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Optimization of Cutting Parameters on turning of Incoloy 800H using Al_2O_3 Nanofluid in Coconut oil

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Abstract

Incoloy 800H is a nickel (Ni)-iron (Fe)-chromium (Cr) alloys with good strength at high-temperature exposure (810°C) and outstanding resistance to oxidation, carburization and other types of high-temperature corrosion. But, it is very difficult to turn and hence the present work is carried out and investigated. In this paper, the effect of cutting parameter and Al_2O_3 Nano-fluid suspension regarding varying concentration in coconut oil on the force, roughness and tool wear are studied. The CNC experiments are planned according to L_9 Taguchi design and turned using AlTiN coated carbide tool inserts. 3D factor effect plots, 1D plots, Analysis of variance (ANOVA) and response optimizer in desirability analysis are applied in the present study. From the empirical research, 0.25% Al_2O_3 Nano-fluid in coconut oil along with speed of 100 m/min and 0.14 mm/rev feed has proved the better machining performance to minimize the force, roughness and tool wear.

Keywords: turning responses; coated carbide inserts; nanofluid; coconut oil; optimization;

1. Introduction

Superalloy of nickel is found as many critical components in aero system applications. In fact, nearly it contributes half of the total weight of an aero engine because of its high rupture strength, creeps strength, corrosion,

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and oxidation resistance [1]. Among examples of nickel alloys, Incoloy 800H are used as one of the essential materials in a variable field especially in aerospace industries [2, 3]. Typical applications are heat-treating equipment in power and petrochemical plants, super-heater tubes in nuclear power plants. Also, it is found in baskets, fixtures, steam generator tubes and re-heater where the operational temperature generally ranges between 550°C-700°C [4-6]. But, conversion of nickel alloys into required components would need machining process. The turning research of Alloy 800H using various cryogenically-treated multilayer chemical vapor deposition (CVD) coated tool reveals good surface finish, decreases in micro-hardness and high material removal rate is achieved at more top cutting speed. The most affecting parameters is feed rate followed by speed and cutting depth [3, 5]. The effect of heat treatment on Incoloy 800H are investigated using the uncoated tool. Reported that lower cutting force, better surface finish and lower value of mechanical strength has observed under furnace cooled that of the air cooled condition and dry machining [4]. The degree of work hardening decreases with cryogenically treatment of −196 ◦C with 24hr CVD tool on turning of alloy 800H. With the application of TOPSIS, the optimal level of the combination are identified as 55m/min cutting speed 0.06 mm/rev feed rate and 1mm cutting depth [5]. Taguchi-based Grey relational analysis has improved the performance to approximately 48.98 % at 35 m/min, 0.06 mm/rev and 1 mm reported on turning of Alloy 800H using the uncoated tool. The formation of chip shape under-investigated parameters shows the large diameter of curl due to high friction on the tool/chip contact surface on turning of alloy 800H [6]. Use of Nano cutting fluids in MQL is of greater importance which can reduce the environmental hazards caused by conventional cutting fluids [7]. Results show that MWCNTs showed better performance than alumina (Al_2O_3) nanofluids due to enhanced lubricity at the tool/workpiece contact region while cutting of Inconel 718 [8]. Application copper (Cu) nanofluids under MQL flagged a way to reduce the tool wear by 36 and 24% surface roughness by 92 and 76% and lessened cutting temperature by 51% and 27% that of dry and oil lubrication in drilling on AA 5052 alloy [9]. The 0.5% nanofluids suspensions of molybdenum disulfide (MoS_2) in coconut show better machining performance when 40 m/min and 0.14mm/rev are applied on turning AISI 1040 steel [10]. Results also displays of about 40% and 16% lessening in cutting force over is flood and MQL using coated tool [11]. Based on the above facts, the study of nanofluids suspension in MQL leads to protect environment and cost. Also, there is no note of research in MQL on Inconel 800H. Therefore, the present work aims to examine the effect of machining parameters (cutting speed and feed rate) and % concentration nAl_2O_3 gamma cooling strategy on machinability characteristics using AlTiN coated carbide tool insert. Finally, the morphology of chip, tool wear mechanism and optimal level of cutting parameters is discussed.

