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Review of Optimizing Machining Parameters for Improving Surface Texture

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Abstract—*In any machining process, apart from obtaining the accurate dimensions, obtaining a good surface texture is also important. A machining process includes many process parameters which directly or indirectly influence the surface quality of the product. Surface roughness in turning process are caused due to various parameters of which speed, feed and depth of cut are important ones. This paper addresses a review of both former and latter state-of-the-art approaches on improving surface finish by optimizing the machining parameters. The scope of the paper is to provide a review on optimizing the process parameters so as to obtain good surface finish, increase material removal rate and decrease machining time without decreasing the quality of the product. In this paper, optimization of machining processes is addressed to different parameters such as cutting speed, depth of cut and feed rate. The retrospection of the work shows various techniques such as Genetic Algorithm, AANOVA employed to improve the machining results under the distinct environments. Further optimization model has been formulated which describes the various steps and the sequence to be followed in order to carry optimization process. Finally, challenges in this field are recommended and investigated. The present survey depicts that the optimizing techniques framed for optimization of cutting parameters draw a significant interest from both conceptual and practical contexts.*

1. INTRODUCTION

Machining is one of the various processes in which a piece of raw material is cut into a fixed shape and size by a controlled material removal process. As technology improves, the term "machining" has been changing from time to time. In the Machine Age, it was known as the "traditional" machining processes, such as turning, facing, tapping milling, planning, reaming, drilling, boring, broaching and sawing. In these "traditional" or "conventional" machining tool, processes, machine process, like milling machine, drill presses, lathes, etcetera, are used with a tool in order to remove material and to achieve a pre-determined shape. After the incoming of modern technologies such as, electrochemical machining, and electrical discharge machining, ultrasonic machining and photochemical machining. The word "conventional machining" is used to denote those traditional technologies from the modern ones. In present usage, the term "machining" usually points out the classic machining processes. Machining is used in the production of various metal products, and also other materials such like wood, ceramic, composites and plastics. Most of the day-to-day machining is carried out by computer numerical control (CNC), where computers monitor the functioning of the cutting machines such as lathes, mills, and others. A.K. Ghani *et al,* (2002) studied the tool life, vibration and surface finish while machining cast iron using ceramic tool. Cutting tests have been performed to check the change in surface texture of work piece because of increase in tool wear. It is found that minimum surface roughness results with the combination of high cutting speed and low feed rate. The test is carried out under various combinations of feed, speed and depth of cut. It is found that the cutting process becomes more stable as the speed gets high. N. Muthukrishnan *et al,* (2009) studied the surface texture of Al-SiC by turning the composite bars. Experiments was carried on Lathe using PCD coarse grade cutting tool, the data surface roughness was collected under various cutting conditions for various combinations of feed rate, cutting speed and depth of cut. Experimental data gathered are referred with analysis of various ANOVA and artificial neural network ANN technique. In ANOVA, it is found that the feed rate has highest influence on the surface roughness. The difference in percentage of the experimental and predicted values is found that minimum of 0.39 and maximum of 4.78. . Ashvin J *et al*. (2013) studied the outcome of the turning parametric quantities which are feed rate, depth of cut and spindle speed on the surface of AISI 410 steel using design of experiment method. Response surface methodology [RSM] is used to study the outcome of these parametric quantities on the surface roughness. To study the outcome of the input parameters on the surface roughness variance analysis (ANOVA) is used. It is found that the feed rate is the most affecting factor on the roughness, the second most affecting factor is the nose radius of the tool and the next is followed by cutting speed. The parameter which less affects the surface roughness is the depth of cut.

2. LITERATURE REVIEW

M. Vijay Kani, A.M. Chincholkar, [4] Studied the outcome of various machining variables in turning operation on material removal rate and roughness of surface of fibre reinforced polymers which is used as work piece. Coated tungsten carbide is used as insert for dry turning. Taguchi method is used for design of experiments. At the end of the study, they have found that the feed rate is the most affecting parameter on surface roughness of the work piece which is followed by spindle speed. Material removal rate (MRR) is highly affected by tool nose radius and feed rate combination and cutting speed.

