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Optimization of Surface Roughness and Material Removal Rate in CNC Turning of Al5083/SiCp Using Taguchi Method

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Abstract: Machining involves many process parameters. To achieve accurate dimensions, good surface quality and to maximize metal removal rate, the turning parameters contributes significantly. The aim of this research is to optimize the Spindle parameters like Spindle speed, feed and depth of cut to minimize surface roughness and to maximize the material removal rate in turning of Al5083/SiCp. The tungsten carbide tool is used for the turning operations. The experiments were carried out using Taguchi design of experiments with L27 orthogonal array. The Analysis of means is employed to analyze the performance characteristics in turning operation of Al5083/SiCp. Response variables measured for the analysis of surface finish and the material removal rate. The ANOVA results revealed that DOC & feed are most predominant factors for MRR & surface roughness respectively.

Keywords: Radial Distribution Network (RDN), Distributed Generation (DG), Particle Swarm Optimization (PSO).l.

1. Introduction:

The presented research [1] investigates the short circuit analysis of power distribution networks incorporating distributed generations. The study emphasizes the importance of understanding the impact of distributed generations on the short- circuit characteristics of the network. The findings provide valuable insights into the challenges and considerations for ensuring the stability and reliability of power distribution networks in the presence of distributed energy sources. Paper [2] addresses the issue of harmonic pollution in distribution networks through reconfiguration. Their work introduces a modified discrete particle swarm optimization method with a smart radial approach to optimize network configuration. This research contributes to the field by proposing a novel technique to mitigate the effects of harmonics, presenting a promising avenue for enhancing power distribution systems' overall performance and quality. Contribution in [3] assessing the reliability of electrical equipment in the presence of higher current and voltage harmonics. The study offers a comprehensive evaluation of the impact of harmonics on equipment reliability. This research is crucial for designing resilient systems capable of withstanding harmonic-related challenges and ensuring the continued functionality of electrical equipment. Work in [4] explores the impact of electric vehicle (EV) charging stations on the reliability of distribution networks. In light of the increasing integration of EVs into the power grid, their research addresses the challenges and opportunities associated with the proliferation of charging stations. The findings contribute to understanding the dynamics of network reliability and suggest enhancements needed to accommodate the growing demand for electric transportation.

Author in [5] focus on the reliability analysis of distribution networks with distributed power supply. Their study explores the impact of distributed power generation on the reliability of the distribution network. The findings contribute valuable insights into the challenges and considerations for ensuring the robustness and dependability of power distribution systems incorporating distributed energy sources.[6] address the optimal mitigation of harmonics in distribution systems with inverter-based distributed generation. The research presents strategies to minimize harmonic distortions introduced by distributed generation, offering practical solutions to enhance the quality and performance of power distribution systems. [7] explore the use of D-STATCOM for harmonic mitigation in low voltage distribution networks with high penetration of nonlinear loads.

Their work provides insights into the application of dynamic reactive power compensation to mitigate harmonic distortions, thereby improving the overall power quality in distribution networks. [8] investigate harmonic emissions from three-phase diode rectifiers in distribution networks. The study contributes to understanding the impact of these rectifiers on harmonic content, addressing challenges related to the integration of nonlinear loads into power distribution systems. [9] propose a high-impedance arc fault detection method based on harmonic randomness and waveform distortion in the distribution system. This work focuses on improving the reliability of distribution networks by detecting and addressing high-impedance arc faults through harmonic analysis. [10] provide a comprehensive review of challenges and perspectives related to micro grids. The study discusses the role of micro grids in the context of power distribution, offering insights into the challenges and potential solutions for integrating these decentralized energy systems into distribution networks.