2. Experimental details

The workpiece material is Incoloy 800H with 32mm diameter and 300 mm length. Table 1 shows the chemical composition of Incoloy 800H. The experiments are performed in a computerized numerical controlled (SimpleTurn5075-SPM) machine lathe with a capacity of 4000 rpm and power of 7.5 kW. The schematic diagram of the experimental setup and its research methodology adopted is presented in Figure 1. An ISO regarded as PCNRL2525 tool holder and CNMG120408-MP: KCU25 PVD (AlTiN) coated inserts are used. For parameter design, a standard L_9 orthogonal array are chosen and their three levels of factors are listed in Table 2. The Dinolite Edge 3.0 – 5MP digital microscope is used to measure the tool wear under a magnification of 200x. The surface roughness of the workpiece is measured using a stylus type surface roughness tester by Mahrsurf. The cutting force is recorded by a piezoelectric dynamometer (Kistler type 9257B). Finally, chip shape is examined using Dinolite Edge 3.0 – 5MP digital microscope to study the % concentration on alloy 800H. Ultrasonication was employed to mix the coconut oil with nanoparticles of nAl_2O_3.After proper analysis, 0.25%, 0.5% and 1% concentration by weight is fixed for Nanoparticles. Sonication process was carried out for one hr for preparation of a single Nanofluids. Stabilization time was obtained to be around 18 hrs. The experimental results are collected for a machining length of 30 mm at a constant cutting depth of 0.5 mm is listed in Table 2.

Table 1.The chemical composition of 800H.

Element	%Fe	%Ni	%Cr	%Mn	%C	%Cu	%Si	%S	%Al	%Ti	%P
Weight %	45.56	31.77	19.65	0.70	0.069	0.42	0.13	0.001	0.5	0.56	0.014

Table 2. Results of cutting trials.

Trial	Con. (%)	V (m/min)	F(mm/rev)	Fz (N)	Ra(μm)	Vba (μm)
1	0.25	40	0.14	219.0	0.5450	75.9
2	0.25	60	0.17	253.1	0.7650	91.0
3	0.25	100	0.20	237.9	1.0762	116.3
4	0.50	40	0.17	339.0	0.6037	447.5
5	0.50	60	0.20	450.7	0.6441	741.4
6	0.50	100	0.14	333.9	0.3183	928.2
7	1.00	40	0.20	474.8	1.9576	630.0
8	1.00	60	0.14	265.9	0.5176	238.0
9	1.00	100	0.17	197.0	0.6877	50.6

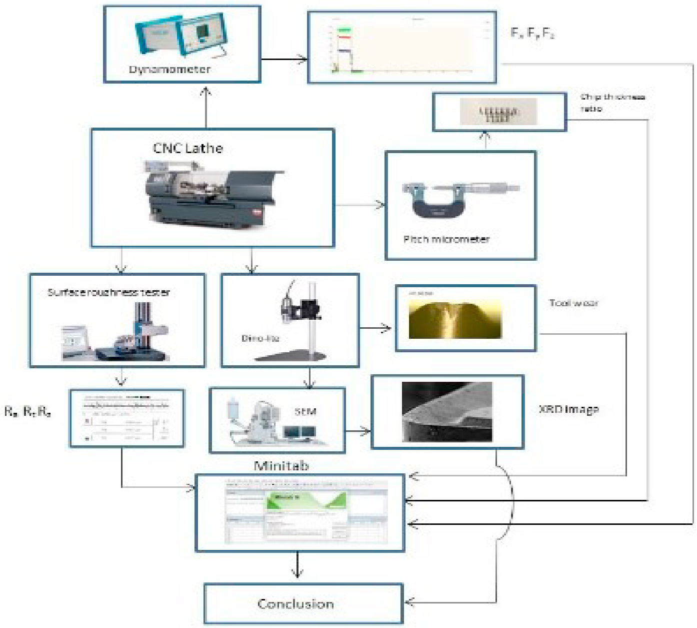

Fig. 1. Research methodology adopted for the present study.