Ilhan Asilturk and HarunAkkus, [5] Optimized the turning parameters based on the Taguchi method to reduce surface roughness caused after machining. They have used CNC turning machine for conducting experiment. L9 orthogonal array is used to minimise the number of experiments to be conducted. Hardened AISI 4140 (51 HRC) is used as work piece material and coated carbide insert is used as cutting tools. Dry turning operation is performed on the work piece. The analysis of variance (ANOVA) and the statistical methods of signal to noise ratio (SNR) are used to study the outcome of various machining parameters on surface roughness.

Mustafa Gunay and EmreYucel, [6] studied for decreasing the surface roughness caused after machining process by optimizing the machining parameters. High-alloy white cast iron (Ni-Hard) is used as work piece material. Two different hardness levels (50 HRC and 62 HRC) is used. CNC lathe was used to perform machining experiments. Ceramic and cubic boron nitride (CBN) is used as cutting tool. Depth of cut, feed rate and cutting speed are selected as the machining parametric quantities. Analysis of variance (ANOVA) is used to find the influence of the machining parameters on surface finish. The feed rate was found as the most affective parameter for Ni-Hard with 62 HRC while the cutting speed was found to be more affective parameter for Ni-Hard with 50 HRC. Zahia Hessainia, et al, [7] done the research work in which response surface methodology (RSM) is used to find the effect of various machining parameters at the time of dry turning process. The main input parametric quantities of this model are the cutting parametric quantities such as depth of cut, cutting speed, feed rate and tool vibration in radial and cutting force direction. 42CrMo4 hardened steel is used as work piece material. It is found that the two main factors affecting the surface roughness are tool vibration and feed rate. Tool vibrates more when the machine operating at high cutting speed.

Muammer Nalbant et al [8] investigated the outcome of uncoated, PVD and coted CVD cemented carbide tool and cutting parameters on surface texture in CNC turning and using artificial neural networks it is predicted that with different feed rate and cutting speed. In this study depth of cut is kept steady and coolant liquid is not used. The results of surface roughness caused by the factors like coating method, coating material, cutting speed and feed rate on the work piece have been examined. It is found that number of coating layer, coating material type, and coating method plays an important role in changing the thermal conductivity and thermal coefficient of cutting tool.

Upinder Kumar Yadav et al. [9] experimentally investigated the outcome of machining parameters on surface roughness using ANOVA method. They used CNC lathe to perform turning operation on AISI 1045.Taguchi method is used to minimize the number of test required. In this experiment the outcome of three machining parametric quantities and their effects are evaluated using ANOVA and with the help of MINITAB 16 statistical software.

Krishnakant et al, [10] Conducted experimental investigation on turning process of EN24 steel using MIRANDA S-400 tool. He has conducted two sets of experiments for measuring surface roughness and material removal rate. This experiment is conducted by using Taguchi method. Taguchi method concentrates on the importance of studying the response variation using the signal-to-noise {S/N} ratio, resulting in minimizing of quality characteristic variation due to uncontrollable parametric quantities.

Manan Kulshreshtha, [11] analysed the results of machining variables such as feed rate, depth of cut and cutting speed on surface roughness. Dry turning operation is used on Nickel Steel EN 36 as work piece material. CNC lathe has been used to perform turning operation by Tungsten Carbide tool. He has done this study in search of an optimal parametric combination capable of producing desired surface quality of the turned product. Taguchi is used for design of experiments and ANOVA is used for analysing the significance of machining parameters on surface roughness.

I. Korkut, K. Venkata Subbaiah *et al.* [12] looked into the effect of machining parameters on surface finish of the work piece material when machined on AISI 304 austenitic stainless steel. Machining is done by using CNC lathe. Taguchi method is used for creating Design of Experiments. It is used to examine the outcome of machining variables on surface waviness to obtain their optimal setting. The effect of machining variables is analysed by using variance analysis (ANOVA) during machining. It is found that feed rate and spindle speed are the most affecting parameters.

U. Gupta and A. Kohli, [13] presented a use of response surface and genetic algorithmin designing the parametric optimization of turning process. Turning operation was performed by CNC lathe on AISI-410 steel. The signal-to-noise ratio, the L18 orthogonal array and analysis of variance are used to study the effect on characteristics of turning operation of work piece. The experimental results shows that the feed rate and the insert radius are the most effective parametric quantities from the four machining parameters such as depth of cut, insert radius, cutting speed and feed rate that influence the surface texture in turning AISI 410 Steel.