Work [11] propose a novel reliability index-based approach for electric vehicle (EV) charging station allocation in distribution systems. Their research addresses the challenges associated with the integration of EV charging stations, providing a methodology for optimal station allocation to enhance the reliability of the distribution network. [12] analyze the impact of varying photovoltaic (PV) penetration levels on the harmonic content of active distribution systems. The study explores the harmonic distortions introduced by grid-integrated solar farms, contributing insights into the challenges and considerations for managing harmonics in the presence of renewable energy sources. [13] present a harmonic transform-based non- parametric density estimation method for forward uncertainty propagation and reliability analysis. Their work introduces an innovative approach to assessing reliability in power distribution systems, considering uncertainties, and providing a tool for effective risk management. [14] focus on probabilistic harmonic forecasting of the distribution system, considering time-varying uncertainties of distributed energy resources and electrical loads. This research contributes to forecasting methodologies that account for dynamic uncertainties, enhancing the ability to predict and manage harmonic content in distribution networks. The paper [15] concludes by emphasizing the significance of the integrated approach, highlighting its potential to enhance the automation of distribution systems. Future research directions may include further refinement of the algorithm, validation through practical implementations, and exploration of broader applications in power network optimization.

$$EPLOSS = \frac{with\ DG\ Loss}{without\ DG\ Loaa} = \frac{P}{P0} \quad (1)$$

$$EQLOSS = \frac{with\ DG\ Loss}{without\ DG\ Loaa} = \frac{Q}{Q0} \quad (2)$$

$$EV == \frac{del\ v}{Vr} \quad (3)$$

B. Optimization Technique

The paper [16] concludes by emphasizing the importance of the developed heap-based optimizer for DG allocation in reconfigured radial feeder distribution systems. Future research directions may include further refinement of the optimization algorithm, validation through practical applications, and exploration of its adaptability to different network configurations.

In summary, these research works contribute to advancing the understanding of power distribution network analysis and optimization. They address various aspects, including distributed generations, harmonic pollution, reliability assessment, and the impact of emerging technologies like electric vehicles, providing a comprehensive overview of the current state of research in this critical domain. these selected works collectively contribute to the evolving landscape of power distribution network analysis and optimization. They address a range of challenges, from distributed generation and harmonic mitigation to the integration of new technologies, providing valuable insights for researchers, engineers, and practitioners in the field.

These papers collectively address vital topics in power distribution systems, including reliability assessment, advanced learning algorithms for reliability analysis, optimization, fault detection, and location in DN incorporating distributed generation and micro grids

2. Literature Review

A literature review is a piece of academic writing demonstrating knowledge and understanding of the academic literature on a specific topic placed in context. A literature review also includes a critical evaluation of the material; this is why it is called a literature review rather than a literature report. Y. Rameshwara Reddy (2023).

This study explored multi-objective optimization of the turning process for AISI1045 steel using a CNMG cutting tool. The goal was to achieve the optimal combination of parameters for minimizing surface roughness and maximizing material removal rate (MRR). To address the limitations of the traditional Taguchi method in handling multi-objective optimization, Grey relational analysis (GRA) was integrated with the Taguchi approach. Nine experimental runs were conducted based on a Taguchi orthogonal array, and the significance of factors influencing cutting process quality was quantitatively assessed using Analysis of Variance (ANOVA). Optimal results were confirmed through additional experiments.[1]

Nihal Raghuvanshi and Aditya Narayan Bhatt (2023) Industrial revolution of manufacturing industry, the machining operations is backbone of every industry. Industry involved in material removing operation is greatly focusing on choosing right and optimized machining process. Machining is a part of manufacturing. In every industry machining is done to remove the excess material from the work piece to get desired shape and size with accuracy This study is an attempt to review and optimize of turning of Al 6061 and influence/effect of machining parameters viz. speed, feed and depth of cut, on the surface roughness of Aluminium 6061.[2]

Pytlak et.al (2021) Developed a multi-criteria optimization method for hard turning of cemented 18 HGT steel using CBN-enhanced wiper geometry. Parameters included depth of cut, feed, and cutting velocity. Optimization criteria encompassed production cost, time per unit, and cutting force.

