DOI: https://doi.org/10.52756/ijerr.2024.v38.009 *Int. J. Exp. Res. Rev.*, Vol. 38: 102-110 (2024)

Original Article | Peer Reviewed | Open Access

International Journal of Experimental Research and Review (IJERR)
© Copyright by International Academic Publishing House (IAPH)
ISSN: 2455-4855 (Online)
www.iaph.in

Experimental Analysis of Surface Roughness Optimization of EN19 Alloy Steel Milling by the Cuckoo Search Algorithm

Shubham Jain[1] and Anil Mulewa[2]*

[1]Department of Mechanical Engineering, Maulana Azad National Institute of Technology Bhopal, Madhya Pradesh, India; [2]Faculty of Mechanical Engineering, Shri G. S. Institute of Technology and Science, Indore, Madhya Pradesh, India

E-mail/Orcid Id:

SJ, shubhamjainmanit01@gmail.com, https://orcid.org/0000-0003-1254-522X;
AM, anilmulewa89@gmail.com, https://orcid.org/0000-0002-0731-9458

Article History:

Received: 05th Nov., 2023
Accepted: 17th March, 2024
Published: 30th Apr., 2024

Keywords:

Cuckoo search algorithm, EN19 alloy steel, milling, optimization, surface roughness

How to cite this Article:
Shubham Jain and Anil Mulewa (2024). Experimental Analysis of Surface Roughness Optimization of EN19 Alloy Steel Milling by the Cuckoo Search Algorithm. *International Journal of Experimental Research and Review, 38*, 102-110.
DOI: https://doi.org/10.52756/ijerr.2024.v38.009

Abstract: In the present paper, end milling has been performed on EN19 alloy steel by selecting cutting speed, feed rate, & depth of cut as input parameters and surface roughness (SR) as a response. EN19 alloy steel milling is widely used in various sectors, such as the automotive, defence, construction, aerospace, and nuclear sectors. A parametric study of EN19 alloy steel is needed for better machining. The central composite design was used for designing the experiments & modeling the surface roughness as a response. A cuckoo search algorithm was applied to minimize the surface roughness. It was found that feed rate is the most important factor affecting surface roughness (SR). The Cuckoo Search Algorithm also reveals that a minimum SR 1.8576 micrometer has been achieved at a higher speed of 765 RPM, a lower feed rate of 55.9516 mm/min., & a lower depth of cut of 0.4846 mm. The experiment concludes that it is so that the optimum SR is exhibited at both lower feed rates & high speeds. This, in turn, indicates that our implementation of CCD-based SR, followed by the real cuckoo search algorithm optimization, provides similar results and a good model to the practical results we would expect.

Introduction

The milling process is a high-material removal process. Due to its wide application in industries, it is essential to investigate the surface quality of the milled products. Surface roughness shows the quality of the machined products, & hence analysis of surface roughness is required (Mandal et al., 2022; Shashwath et al., 2023). There are different types of milling processes like High-speed milling (Das and Ghosh, 2023), High-speed milling with minimum quantity lubrication (MQL) & liquid N_2 (Wu et al., 2023), & chemical milling (Çakır, 2023) have been developed to cut the harder material with high material removal rate & good surface quality (Jain and Parashar, 2022).

The cuckoo search algorithm is a nature-inspired mathematical optimization algorithm. It can solve many real-life problems very easily due to inspiration from the cuckoo egg-laying phenomenon & requires no derivatives for calculation. Hence, using employability & exploitability features, it can easily solve many real-life complicated problems. In this research, the cuckoo search algorithm was used for parametric optimization of Surface Roughness by considering 3 process parameters speed, feed & depth of cut as input process parameters.

Mali & Chakraborty modified the cuckoo search algorithm by using Mcculloch's approach & Luus-Jaakola's heuristic approach in a balanced manner to enhance its exploring capability (Chakraborty and Mali, 2024). Zhao et al. (2023) performed a direct energy deposition arc hybrid method with interpass milling on 304 Stainless Steel. They found that its surface quality, microhardness, tensile strength & elongation improved

*Corresponding Author: anilmulewa89@gmail.com

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License.

when compared with additive manufacturing alone (Zhao et al., 2023). Muanpaopong et al. (2023) compared the fine milling for breaking the cement clinker into very fine particles using steel balls & Al balls. They concluded that steel balls achieve faster breakage of cement clinker than the Al balls. It has also been found that if slower breakage of cement clinker is allowed, then Al balls will be the greatest replacement for steel balls for significant energy saving (Muanpaopong et al., 2023). Amit Kumar et al. (2023) investigated the cryogenic treatment on the performance of cutting insert while milling En 24 steel. They found that this treatment improves the surface roughness of the workpiece specimen, reduces flank wear of the tool, & improves microhardness (Kumar et al., 2023). Patel et al. investigated end milling on AISI D2 tool steel using an AlCrN-coated tool considering 4 input process parameters cutting speed, feed, width of cut, & depth of cut. Cutting force was selected as a response & the verification experiments validated the developed model that predicts cutting force (Patel et al., 2023). Jackson et al. (2023) investigated about clean production by using a coated mill tool during dry milling machining. They concluded that coated tools have a longer tool life in dry conditions than uncoated tools (Jackson et al., 2023).