3. Results and Discussion

3.1. 3D surface for cutting force

For all the levels of cutting velocity, from 3D plots of plot 1 at hold value of 0.17 mm/rev in Fig. 2, the increment in cutting force noticed as the % concentration is increased. Also, the higher value of force is obtained at low speed and high-level of % concentration that of low-level of % concentration and higher-level of cutting velocity. It is noticed from plot 2 at hold value of 60 m/min the magnitude of cutting force is increased with an increase in the % concentration and feed rate. From the surface plot of plot 3 at % concentration (0.5%), the generated cutting force magnitude is found to be increased significantly from 200N to 300 N with an increase in cutting velocity at a low-level feed rate of 0.14 mm/rev. The low-level of cutting velocity and higher feed rate resulted in higher cutting force (400N) that of higher-level of cutting speed and lower-level of feed rate (200N). From the main effect plots (Fig. 3), the magnitude of force is contributes to increasing of about 36% with an increment of 0.25% to 0.5% then declined to 16.5% with 1.00%. From feed rate plots, the value of force contributes to decrasing by 3% obtained from 0.14

mm/rev-0.17 mm/rev and increased by 32% while the feed rate at 0.17 and 0.2 mm/rev. The note from cutting speed reveals a decrement from 344 N to 323 N which contributes to only 6% during an increment of speed from 40 m/min to 60 m/min. The further increase in speed, it provides only 20 %. From the study of Taguchi Signal to Noise (S/N) ratio and Analysis of variance shown in Table 3, the % concentration (3.92, 35.86%) and feed rate (3.19, 36.18%) has a substantial effect on force with an error of 12.06% and R^2=87.94%.

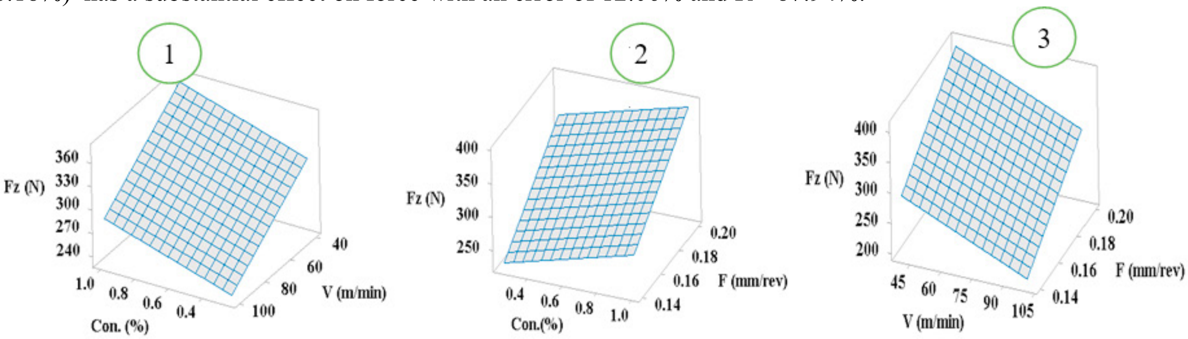

Fig. 2. Response plots for cutting force at 0.17 mm/rev (Plot 1), 70 m/min (Plot 2) and 0.5% concentration (Plot 3).