A hierarchical strategy was used to ensure low production costs and minimal cutting forces. For Pareto sets, we used the Weighted Goals and Modified Division approach. Design and Analysis of Computer Experiments (DACE) was used to simulate the hard turning of AISI 6150 steel with PCBN tools and factors such as feed, depth of cut, and cutting rate. DACE demonstrated its effectiveness in modeling complex non-linear factors.[3]

Maheshwara Rao et. al. (2020) This study investigates the impact of CNC turning parameters on surface roughness in AA7075 using a tungsten carbide insert. Taguchi's L9 orthogonal array was employed, and ANOVA revealed feed and cutting speed as critical factors. Optimal parameters (1000 rpm, 0.2 mm/rev, 0.5 mm) were identified for minimum surface roughness. Predictive models using MINITAB-16 and regression analysis showed close alignment between predicted and experimental values, indicating accuracy and adequacy.[4] D. Philip Selvaraj et. al. (2020) used AISI 304 Austenitic treated steel to consider the effect of cutting parameters like cutting rate, feed rate and profundity of cut superficially unpleasantness. A plan of assessments subject to Taguchi's technique has been used to pick up the data. A symmetrical exhibit, the sign to uproar (S/N) extent and the assessment of contrast (ANOVA) are used to look into the cutting qualities of AISI 304 austenitic solidified steel bars using TiC and TiCN secured tungsten carbide cutting tool. Finally, the certification tests that have been finished to differentiate the foreseen characteristics and the preliminary regards assert its ampleness in the assessment of surface unpleasantness.[5]

R. Ramanujam et.al. (2019) presents another technique for the optimization of the machining parameters on turning Al-15%SiCp metal network composites. Optimization of machining parameters was done by an examination called appealing quality limit assessment. Taguchi's L27 symmetrical cluster is used for preliminary arrangement. The machining methodology parameters, for instance, cutting velocity, feed rate and profundity of cut are streamlined with various execution considerations to be explicit surface harshness and power use. The perfect machining parameters have been recognized by a composite appealing quality worth got from charm work assessment as the introduction list, and important responsibility of parameters would then have the option to be managed by examination of progress. Certification test is similarly prompted endorse the test result. Exploratory results have shown that machining execution can be improved effectively through this strategy.[6] M. Vellibor et.al (2017) presented Taguchi solid parameter plan for displaying and optimization of surface unpleasantness in dry single-point turning of infection moved blend steel 42CrMo4/AISI 4140 using TiN-secured tungsten carbide installs. Three cutting parameters, the cutting speed (80, 110, 140 m/min), the feed rate (0.071, 0.196, 0.321 mm/fire up), and the profundity of cut (0.5, 1.25, 2 mm), were used in the preliminary. All of various parameters was taken as steady. The typical surface unpleasantness (Ra) was picked as an extent of surface quality. [7]

P. G. Inamdar et.al. (2017) The main aim of this paper is to optimize the surface roughness in conventional turning operation using Taguchi Method for the material medium carbon steel EN8. In this work cutting speed, feed rate and depth of cut are taken as performance parameters to achieve better surface roughness. Taguchi Method is used to obtained the main parametric effect on the surface roughness using their levels and factors. L9 orthogonal array is used to design the experiments. Also, analysis of variance (ANOVA) was carried out with the significance factor of 95%. After the experimentation, it was found that cutting speed has more influenced on the surface roughness in conventional turning process than feed rate and depth of cut.[8] N. Ramesh et. al. (2016)

This paper focuses on optimizing material removal rate (MRR) and surface roughness (Ra) in CNC machining of AA 6061 using the Taguchi method. Three parameters-Speed, Feed, and Depth of cut-were varied across three levels. The study employs Particle Swarm Optimization (PSO) to enhance MRR and minimize surface roughness. The optimized parameters contribute to increased machining efficiency and reduced production costs in automated manufacturing.[9]

3. Objectives of Research Work:

The objective of the topic "Optimization of Surface Roughness and Material Removal Rate in CNC Turning of Al5083/SiCp Using Taguchi Method" is to systematically identify and optimize the machining parameters in the CNC turning process for a composite material consisting of aluminum alloy Al5083 reinforced with silicon carbide particles (SiCp). Specifically, the study aims to:

- Surface roughness optimization.
- Material removable rate optimization.
- Taguchi method implementation

4. Methodology:

- Turning of Al5083/SiCp rod has been performed on a CNC machine using Taguchi Method.
- Taguchi based Design of experiments has been used to find out optimum number of experiments to be conducted to achieve the said objectives.
- Surface roughness of machined surface has been measured using a surface analyzer during experimentation
- Material removal rate has been evaluated using high precision balance by weighing samples before and after experimentation.
- Analysis has been carried out using analysis of variance (ANOVA). The significance of the regression model and significant model term i.e spindle speed, feed and depth of cut are clearly highlighted.
- Models have been developed to correlate output variables such material removal rate and surface roughness, with the input variables i.e. spindle speed, feed and depth of cut

5. Result and Discussion:

Analysis of Surface Roughness and Material Removal with Al5083/SiCp Figures 2 and 3 illustrate Taguchi's primary effect graphs for surface roughness.

