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Research Paper

OPTIMIZATION OF MILLING PARAMETERS OF OHNS STEEL USING TiALN COATED CUTTER BY DESIGN OF EXPERIMENT TECHNIQUE

S Nizam Sadiq[1]*, T R Raguraman[1], D Thresh Kumar[1], R Rajasekaran[2] and T T M Kannan[2]

*Corresponding Author: S Nizam Sadiq, ✉ Nizamsadiq86@gmail.com

Recently Oil Hardened Non Shrinkable (OHNS) steel finding many applications in Manufacturing parts like Shaft, Gears and Tooling due to their excellent Mechanical properties. The continuous development of carbide milling cutter and its coating technology are great concern with manufacturing Environment. Titanium Aluminum Nitrite coating play an important role in milling cutter to produce better surface finish and tool life with minimum cost. In this Experimental investigation of face milling operation of OHNS steel plates with different process parameters like spindle speed, feed rate and depth of cut and to find optimal machining conditions of minimum surface roughness (Ra).The experiments are designed and conducted based on Taguchi's design of experiments using L9 orthogonal array and analyzed by ANOVA.

Keywords: Face milling, OHNS steel, Taguchi, DOE, ANOVA

INTRODUCTION

Mustafa Kurt and Eyup Bagci (2007) has studied and discussed an application of the Taguchi method for investigating the effects of cutting parameters on the surface finish and hole diameter accuracy values in the dry drilling of Al 2024 alloy. Akhyar and Che Haron (2008) discussed taguchi's robust design method is suitable to optimize the surface roughness milling Ti-6Al-4V ELI. Suresh *et al.* (2002) discussed about the use of highly automated machine tools in the industry. Yang *et al.* (2009) applied the design of experiments approach to optimize machining parameters of high purity graphite under dry machining in end milling. Ozcelik and Mahmud (2006) discussed about the importance of surface roughness for any machining operation. Zhang *et al.* (2007) used Taguchi design to optimize surface quality in a CNC face milling operation. El-Sonbaty *et al.* (2008) used artificial neural network and fractal geometry approach to Predict surface roughness profiles for milled surfaces. Che-Haron and Jawaid (2005) the

[1] Department of Mechanical Engineering, PTR College of Engg. & Tech., Madurai, India.

[2] Department of Mechanical Engg., Pavendar Bharathidasan Institute of Information Technology, Trichy, India.

effect of machining on surface integrity of titanium. Ginta Tl and Nurul Amin AKM *et al.* by using Response Surface Methodology the Tool Life is predicted in Titanium Alloy Ti-6Al-4V. Zhang *et al.* (2007) Using the Taguchi Design Method the Surface Roughness is Optimized. Palanisamy *et al.* (2008) using regression and ANN models the tool wear is predicted in end-milling operation. Nurul Amin *et al.* (2007) studied the Effectiveness of uncoated WC-Co and PCD inserts in end milling of titanium alloy. Azlan Mohd Zain *et al.* (2009) by using ANN Predicted the surface roughness in the end mill machining. Routara *et al.* (2009) by using RSM, the Roughness modeling and optimization in CNC end milling. Baek *et al.* (2001) by using RSM, Optimized the feed rate in a face milling operation. Henriques VAR and Campos PP *et al.* by using powder metallurgy, Prediction of Titanium Alloys for Advanced Aerospace Systems. There are relatively few researches relating to surface roughness in the field of high-speed milling of hardened steels, and studies on chip formation are scant. As is stated by Ghani *et al.* (2009) when high cutting speed, low feed rate and low depth of cut were adopted, good surface finish can be obtained in semi finish and finish machining hardened AISI H13 steel using TiN-coated carbide insert tools. The effects of cutting parameters on surface roughness in high-speed side milling of hardened die steels were investigated by Vivancos et al and mathematical models of surface roughness were established by means of the Design of Experiment (DOE) method. Ding *et al.* (2010) experimentally investigated the effects of cutting parameters on cutting forces and surface roughness in hard milling of AISI H13 steel with coated Carbide tools. Aslan (2005) studied face milling of AISI D3 steel at 62 HRC and found that the best cutting performance in terms of flank wear and surface finish was reached by polycrystalline cubic boron insert tools (cBN),which were capable of removing material volume of 65 cm 3 and generated a surface finish of Ra between 0.3 and 3 μm for a flank wear up to 300 μm and with one single insert ($z = 1$). Ceramic tools, made of aluminum oxide (Al_2O_3),were capable of removing less material volume (8 cm 3) and reaching a surface roughness Ra between 1.3 to 3 μm, for a flank wear up to 300 μm, but both tools caused a rapid deterioration of the workpiece surface in the final stage of tool life. Oshy *et al.* (2009) tested face milling of AISI D2 hardened steel at 58 HRC with a round cBN insert and found acceptable tool life (43 cm of removed material) together with excellent surface finish in the range of 0.1 to 0.2 μm in Ra. Braghini and Coelho tested a cBN insert ($z = 1$) to face mill AISI D6 hardened steel at 58 HRC, removing 15 cm 3 of material with 300 μm of tool wear. In this case, surface finish was between 0.2 and 0.3 μm in Ra. Conclusions of these two experimental works point out that tool life would need to be extended to make the process economically viable. Since the fact that cBN tools are still very expensive and are difficult to find with complex shapes for better finishing performance, it is proposed in our study the use of geometrically complex inserts made of PVD AlCrN coated tungsten carbide. summarizes the literature review and shows workpiece material, hardness, cutting tool material, process factors (cutting speed Vc, feed per tooth fz) and related responses (flank wear VB, surface roughness Ra, and dimensional variation ΔZ) used in previous