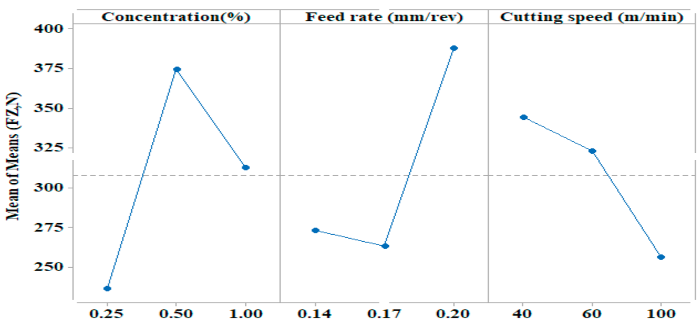

Fig. 3. Main effect plots for cutting force.

Table 3. Signal-to-Noise (S/N) and Variance (ANOVA) table for cutting force (Fz).

Response	S/N : Fz			ANOVA: Fz				
	Con. (%)	F (mm/rev)	V (m/min)	Source	DF	SS	F-Test	PCR (%)
Level 1	-47.47	-48.59	-50.31	Con. (%)	2	28608	2.97	35.86
Level 2	-51.38	-48.19	-49.88	F (mm/rev)	2	28859	3.00	36.18
Level 3	-49.30	-51.38	-47.96	V (m/min)	2	12671	1.32	15.08
Delta	3.92	3.19	2.35	Error	2	9622		12.06
Rank	1	2	3	Total	8	79760		R^2=87.94%

3.2. 3D surface for surface roughness

The roughness magnitude is to be increased as the concentration increased for all the cutting speed as shown in Plot 1 of Figure 4 at middle-level of feed rate. Also, the magnitude of surface roughness decreases (from 0.8µm to 0.4µm) at low-level of concentration that of high-level of concentration (from 1.0µm to 0.8µm) as the cutting velocity increased. The value of surface roughness is higher at higher-level of concentration and feed rate that of low-level of feed rate and % concentration in plot 2 in Figure 4 at middle-level of cutting speed. From the surface plot of plot 3, the obtained value of surface roughness is found to be an increased relationship with an increase in the feed rate for all level of % concentration in plot 3 in Figure 4 with middle-level of % concentration. From Figure 5, the magnitude is decreased from 0.80 µm to 0.50 µm with an increment of 0.25% to 0.5% and contributes to increasing of about 35%. Then increased to 50% further increment of 1.00%. From the plot of feed rate, it contributes to increasing by 32% obtained from 0.14 mm/rev-0.17 mm/rev that of 45% after 0.17 mm/rev. The note from cutting speed reveals a decrement increment from 1.03 µm to 0.652 µm which contributes to only 36% during the increment of speed from 40 m/min to 60 m/min. The further increase in speed, it provides only 7.2 %. From the study of Taguchi Signal to Noise (S/N) ratio and Analysis of variance in Table 4, the feed rate (7.86, 49.10%) has a substantial effect on surface roughness than percentage concentration (5.00, 22.74%) and cutting speed (2.93, 14.64%) along with an error of 12.89% and R^2=87.10%.

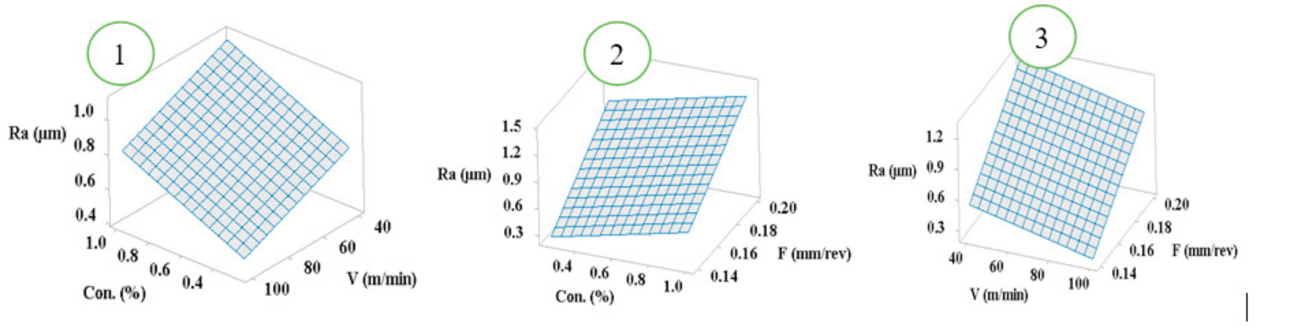

Fig. 4. Response plots for surface roughness at 0.17 mm/rev (Plot 1), 70 m/min (Plot 2) and 0.5% concentration (Plot 3).