Gaurav Mohanty et al. (2018) studied EDM machining on En24 alloy steel, while DOE was used to optimize the process parameters (Mohanty et al., 2018). Abhishek Tiwari et al. have investigated ECM machining on En19 tool steel using the Taguchi method. ANOVA obtained a significant factor for overcutting (Tiwari et al., 2015). Dr. Vijay Kumar M (2018) performed CNC turning on En19 steel and responses (MRR and SR) are modeled by the L18 Taguchi orthogonal array (Kumar et al., 2018). Selvarajan et al. (2018) used a pentagonal-shaped Cu electrode for EDM machining on En19 alloy steel. At the same time, responses (Material Removal Rate, Wear Ratio, machining time, and Tool Wear Rate) were optimized by the Taguchi L9 orthogonal array (Selvarajan et al., 2018). Tilak and Nagarju used Taguchi L9 orthogonal array to optimize CNC Milling on Aluminium alloy 1100. They have concluded that minimum SR is obtained at a speed of 4000 RPM, feed 600 mm/rev, and depth of cut 1.5 mm (Tilak & Nagaraju, 2018). V.S. Kaushik et al. have optimized temperature during end milling on Aluminium Al 7068 by RSM and Genetic Algorithm (Kaushik et al., 2018). Pillai et al. found that by applying Taguchi and ANOVA during end milling, tool path strategy is the most significant factor affecting SR and machining time (Unnikrishna Pillai et al., 2018). Gaikhe et al. investigated the best minimizing cutting force conditions in helical ball-end milling of Inconel 718. From GA, it is clear that a low feed rate, high cutting speed, and moderate depth of cut are the optimum conditions for the lowest cutting force (Gaikhe et al., 2018). Vardhan et al. (2018) carried out CNC milling on P20 steel by Taguchi L50 orthogonal array. They concluded that feed rate is an important factor for responses (SR and MRR) (Vishnu Vardhan et al., 2018). Tansukatanon et al. performed micro-milling on stainless steel to make microchannels. By fluctuating depth of cut and feed rate as process variables, its effect on responses like MRR, SR, Burr height, and channel dimension has been studied (Tansukatanon et al., 2019). Parashar et al. have investigated wire EDM parameters for SR of stainless-steel grade 304L using the L32 Taguchi standard Orthogonal array method (Parashar et al., 2010).

Methodology

Design of experiment (DoE) is a technique that is used in various fields like finding the interaction between process parameters (Pisani et al., 2022), finding the best combination of mixtures (Pratap Singh et al., 2023) & optimizing the process parameters for specific responses (Ng et al., 2022). It is done by using linear regression (Ermergen and Taylan, 2024), & analysis of variance (Chen et al., 2022) methods. Taguchi is also a type of systematic DoE approach (Sharma et al., 2022) that uses the orthogonal array method to find the optimal solutions for a given problem (Kumar et al., 2020).

In this investigation, two rectangular blocks of size 100mm×100mm×50mm with a density of 7.85 gm/cm^3 of En19 alloy steel have been used as a specimen. On each block, ten experiments were performed. Carbide was used as a tool material for end milling (figure 1). The surface roughness was measured by MITUTOYO SJ 210 SURFTEST 178. Due to having star points CCD predicts a more accurate & precise model for the responses & therefore used in this research for modeling the SR. In this work, three factors (speed, feed rate, doc) with 5 levels were taken for performing 20 experiments to analyze the response. Table 1 shows the coded value of the variable ($-\gamma$ and $+\gamma$ are the axial points, the factorial points are +1 and -1, and 0 is the center point. Whereas $\beta=2^{k/4}$, where k=number of factors) (Aslan, 2008). Design Expert has been used to fit the regression model and to analyze the SR. MATLAB has been used to minimize SR by a cuckoo search algorithm. The actual process parameters are defined in Table 2. An experimental chart for the SR as a response is presented in Table 3.

Surface roughness optimization is required because SR affects the quality, life, & cost of the product. A minimum SR is required to improve the product's surface quality. While EN19 steel has wide applications in gears, pinion, shafts, spindles, oil & gas industries, automobile aircraft, & transport industries, where its surface quality plays a major role. Therefore, this research used the cuckoo search algorithm for SR optimization of EN19 alloy steel after milling.