research and during the current study as well. A series of experiment have been carried out in Design of xperiments to investigate the influence of cutting parameters such as cutting speed, feed rate and depth of cut on surface roughness in face milling operation. Taguchi parameter design which provides a systematic procedure that can effectively and efficiently identify the optimum surface roughness in the process control of individual end milling machines. A series of experiment have been carried out in design of experiments to investigate the influence of cutting conditions such as cutting speed, feed rate per tooth, feed velocity on tool life, tool wear and surface finish in face milling operation. Investigated the machining parameters such as number of passes, depth of cut in each pass, spindle speed and feed rate to get better surface finish, dimensional accuracy and tool wear. A series of experiment have been carried out in Taguchi's parametric design in which signal to noise ratio and Pareto analysis of variance are employed to analyze the effect of milling parameters such as cutting speed, feed rate and depth of cut on surface roughness. Proposed a Grey-Taguchi parameter method to optimize the milling parameters to get better surface finish. There are relatively few researches releasing to surface roughness with using side and face milling cutter in hardened steel. Koshy *et al.* (2002) used Taguchi design of optimization to predict surface roughness CNC milling operation. El-Sonbaty et al used artificial neural networks and traced geometry approach to predict the surface roughness profile milling operations. Previous study provides much valuable information for under studying of surface roughness in milling process, very few researches were conducted to investigate surface roughness in hardened steel. All above researchers are done on experiments in milling optimization on Hardened steels only, so we conduct experiment on OHNS steel in Face milling process.

OHNS STEEL

OHNS steel refers to a variety of carbon and alloy steels that are particularly well-suited to be made into tools. Their suitability comes from their distinctive hardness, resistance to abrasion, their ability to hold a cutting edge, and/or their resistance to deformation at elevated temperatures (red-hardness). Generally used in a heat-treated state. Many high carbon tool steels are also more resistant to corrosion due to their higher ratios of elements such as vanadium and niobium. With a carbon content between 0.7% and 1.5%, tool steels are manufactured under carefully controlled conditions to produce the required quality. The manganese content is often kept low to minimize the possibility of cracking during water quenching. However, proper heat treating of these steels is important for adequate performance, and there are many suppliers who provide tooling blanks intended for oil quenching.