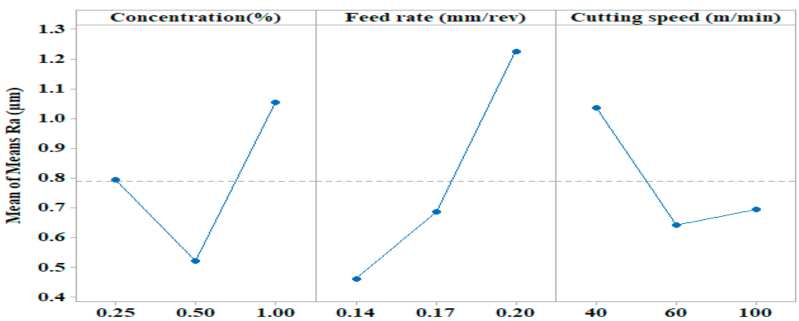

Fig. 5. Main effect plots for surface roughness.

Table 4. Signal-to-Noise (S/N) and Variance (ANOVA) for surface roughness (Ra).

Response	S/N : Ra			ANOVA: Ra				
	Con. (%)	F (mm/rev)	V (m/min)	Source	DF	SS	F-Test	PCR (%)
Level 1	2.320	6.978	1.273	Con. (%)	2	0.4251	1.76	22.74
Level 2	6.049	3.320	3.955	F (mm/rev)	2	0.9291	3.85	49.71
Level 3	1.0459	0.883	4.185	V (m/min)	2	0.2738	1.14	14.64
Delta	5.00	7.86	2.9	Error	2	0.2410		12.89
Rank	2	1	3	Total	8	1.8690		R^2=87.10%

3.3. 3D surface for flank wear

From Plot 1 in Figure 6, the magnitude of flank wear is higher at low speed and higher concentration that of higher cutting speed and low concentration. Also, the decrease in magnitude is observed for an increase of cutting speed for all concentration. From plot 2, a higher value of flank wear is observed at a higher feed rate and concentration that of low feed rate and low concentration. Additionally, the magnitude is increased for an increase of concentration for all level of feed rate. From Plot 3, the higher magnitude of flank wear is observed at a higher feed rate and low cutting speed. The lowest value is obtained at a higher speed with a low feed rate. For given concentration, increase cutting speed trend to decrease the magnitude while the increase in magnitude is obtained with the increase of feed rate. From Figure 7, the magnitude is increased from 100 µm to 700 µm with an increment of 0.25% to 0.5% and contributes to an increase of about 85%. Then declined to 56% with an increment of 1.00%. However, when compared to 0.25% the tool wear is increased to 67%. The observation made from the plot of feed rate the flank wear is increased by 69% while comparing the flank data obtained at 0.14 and 0.2 mm/rev the flank wear increased only 15%. The note from cutting speed reveals a straight line decrement from 384 µm to 356 µm which contributes to just 7.2%. From the study of Taguchi Signal to Noise (S/N) ratio and Analysis of variance in Table 5, the percentage concentration (17.2, 66.35%) have a substantial effect on flank wear than cutting speed along with an error of 18.68% and R^2=81.31%.