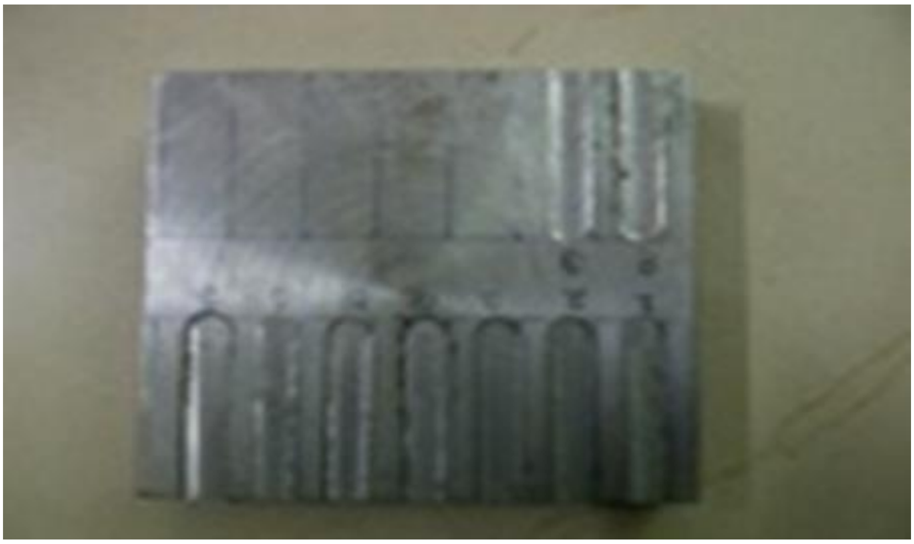

Figure 1. En 19 Alloy specimen.

Table 1. Coded value of variable

Coded Level	Actual Parameter Value
-γ	W_{min}
-1	$[(W_{max} + W_{min})/2] – [(W_{max} – W_{min})/2\beta]$
0	$[(W_{max} + W_{min})/2]$
+1	$[(W_{max} + W_{min})/2] + [(W_{max} – W_{min})/2\beta]$
+γ	W_{max}

Table 2. Actual value of variable

Variables	Symbol	levels of coded Variables				
		Lowest	Low	Centre	High	Highest
		-γ	-1	0	+1	+γ
Speed (rpm)	W_1	137	264	451	637	765
Feed (mm/min)	W_2	20	40	70	100	120
doc (mm)	W_3	0.2	0.3	0.5	0.7	0.8

Cuckoo search algorithm

Cuckoos are birds known for their excellent sounds and power generation system. The cuckoo lays eggs in typical nests. Many bird varieties parasitize by putting their eggs in the nests of other birds. A few host birds may scuffle directly with the cuckoo. Assuming that a host bird knows that the egg is not its own, it will either remove the extraneous eggs or leave them in the nest and assemble them somewhere else. Tapera is a female cuckoo that is exceptionally skilled at regular copulation. This reduces the chances of their eggs being ruined. Apart from this, the condition of egg-laying in some classes is also shocking. The cuckoo routinely chooses a nest where the host bird only lays its eggs. It is a fact that cuckoo eggs incubate somewhat faster than host eggs. When the main cuckoo chick emerges from the egg, the primary move is to expel the host egg, which forms the cuckoo chick's portion of the food provided by its host bird. A cuckoo chick may also imitate the calls of host chicks to gain additional care opportunities (Yang & Deb, 2010). The pseudocode of the cuckoo search algorithm is presented in Table 6.

Results and discussion

The fitted statistics of the SR are presented in Table 4. The R-squared value is 0.9591, which is very close to 1, therefore showing good fitness of the regression model. A "pred r-square" of 0.8162 is in proper bond with an "adj R-square" of 0.9223. "Adeq Precision" scales the signal-to-noise ratio. A fraction of more than four is wanted. A fraction of 19.444 shows a sufficient signal. This model can be practiced to handle the design space.

ANOVA for SR is shown in Table 5. From ANOVA, it is clear that the quadratic model is best close-fitting for

SR with an F-value of 26.07. It has also been obtained that feed rate is the most critical factor for SR with a p-value less than 0.0001. The lack of fit has a p-value of more than 0.05, which is 0.5189, indicating an insignificant lack of fit (i.e., showing good fit).

Figure 2 shows Normal plots of Residual for SR. It offers a fitted straight line, indicating the regression model's good fitness for SR. Figure 3 displays the Residual vs. Predicted plot for SR. From this, it is clear that all residuals are not crossing outliers (i.e., within the .

Table 3. Experimental chart for SR

	Parameter1	Parameter 2	Parameter 3	Response
S. No.	A : Speed	B : Feed Rate	C : Depth of Cut	SR
	(RPM)	(mm/min)	(mm)	(micrometre)
1	264.00	40.00	0.30	2.77
2	637.00	40.00	0.30	2.28
3	264.00	100.00	0.30	3.6
4	637.00	100.00	0.30	2.99
5	264.00	40.00	0.70	2.46
6	637.00	40.00	0.70	2.27
7	264.00	100.00	0.70	3.61
8	637.00	100.00	0.70	3.01
9	137.00	70.00	0.50	2.99
10	765.00	70.00	0.50	1.95
11	451.00	20.00	0.50	2.63
12	451.00	120.00	0.50	4.33
13	451.00	70.00	0.20	2.85
14	451.00	70.00	0.80	2.9
15	451.00	70.00	0.50	2.48
16	451.00	70.00	0.50	2.23
17	451.00	70.00	0.50	2.53
18	451.00	70.00	0.50	2.19
19	451.00	70.00	0.50	2.51
20	451.00	70.00	0.50	2.21