Table 1: Chemical Composition of OHNS Steel

C	Mn	Cr	W	V
0.95	1.15	0.5	0.5	0.2

Table 2: Mechanical Properties of OHNS Steel

Max. Stress	Yield Stress	Proof Stress	Elonga-tion	Impact Strength	Hard-ness value
950 N/mm^{-2}	465 N/mm^2	480 N/mm^2	10%	25j	288 Brinell

TAGUCHI DESIGN OF EXPERIMENTS

Taguchi method is a powerful tool in quality Optimization makes use of a special design of Othogonal Array (OA) to examine.

Number of experiments used to design the orthogonal array for 3 parameters and 3 levels of milling parameters

Minimum experiments = $[(L-1) \times p] + 1$

$= [(3-1) \times 3] + 1 = 7 \approx L9$

Table 3: Surface Rouhness of OHNS

Test No.	Spindle Speed (RPM)	Feed Rate (mm/rev)	Depth of Cut (mm)	Surface Roughness (mm)
1	600	0.08	0.4	0.670
2	600	0.05	0.8	0.650
3	600	0.03	1.2	0.790
4	1000	0.08	0.8	0.634
5	1000	0.05	1.2	0.646
6	1000	0.03	0.4	0.694
7	1500	0.08	1.2	0.726
8	1500	0.05	0.4	0.683
9	1500	0.03	0.8	0.980

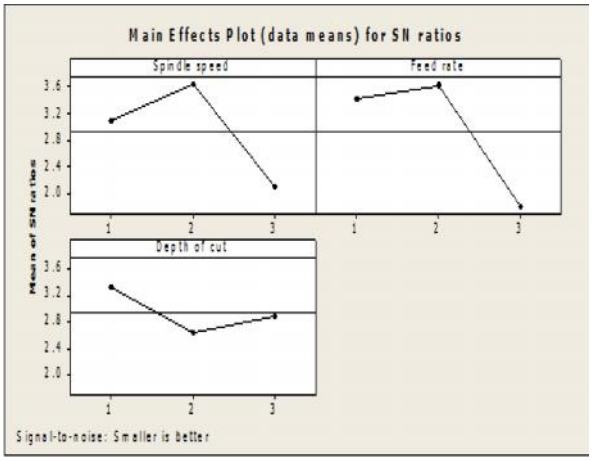
SURFACE ROUGHNESS 0F MILLING PARAMETERS

Response Table for Signal to Noise Ratios of surface roughness values (Smaller is better)

Table 4: S/N Ratio of Milling Parameters of Surface Roughness

Level	Spindle Speed	Feed Rate	Depth of Cut
1	3.089	3.406	3.321
2	3.642	3.616	2.625
3	2.089	1.799	2.875
Delta	1.553	1.818	0.696
Rank	2	1	3

Figure 1: S/N Ratio for Surface Roughness in Milling Parameters of OHNS



Analysis of Variance of Milling Parameters of OHNS Steel

Table 5: ANOVA for Surface Roughness

Source	DF	Seq. SS	Adj. SS	Adj. MS	F	P
Spindle Speed	2	0.029840	0.029840	0.014920	3.05	0.247
Feed Rate	2	0.047354	0.047354	0.023677	4.83	0.171
Depth of Cut	2	0.007858	0.007858	0.003929	0.80	0.555
Error	2	0.009796	0.009796	0.004898		
Total	**8**	**0.094848**				