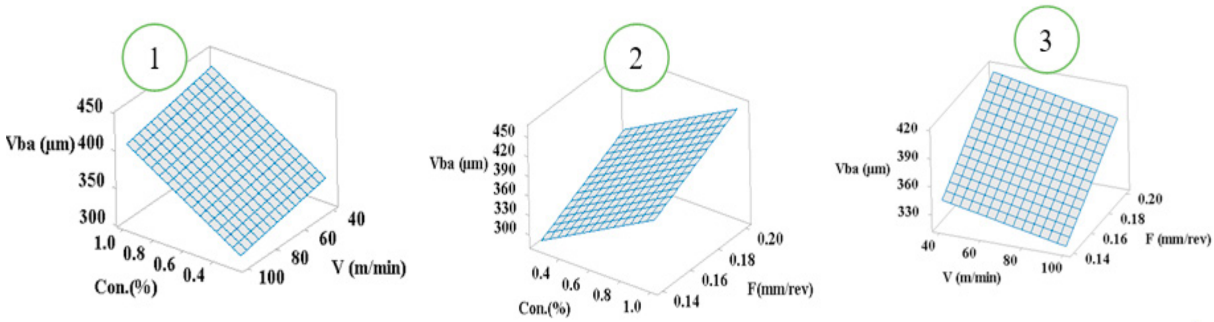

Fig. 6. Response plots for flank wear at 0.17 mm/rev (Plot 1), 70 m/min (Plot 2) and 0.5% concentration (Plot 3).

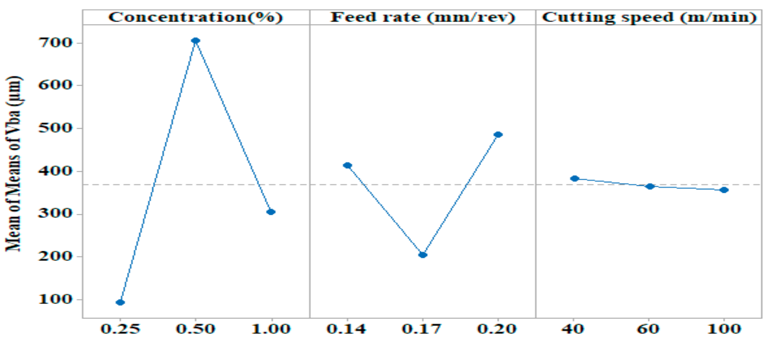

Fig. 7. Main effect plots for flank wear.

Table 5. Signal-to-Noise (S/N) and Variance (ANOVA) for tool wear (Vba).

Response	S/N : Vba			ANOVA: Vba				
	Con. (%)	F (mm/rev)	V (m/min)	Source	DF	SS	F-Test	PCR (%)
Level 1	-39.37	-48.16	-48.87	Con. (%)	2	578147	3.35	66.35
Level 2	-56.59	-42.80	-48.75	F (mm/rev)	2	129071	0.79	14.81
Level 3	-45.87	-50.89	-44.21	V (m/min)	2	1221	1.14	1.50
Delta	17.2	8.05	4.66	Error	2	162818		18.68
Rank	1	2	3	Total	8	871258		R^2=81.31%

3.4. Investigation on Tool wear modes, optimal search and chip morphology

Figure 8 shows the optical graph tool wear against the investigated cutting trials for varying percentage concentration. It is seen from Figure 8 (a) that abrasive wear as a result of frictional rubbing between the machined surface and flank face of the tool. Presence of hard abrasive particles in work material is responsible for such wear mechanism. From Figure 8(b) micro-chipping can be seen as a portion of the tool surface is completely removed, formation of built-up edge/adhesive wear and chip breakage are observed on the tool surface. The presence of the parallel groove is higher at 0.5% concentration that of 0.25% concentration. In Figure 8 (b) the formation of built-edge is higher compared to 0.25% and 1.00% concentration. This may be labeled as cyclic adhesion and workpiece material removal from the cutting insert. The broken tool particles are then carried away by the chips resulted in accelerating flank wear. From Figure 8(c) both 40 m/min and 60 m/min at 1.00% concentration resulted to higher flank wear due to ineffective lubricating ability and this increased cutting force and generated high temperature at the tool/workpiece interface. Thus adhesion appears on the tool flank face. At more top speed, the cutting temperature decreased due to the lubricating film thickness reduction.