Table 4. FIT statics for SR

Adequate Precision	19.444	**Coefficient of Variance**	5.91
Mean	2.74	**Adjusted R-Squared**	0.9223
Predicted R-Squared	0.8162	**PRESS**	1.18
R-Squared	0.9591	**Standard Deviation**	0.16

Table 5.Analysis of SR by ANOVA

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	
Model	6.15	9	0.68	26.07	< 0.0001	Significant
A	0.97	1	0.97	36.94	0.0001	
B	2.89	1	2.89	110.27	< 0.0001	
C	3.669E-003	1	3.669E-003	0.14	0.7162	
A^2	8.123E-004	1	8.123E-004	0.031	0.8638	
B^2	1.94	1	1.94	73.92	< 0.0001	
C^2	0.33	1	0.33	12.75	0.0051	
AB	0.035	1	0.035	1.33	0.2748	
AC	0.012	1	0.012	0.46	0.5134	
BC	0.015	1	0.015	0.58	0.4625	
Residual	0.260	10	0.026			
Lack of Fit	0.130	5	0.026	0.96	0.5189	Not Significant
Pure Error	0.130	5	0.027			
Cor Total	6.42	19				

agreement). Figure 4 shows the Residual vs. Run plot for SR. It reveals that there is no specific pattern, hence indicating the model is of excellent fitness. Figure 5 shows the perturbation plot for SR. It shows that at higher speeds and lower feed rates, SR is minimal. In contrast, the depth of cut has a very negligible effect on SR.

Figures 6,7 & 8 are 3D plots for SR. From these plots, it is pretty clear that SR reduces by increasing speed and reducing feed rate. At the same time, the doc has no significant effect on SR. Regression equation for surface roughness in terms of process parameters is shown in Equation (1).

Table 6. Pseudocode of cuckoo search algorithm.

Cuckoo Search Algorithm
Start
Define Input Parameters like number of nests(population), Discovery alien probability (pa),
number of iterations, limits of lower bound (lb) and upper bound (ub);
Randomly generate the position of all nests within the lb and ub;
Evaluate the fitness of each nest;
Find the current best nest;
For i = 1: Maximum number of iterations
Generate new nests by Levy Flight;
Evaluate the fitness of each new nest;
Update the current best nest;
Worst nests discovered by pa (among nest and new nest);
New nests generated by random walk;
Evaluate the fitness of each new nest;
Update the current best nest;
End
Best nest and its fitness found;
End

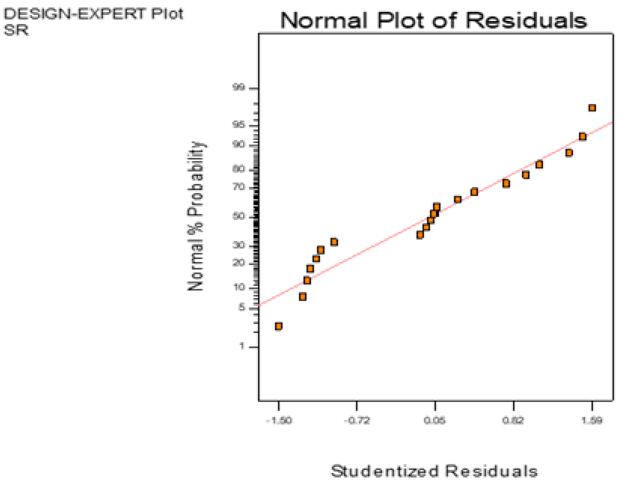

Figure 2. Normal graph of residual for SR.

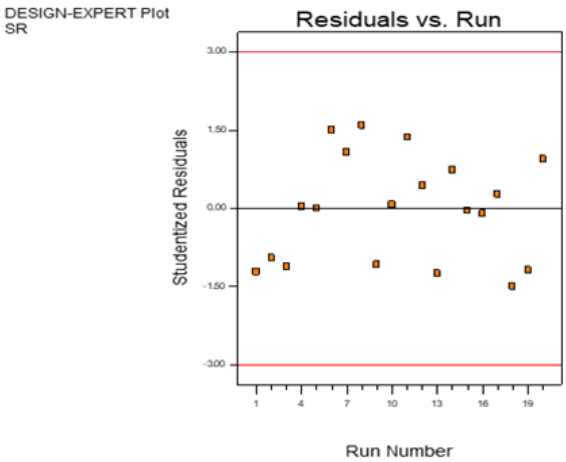

Figure 4. Residual vs. Run graph for SR.

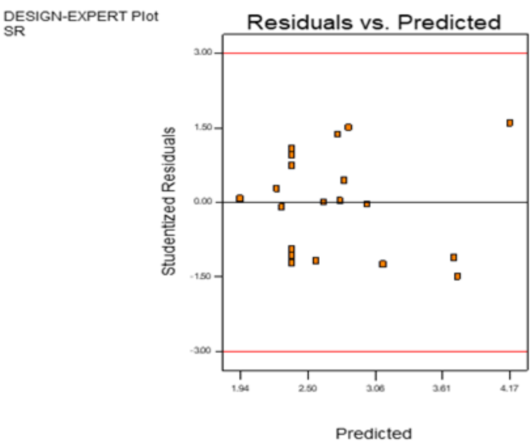

Figure 3. Residual vs. Predicted graph for SR.