The main effect plot displays the variation in surface roughness as a function of spindle speed, feed rate, and cut depth. The X axis shows the change in variable level, while the Y axis represents the change in the consequent reaction.

Form the graph 2 it is observed that cutting speed increases the surface roughness decreased because as the speed increasing the contact between the surface and the tool contact decreased as friction between the two surfaces decreases due to this surface roughness decreased. When feed is increased the surface roughness increased because the tool is moving against work piece low feed the surface roughness is low because the tool moves very slowly the marks are even on the surface than compared with high feed, because of this feed increased surface roughness also increased.

If depth of cut is increased surface roughness increased because as depth is more against surface the surface has more uneven while machining due to this as depth of cut increased roughness increased. From the probability graph 3 the experimental values nearer to the linear curve. The Predicted values verse experimental values are within the limits of region which prove the experimental values are true for surface roughness

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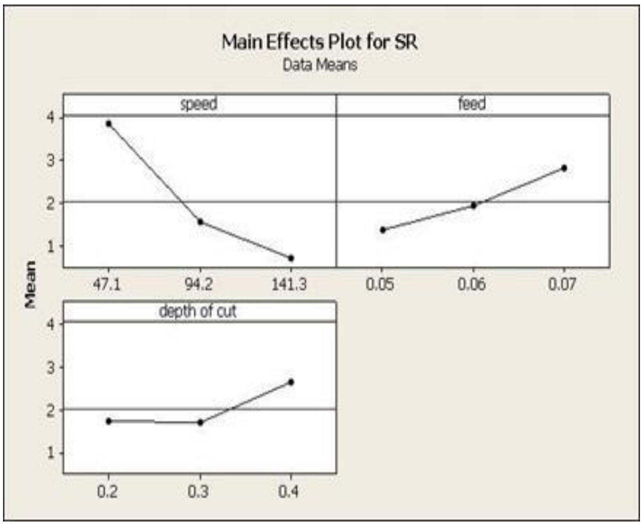

Figure 2 Main effects plot for means for surface roughness

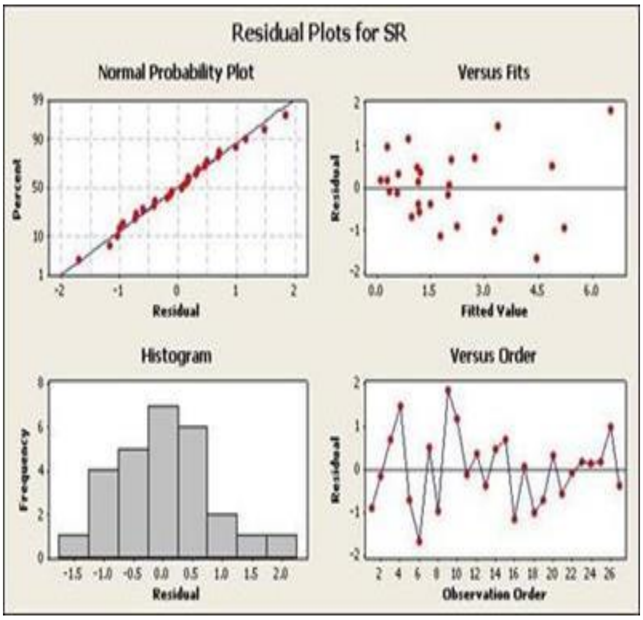

Figure 3 Residual plots of Surface Roughness for Al5083/SiCp

5, Conclusions:

The Surface roughness is mainly affected by feed rate, depth of cut and spindle speed. With the increase in feed rate the surface roughness also increases, as the depth of cut increases the surface roughness first increase and decrease and as the spindle speed increase surface roughness decreases

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