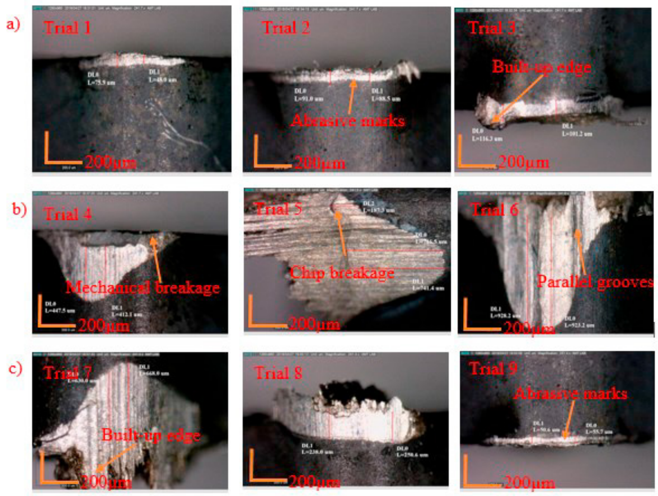

Fig. 8. Optical micrograph of tool wear image;

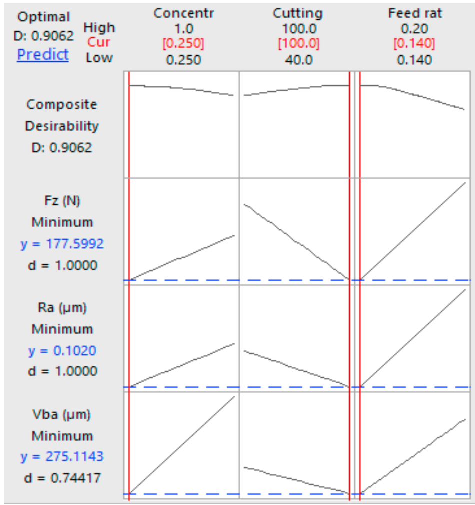

Fig. 9. Optimization Plot.

From the above analysis, the addition of 0.25% nAl_2O_3 in coconut oil lead to enhance the thermal conductivity and accordingly resulted in better performance of heat transfer rate, and offered less force and tool wear than 0.5% and 1.00%. On the other hand, 0.5% concentration provided better results in reducing the surface roughness that of different two-level added of nAl_2O_3 in coconut oil. Thus, a single response is required to justify the machining performance under nAl_2O_3 in coconut oil. From the optimized plot of Figure 9, it can be observed that the highest desirability (d) value is 0.9062, which gives us the optimal value of parameters to minimize the responses. The form of the chip is surveyed with a digital camera is shown in Figure 10. The chip shape under the investigated cutting parameters are short/long helical and ribbon chip is formed. Curled chips are produced with a different diameter due to high friction on the contact surfaces on turning of Alloy 800H. The curl diameter increased with the increment of % concentration as shown Figure 10 (a-c). In case of 1.00% concentration, the increase of curl diameter (Trial 9) due to due to the decrease in lubricity and increase tool friction. From this findings, the 0.25% concentration reduce the friction and could not break the film chip thickness.