Figure 2: Interaction Plot for Surface Roughness

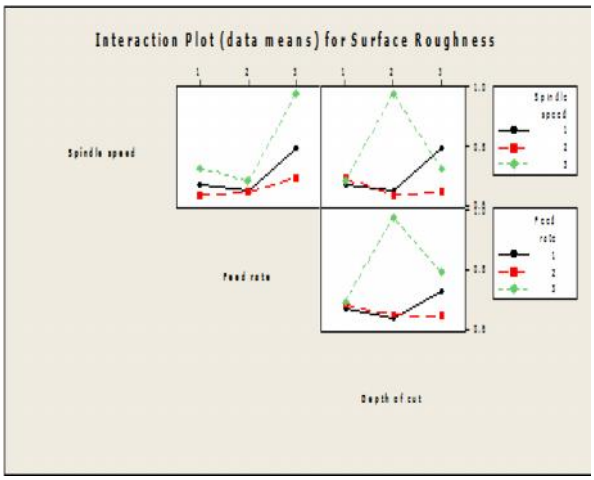


Figure 3: Contour Plot for Surface Roughness

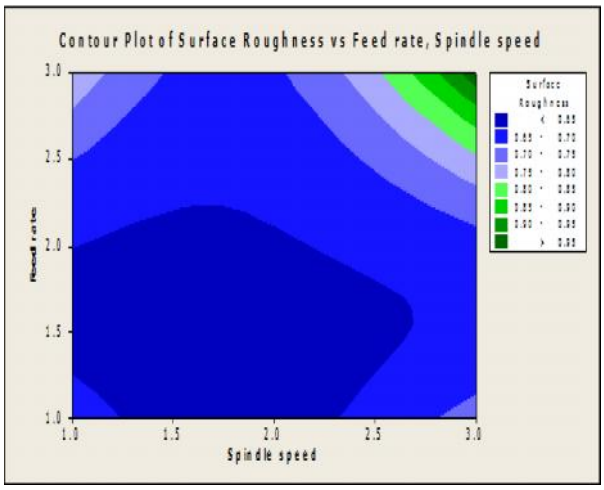
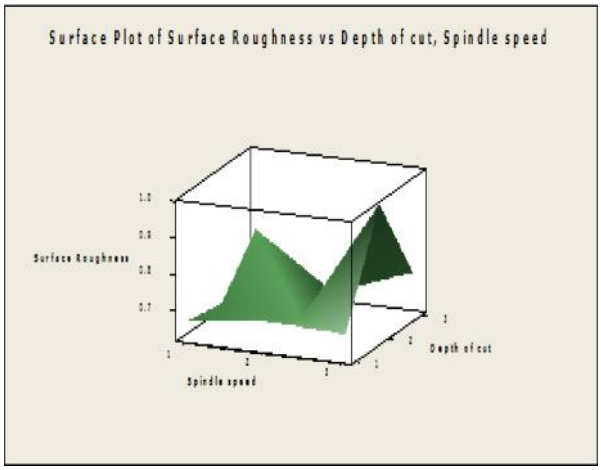


Figure 4: Surface Plot for Roughness Value of OHNS Steel



RESULTS AND DISCUSSION

Surface Roughness

After conducting the experiments of milling operation on OHNS steel Plates (50 x 50 x 16 mm) of surface roughness values are predicted and optimum parameters are found.

- Feed rate is a dominating parameter of milling process of OHNS steel plates.
- The optimum parameter of milling operation of OHNS steel plates were 1000 RPM of spindle speed, 0.08 mm of Feed and 0.8 mm Depth of cut.
- However OHNS Steel plate having good machinability characteristic and Produce reasonable surface finish.
- Obtained Good surface integrity and minimum wear occur during milling operation of OHNS steel plates.
- During milling processes all parameters are interact and dependant able the milling operation of OHNS steel plates.
- Response table indicate the Feed rate is a dominating parameter of milling process of OHNS steel and also mention Rank of surface roughness are Feed rate, Spindle speed and Depth of cut of milling process in the basisOf smaller the best concept.
- ANOVA table indicate the Bigger value of F test milling parameters and Feed rate is a dominating parameter of milling process of OHNS steel based on R square Value of 89.67%.
- The interaction plot indicate the dependant parameters of surface roughness of milling process of OHNS steel plates are spindle speed, feed rate and depth of cut and 3rd level parameters are independent in milling process.
- Control plot for milling parameters indicate the 2nd level of feed rate and 2nd level of spindle speed are the optimum parameters of milling process of OHNS steel plates.
- However the OHNS steel plates are probable for manufacturing tools and having good machinability property by using TiAlN coated milling cutter with optimum cutting parameters.

CONCLUSION

Feed rate is a dominating and influencing parameter and optimum milling process parameters for achieving lower surface roughness are 1000 rpm of spindle speed, 0.08 mm of feed rate and 0.8 mm depth of cut.

However the OHNS steel plates are probable for manufacturing tools and having good machinability property by using TiAlN coated milling cutter with optimum cutting parameters.

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