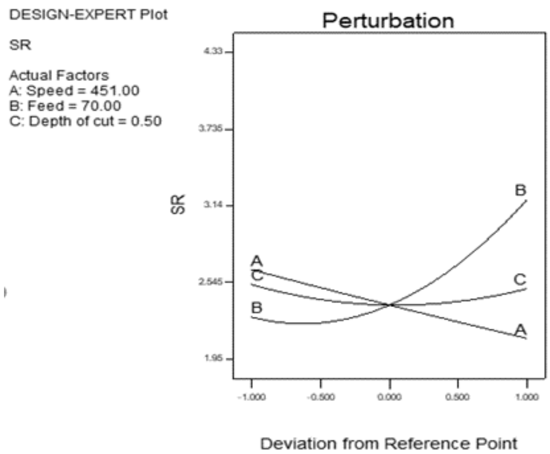

Figure 5. Perturbation graph for SR.

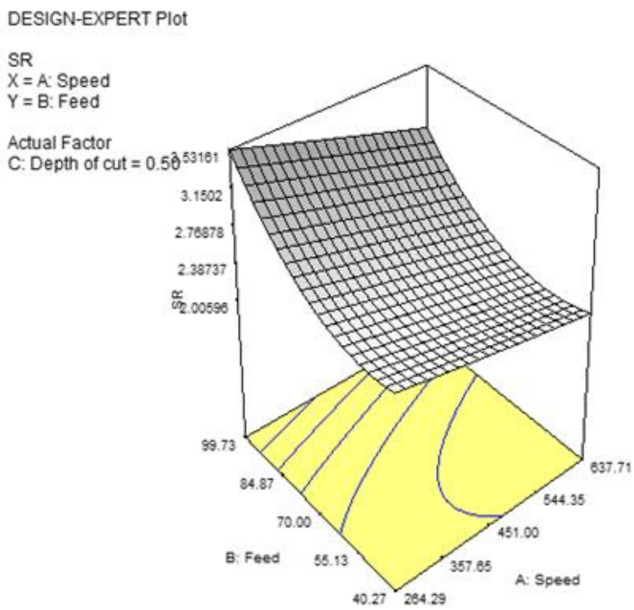

Figure 6. 3D curve of Speed vs. Feed vs. SR.

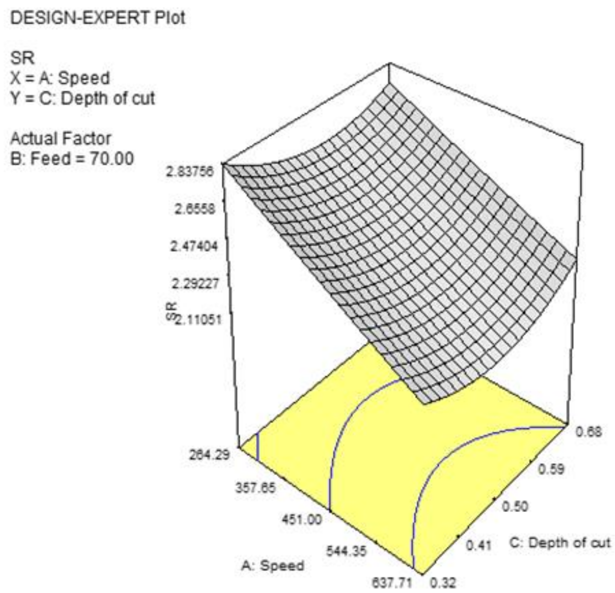

Figure 7. 3D curve of Speed vs. doc vs. SR.

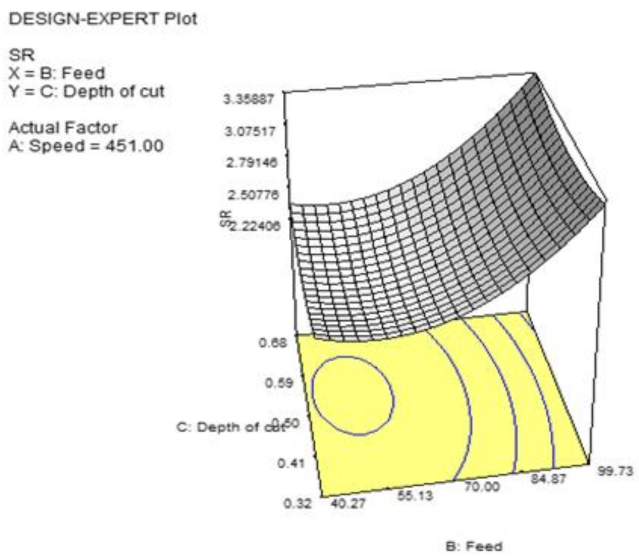

Figure 8. 3D curve of Feed vs. doc vs. SR.