Table 1: Review of Methods Literature

Referene	Methodology and software	Input	Conclusion
[4], [5] and [12]	Taguchi Technique	Feed, and cutting speed	Surface roughness improves.
[6]	ANNOVA	Cutting Speed and Feed rate	Decrease in Surface Roughness
[7], [10]	Response Surface Methodology	Depth of cut, cutting Speed, Feed and tool Vibration	Tool vibrates more when the machine operating at
[8]	Artificial Neural Network	Cutting Speed, Feed rate and Nose Radius	Tool life increases due to change in thermal conductivity and thermal coefficient of cutting tool.

Table 1: Table of materials used by different authors and their suggested machining parameters

Refrence	Material	Parameters
[4]	Glass fibre reinforced polymer pipes	Depth of Cut = 0.1 mm Feed Rate = 0.4 mm/rev Cutting speed = 60 m/min
[5]	AISI 4140	Depth of Cut = 0.4 mm Feed Rate = 0.18 mm/rev Cutting speed = 120 m/min
[6]	High alloy cast iron [Ni-hard]	Depth of Cut = 0.5 mm Feed Rate = 0.05 mm/rev Cutting speed = 100 m/min
[7]	42CrMo4 hardened steel	Cutting speed = 180 m/min Feed Rate = 0.08 mm/rev Depth of Cut = 0.15 mm
[8]	AISI 1030 steel	Depth of Cut = 2 mm Feed Rate = 0.25 mm/rev Cutting speed = 200 m/min
[9]	Medium Carbon Steel AISI 1045	Depth of cut = 1.5 mm Feed rate = 0.1mm/min Cutting speed = 264 m/min
[10]	EN24T	Depth of Cut = 1 mm Feed Rate = 0.458 mm/rev Cutting Speed = 150 m/min
[11]	EN 36 Nickel Steel	Feed Rate = 15 mm/min Depth of cut = 0.2 mm Spindle Speed = 1200 rpm
[12]	AISI 304 austenitic stainless steel	Depth of Cut = 0.29 mm Feed Rate = 0.28 mm/rev Cutting speed = 280 m/min
[13]	AISI – 410 Steel	Depth of Cut = 1 mm Feed Rate = 0.14 mm/rev Cutting Speed = 125 m/min

3. METHODOLOGY

Every machined surfaces fails to display the ideal geometrical surface. Huge number of macro and micro-geometrical irregularities are present in the machined surface. The variation from the nominal surface of the third up to sixth order is defined as surface roughness. In order to improve the surface quality different machining parameters have to be optimized by applying different optimization method such as: ANNOVA, Taguchi, Response Surface Methodology and Artificial Neural Network. W.H. Yang, Y.S. Tarng [9] Designed optimization of cutting parameters for turning operations by Taguchi method. The Taguchi technique is a simple tool to design optimization of machining parameters. Turning operation is performed in this study. Orthogonal array, signal to noise ratio and ANOVA method are carried out to find out the cutting parameters effect on S45C steel bars. Tungsten carbide insert is used as cutting tools. To verify the optimum machining parameters experiments were conducted. The improvement of surface roughness and tool life from the initial cutting parametric quantities to the effective cutting parametric quantities is about 250%.Manan Kulshreshtha [14] analysed the results of machining variables such as feed rate, depth of cut and cutting speed on surface roughness. Dry turning operation is used on Nickel Steel EN 36 as work piece material. CNC lathe has been used to perform turning operation by Tungsten Carbide tool. He has done this study in search of an optimal parametric combination capable of producing desired surface quality of the turned product. Taguchi is used for design of experiments and ANOVA is used for analysing the significance of machining parameters on surface roughness. Hamdi Aouici, Kamel Chaoui [15] experimentally examined the outcome of feed rate cutting speed, depth of cut, work piece hardness and cutting force components on surface roughness in the hard turning of AISI H11 steel. It was hardened to (40; 45 and 50) HRC. Cubic boron nitride CBN 7020 is used as cutting tool. The factors hardness, depth of cut, cutting speed and feed rate and three-level designs of experiment is created by the analysis of variance (ANOVA). By using the response surface methodology (RSM) a mathematical models is created for surface roughness and cutting force. It is found that the work piece hardness and feed rate have significant statistical influences on the surface texture and the best surface texture was achieved at the highest cutting speed and the lower feed rate. U.S. Dixit (2003) [16] discovered that surface roughness can be find out within a certain extent of accuracy by using neural network method. This is done by taking the feedback of the radial vibration of the tool holder. By using fitted network it became possible to predict the surface roughness in machining when the same tool material is used but with different shape and size. For wet and dry turning, different neural network models has to be prepared. It has been found that by increasing feed rate to some extent the surface roughness decreases, with some more increase in feed rate starts increasing the surface roughness when TiN coated carbide tool is used for machining.

