal is to reduce production time (i.e. increase production rate) while taking into account different restrictions such as arbour strength, arbour deflection, and cutting power. To establish the best process parameters, such as the number of passes, depth of cut for each pass, cutting speed, and feed, several cutting methods are examined. The research also takes into account the process parameters' upper and lower limits. Artificial bee colony (ABC), particle swarm optimization (PSO), and simulated annealing are three non-traditional optimization methods used in the optimization (SA). To demonstrate the usefulness of the provided algorithms, an application example is shown and solved. The provided algorithms' results are compared to previously published results acquired via the use of various optimization approaches.

II. CONCLUSION

According to the literature review, six researchers used speed of cutting, depth of cut, and feed for their study, two used spindle speed, depth of cut, and feed, one used number of passes, depth of cut, spindle speed, and feed rate, and one used spindle speed, depth of cut, feed rate, flow of coolant, and diameter of drill tool. As a result, this literature focuses on three key parameters: cutting speed, feed rate, and depth of cut. The next research will be based on the three parameters that have been chosen.

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