$$SR = +5.28509 - 1.31355E\text{-}003 * Speed - 0.040582 * Feed - 5.57608 * Depth\ of\ cut + 2.14582\ E\text{-}007 * Speed^2 + 4.11911E\text{-}004 * Feed^2 + 4.51085 * Depth\ of\ cut^2 - 1.18249E\text{-}005 * Speed * Feed + 1.04024E\text{-}003 * Speed * Depth\ of\ cut + 7.29167E\text{-}003 * Feed * Depth\ of\ cut. \quad (1)$$

This research achieves minimum SR by a cuckoo search algorithm with tuning parameters in Table 7. Cuckoo Search Algorithm results for minimum SR are shown in Table 8. These optimization results also verify the results of Response Surface Methodology. Minimum SR of 1.8576 micrometers was achieved at a higher cutting speed (765 RPM) and relatively lower feed rate (55.9516 mm/min). Figure 9 shows the convergence curve for SR. From this convergence plot, it is pretty clear that the Cuckoo search algorithm obtained minimum SR very quickly.

Table 7. Cuckoo search algorithm setting parameters value.

Cuckoo Search Algorithm Setting Parameters	Value
Number of Nests	20
Levy exponent	3/2
Probability of alien eggs	0.25
Maximum Iterations	1000
Random number	Between 0 to 1

Table 8. Cuckoo search algorithm optimization results.

Type of Optimization Process	Optimized Parameters	Optimization Result
Cuckoo Search Optimization Algorithm	Speed 765 RPM Feed 55.9516 mm/min doc 0.4846 mm	Surface Roughness = 1.8576 micrometer

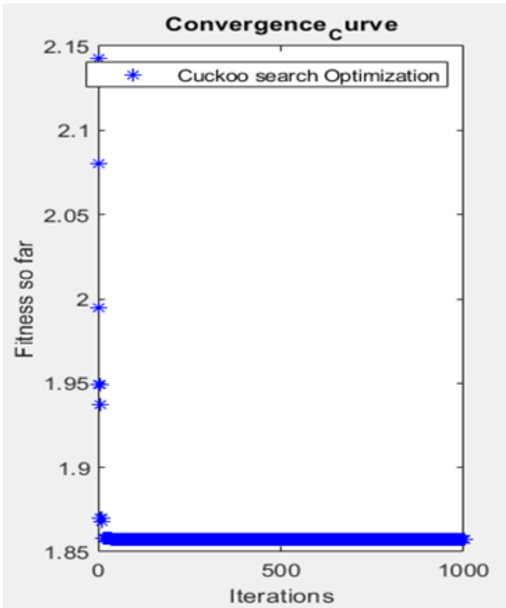

Figure 9. Convergence Curve for SR.

DOI: https://doi.org/10.52756/ijerr.2024.v38.009

Conclusion

A parametric analysis of end milling on EN19 alloy steel by Central Composite Design (an RSM technique) and by the cuckoo search algorithm is shown in this paper. The CCD approach was used to model the SR in terms of speed, feed rate and depth of cut. It was found that minimum SR was achieved at a lower feed rate. Meanwhile, feed rate is also the most significant factor affecting SR. Cuckoo search algorithm results also verify the results obtained by DoE methods. For practical implication, when we compare cuckoo search algorithm results with experimental results, it is found that minimum SR is achieved at high speed & lower feed rate. It implies that our model for SR by CCD & its optimization by the cuckoo search algorithm is quite good & has good agreement with practical results.

- By CCD, SR has been formulated in a quadratic model.
- From the Perturbation plot and 3D plot, it is clear that minimum SR is obtained at a higher speed & lower feed rate, while the depth of cut has no significant effect on SR.
- The Cuckoo Search Algorithm also reveals the same results as RSM. Minimum SR 1.8576 micrometer achieved at 765 RPM, 55.9516 mm/min., 0.4846 mm.
- By considering more process parameters and responses and applying a multi-objective optimization approach, En19 alloy steel milling can be more understood.

Conflict of Interest

The authors declare no conflict of interest.

References

Aslan, N. (2008). Application of response surface methodology and central composite rotatable design for modeling and optimization of a multi-gravity separator for chromite concentration. *Powder Technology*, *185*(1), 80–86. https://doi.org/10.1016/j.powtec.2007.10.002

Çakır, O. (2023). Effects of etchant concentration and process temperature in chemical milling of 430 stainless steel with FeCl3. *Materials Today: Proceedings*. https://doi.org/https://doi.org/10.1016/j.matpr.2023.07.165

Chakraborty, S., & Mali, K. (2024). A balanced hybrid cuckoo search algorithm for microscopic image segmentation. *Soft Comput*, *28*, 5097–5124. https://doi.org/10.1007/s00500-023-09186-6