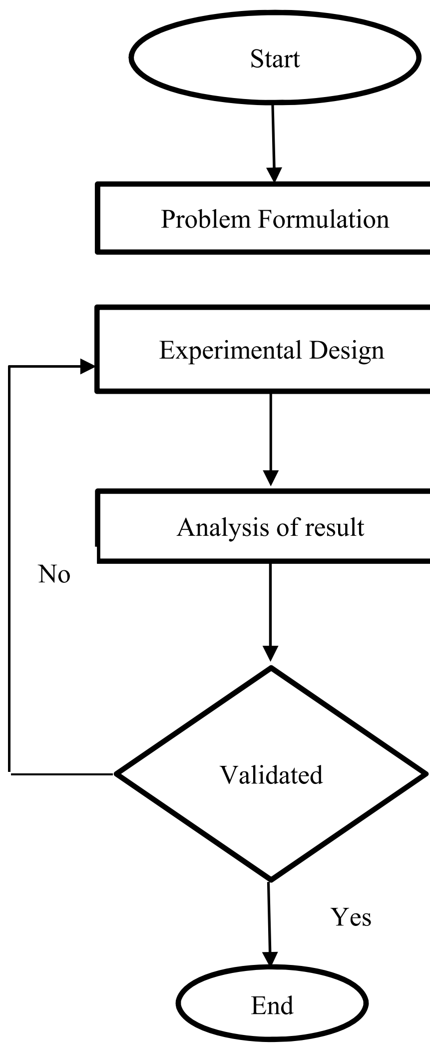

Fig. 1: Optimization Model Formulation as System Architecture Algorithm

Rahul Davis, (2012) [17] Optimized the machining parametric quantities for surface roughness in dry turning operation of mild steel using Taguchi method and to obtained a predictive equation. The Signal-to-Noise ratio and analysis of variance {ANOVA} were used to study the effect characteristics of turning. From the analysis made by Rahul Davis shows that depth of cut was the only parameter found to be significant. A conformation test was performed which depicts that the selected parametric quantities and predictive equation were accurate.

4. CHALLENGES

Many advancements are made in the field of optimizing the surface roughness of the work piece, as there are different methods for optimization but still there stand some challenges to be uplifted.

(i) Computational Time: The time required for formulation is an important factor in selecting a particular optimizing technique. So, it is to be kept in mind that algorithm would not take longer time in order to achieve optimize result. So, number of iterations, complexity of method all directly affects the computational time.

(ii) Utilization of same Parameters: Usage of same parameters again and again have restricted the development of optimization algorithms. Which somehow created shallowness in mindset of new researchers not to discover some new combinations of parameter and constraints.

(iii) Overestimation risk: Different constraints are being used for optimizing the required parameters. Where, Optimization is being done by considering at least more than two parameters, which leads to the more occurrence of the expressions of different parameters, which sometimes leads to the overestimation risk after optimization results.

(iv) Constraints: In order to increase the quality of the optimized result and decreasing the unrequired iteration steps. Constraints are to be chosen very carefully.

(v) Elevating Algorithms: It was found that traditional algorithm will only perform local reasoning. So, in order to get rid of these problem propagation stage of the algorithm should be enhanced.

5. CONCLUSION

The problems related to the optimization of machining parameters for improving the surface texture has attracted many of researchers over a long period of time. Which has resulted in the application of different optimization algorithms with their various variants in wake of optimal solutions. GA, Taguchi, ANN, Fuzzy Logic, RSM, AANOVA are the techniques which had been used by many researchers results in achieving optimal results for small sized problems to large complex one. Taguchi, ANNOVA and Genetic algorithm are widely used for optimizing the surface roughness and tool wear, where Fuzzy logic helps in prediction of selection of cutting parameters to get affective results on flank wear and surface roughness of tool and work piece material and FEM model helps in attaining residual stresses, chip morphology and cutting forces.

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