Chen, W.H., Carrera Uribe, M., Kwon, E. E., Lin, K.Y. A., Park, Y.K., Ding, L., & Saw, L. H. (2022). A comprehensive review of thermoelectric generation optimization by statistical approach: Taguchi method, analysis of variance (ANOVA), and response surface methodology (RSM). *Renewable and Sustainable Energy Reviews*, *169*, 112917. https://doi.org/https://doi.org/10.1016/j.rser.2022.112917

Das, C. R., & Ghosh, A. (2023). Performance of carbide end mills coated with new generation nano-composite TiAlSiN in machining of austenitic stainless steel under near-dry (MQL) and flood cooling conditions. *Journal of Manufacturing Processes*, *104*, 418–442. https://doi.org/https://doi.org/10.1016/j.jmapro.2023.09.020

Ermergen, T., & Taylan, F. (2024). Investigation of DOE model analyses for open atmosphere laser polishing of additively manufactured Ti-6Al-4V samples by using ANOVA. *Optics & Laser Technology*, *168*, 109832. https://doi.org/https://doi.org/10.1016/j.optlastec.2023.109832

Gaikhe, V., Sahu, J., & Pawade, R. (2018). Optimization of cutting parameters for cutting force minimization in helical ball end milling of inconel 718 by using genetic algorithm. *Procedia CIRP*, *77*(Hpc), 477–480. https://doi.org/10.1016/j.procir.2018.08.261

Jackson, M. J., Robinson, G. M., Whitt, M. D., da Silva, R. B., da Silva, M. B., & Machado, A. R. (2023). Achieving clean production with nanostructured coated milling tools dry machining low carbon steel. *Journal of Cleaner Production*, *422*, 138523. https://doi.org/https://doi.org/10.1016/j.jclepro.2023.138523

Jain, S., & Parashar, V. (2022). Analysis of high-speed CNC milling of Ti-6Al-4V by multi-objective crow optimisation and multi-objective PSO. *International Journal of Materials Engineering Innovation*, *13*(2), 128–156. https://doi.org/10.1504/IJMATEI.2022.124196

Kaushik, V. S., Subramanian, M., & Sakthivel, M. (2018). Optimization of Processes Parameters on Temperature Rise in CNC End Milling of Al 7068 using Hybrid Techniques. *Materials Today: Proceedings*, *5*(2), 7037–7046. https://doi.org/10.1016/j.matpr.2017.11.367

Kumar, A., Bala, N., Singh Dhami, S., & Kumar, S. (2023). Effects of cryogenic treatment on the performance of coated tungsten carbide inserts during milling of EN24 steel. *Materials Today:*

Proceedings. https://doi.org/https://doi.org/10.1016/j.matpr.2023.03.449

Kumar, M.V., Kumar, B.J., & N, R. (2018). Optimization of Machining Parameters in CNC Turning of Stainless Steel (EN19) By TAGUCHI'S Orthogonal Array Experiments. *Materials Today: Proceedings*, *5*, 11395–11407. https://doi.org/10.1016/j.matpr.2018.02.107

Kumar, T. B., Panda, A., Kumar Sharma, G., Johar, A. K., Kar, S. K., & Boolchandani, D. (2020). Taguchi DoE and ANOVA: A systematic perspective for performance optimization of cross-coupled channel length modulation OTA. *AEU - International Journal of Electronics and Communications*, *116*, 153070. https://doi.org/https://doi.org/10.1016/j.aeue.2020.153070

Mandal, P., Bala, S., Poddar, S., Sarkar, S., & Biswas, H. S. (2022). Fabrication of Graphene-Fe_3O_4-Polypyrrole based ternary material as an electrode for Pseudocapacitor application. *Materials Today: Proceedings*, *65*, 1001-1010. https://doi.org/10.1016/j.matpr.2022.04.103

Mohanty, G., Mondal, G., Surekha, B., & Tripathy, S. (2018). Experimental investigations on graphite mixed electric discharge machining of En-19 alloy steel. *Materials Today: Proceedings*, *5*(9), 19418–19423. https://doi.org/10.1016/j.matpr.2018.06.302

Muanpaopong, N., Davé, R., & Bilgili, E. (2023). A comparative analysis of steel and alumina balls in fine milling of cement clinker via PBM and DEM. *Powder Technology*, *421*, 118454. https://doi.org/https://doi.org/10.1016/j.powtec.2023.118454

Ng, N. Y. Z., Abdul Haq, R. H., Marwah, O. M. F., Ho, F. H., & Adzila, S. (2022). Optimization of polyvinyl alcohol (PVA) support parameters for fused deposition modelling (FDM) by using design of experiments (DOE). *Materials Today: Proceedings*, *57*, 1226–1234. https://doi.org/https://doi.org/10.1016/j.matpr.2021.11.046

Parashar, V., Rehman, A., Bhagoria, J. L., & Puri, D.Y. M. (2010). Statistical and regression analysis of Material Removal Rate for wire cut Electro Discharge Machining of SS 304L using design of experiments. *International Journal of Engineering Science and Technology*, *2*(5), 1021–1028.

Patel, R. D., Bhavsar, S. N., & Patel, A. K. (2023). Experimental investigation on cutting force during end milling of AISI D2 tool steel using AlCrN coated tool. *Materials Today: Proceedings*, *80*, 1397–1402. https://doi.org/https://doi.org/10.1016/j.matpr.2023.01.153

Pisani, S., Genta, I., Dorati, R., Modena, T., Chiesa, E., Bruni, G., Benazzo, M., & Conti, B. (2022). A Design of Experiment (DOE) approach to correlate PLA-PCL electrospun fibers diameter and mechanical properties for soft tissue regeneration purposes. *Journal of Drug Delivery Science and Technology*, *68*, 103060. https://doi.org/https://doi.org/10.1016/j.jddst.2021.103060

Pratap Singh, D., Kumar Dwivedi, V., & Agarwal, M. (2023). Application of the DoE approach to the fabrication of cast Al2O3-LM6 composite material and evaluation of its mechanical and microstructural properties. *Materials Today: Proceedings*. https://doi.org/https://doi.org/10.1016/j.matpr.2023.03.127

Selvarajan, L., Katherasan, D., Srivijai, B., Rajavel, R., & Ramamoorthi, M. (2018). Experimental Analysis of en 19 Alloy Material on EDM for Improving Geometrical Errors Using Copper Pentagon Shaped Electrode. *Materials Today: Proceedings*, *5*(2), 4508–4514. https://doi.org/10.1016/j.matpr.2017.12.020

Sharma, N., Kumar, S., & Singh, K. K. (2022). Taguchi's DOE and artificial neural network analysis for the prediction of tribological performance of graphene nano-platelets filled glass fiber reinforced epoxy composites under the dry sliding condition. *Tribology International*, *172*, 107580. https://doi.org/https://doi.org/10.1016/j.triboint.2022.107580

Shashwath, Sudhakar Rao, P., Prabhudev, M. S., Kohir, V., & Anjaiah, G. (2023). CNC milling of EN24 steel for assessment of the process parameters using OFAT technique: A preliminary investigation. *Materials Today: Proceedings*. https://doi.org/https://doi.org/10.1016/j.matpr.2023.05.465

Tansukatanon, S., Tangwarodomnukun, V., Dumkum, C., Kruytong, P., Plaichum, N., & Charee, W. (2019). Micromachining of stainless steel using TiAlN-coated tungsten carbide end mill. *Procedia Manufacturing*, *30*, 419–426. https://doi.org/10.1016/j.promfg.2019.02.058

Tilak, K. B. G., & Nagaraju, D. (2018). Investigation on Aluminium Alloy 1100 Using Taguchi Robust Design Methodology on CNC Milling. *Materials Today: Proceedings*, *5*(5), 12719–12724. https://doi.org/10.1016/j.matpr.2018.02.255

Tiwari, A., Mandal, A., & Kumar, K. (2015).

Optimization of Overcut in Electrochemical Machining for EN 19 Tool Steel Using Taguchi Approach. *Materials Today: Proceedings*, *2*(4–5), 2337–2345. https://doi.org/10.1016/j.matpr.2015.07.293

Unnikrishna Pillai, J., Sanghrajka, I., Shunmugavel, M., Muthuramalingam, T., Goldberg, M., & Littlefair, G. (2018). Optimisation of multiple response characteristics on end milling of aluminium alloy using Taguchi-Grey relational approach. *Measurement: Journal of the International Measurement Confederation*, *124*, 291–298. https://doi.org/10.1016/j.measurement.2018.04.052

Vardhan, V. M., Sankaraiah, G., & Yohan, M. (2018). Optimization of cutting Parameters and Prediction of Ra & MRR for machining of P20 Steel on CNC milling using Artificial Neural Networks. *Materials Today: Proceedings*, *5*(13), 27058–27064. https://doi.org/10.1016/j.matpr.2018.09.010

Wu, S., Liu, G., Zhang, W., Chen, W., & Wang, C. (2023). High-speed milling of hardened steel under minimal quantity lubrication with liquid nitrogen. *Journal of Manufacturing Processes*, *95*, 351–368. https://doi.org/https://doi.org/10.1016/j.jmapro.2023.04.013

Yang, X. S., & Deb, S. (2010). Engineering optimisation by cuckoo search. *International Journal of Mathematical Modelling and Numerical Optimisation*, *1*(4), 330–343. https://doi.org/10.1504/IJMMNO.2010.035430

Zhao, X., Li, Z., Yang, B., Sun, X., Sun, G., Wang, S., & Chen, C. (2023). Microstructure and mechanical properties of 304 stainless steel produced by interpass milling hybrid direct energy deposition-arc. *Journal of Materials Research and Technology*, *27*, 3744–3756. https://doi.org/https://doi.org/10.1016/j.jmrt.2023.10.137

How to cite this Article:

Shubham Jain and Anil Mulewa (2024). Experimental Analysis of Surface Roughness Optimization of EN19 Alloy Steel Milling by the Cuckoo Search Algorithm. *International Journal of Experimental Research and Review*, *38*, 102-110.

DOI : https://doi.org/10.52756/ijerr.2024.v38.009

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License.