4. Conclusions

Turning experiments are performed by the L_9 orthogonal array on Incoloy 880H using PVD (AlTiN) coated carbide insert. From 3D surface plots, main effect plots, and Taguchi Signal to Noise (S/N) ratio, the lowest force and tool wear with measurement force of 177N and 275µm at 0.25%,0.17 mm/rev and 100 m/min while lowest measurement surface roughness of 0.204µm at 0.5%, 0.14 mm/rev and 60 m/min. From the results of variance test (ANOVA), % concentration bags the maximum contribution factor (66.35%) compared to feed rate (49.10%) and cutting velocity (36.48%) in reducing the force, surface roughness and tool wear. Using desirability function approach, the optimum levels of settings at which the overall turning performance better are recognized as 0.25% along 100 m/min and 0.14 mm/rev. Abrasion, adhesion/built-up edge, chip crack and micro-chipping are found to be the dominant wear mechanisms on the tool flank face. The curled chips with a different diameter are produced due to high friction on the contact surfaces on turning of Alloy 800H. From this findings, the 0.25% concentration reduce the friction and could not break the film chip thickness.

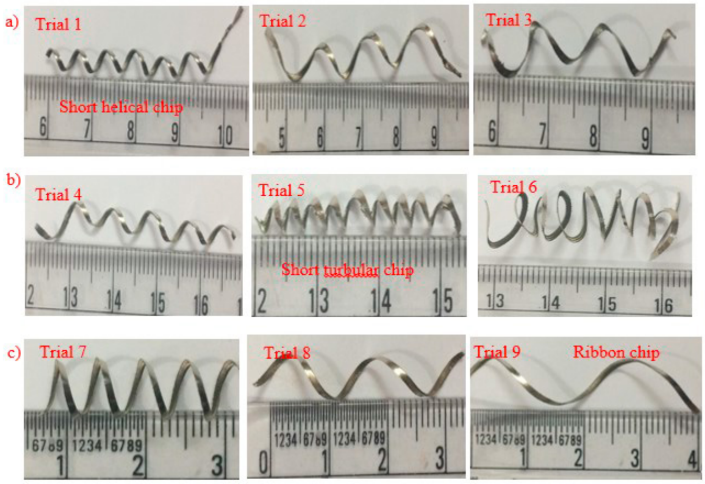

Fig. 10. Chip morphology under-investigated cutting parameters a) 0.25% b) 0.5% c) 1.00% concentration.

References

[1] K. Venkatesan, R. Ramanujam, P. Kuppan. Parametric modeling and optimization of laser scanning parameters during laser assisted machining of Inconel 718, Optics and Laser Technology 78 (2016) 10-18.

[2] Ren, Weiju, Robert Swindeman. Status of Alloy 800 H in considerations for the Gen IV nuclear energy systems. Journal of Pressure Vessel Technology 136.5 (2014) 054001.

[3] A. Palanisamy, T. Selvaraj. Optimization of Turning Parameters for Surface Integrity Properties On Incoloy 800H Superalloy Using Cryogenically Treated Multi-Layer CVD Coated Tool, Surface Review and Letters (2017) 1850139.

[4] A. Palanisamy, T. Selvaraj, S. Sivasankaran. Heat treatment effect on CNC turning of Incoloy 800H superalloy, Materials and Manufacturing Processes (2018): 1-8.

[5] A. Palanisamy, T. Selvaraj, S. Sivasankaran, Optimization of Turning Parameters of Machining Incoloy 800H Superalloy Using Cryogenically Treated Multilayer CVD-Coated Tool, Arabian Journal for Science and Engineering (2018) 1-14.

[6] Angappan, Palanisamy, Selvaraj Thangiah, Sivasankaran Subbarayan. Taguchi-based grey relational analysis for modeling and optimizing machining parameters through dry turning of Incoloy 800H, Journal of Mechanical Science and Technology 31(9) (2017) 4159-4165.

[7] Boswell, Brian, Mohammad Nazrul Islam, Ian J. Davies, Y. R. Ginting, Ai Keem Ong. A review identifying the effectiveness of minimum quantity lubrication (MQL) during conventional machining, The International Journal of Advanced Manufacturing Technology 92 (1-4) (2017) 321-340.

[8] H. Hegab, U. Umer, M. Soliman, and H. A. Kishawy, Effects of nano-cutting fluids on tool performance and chip morphology during machining Inconel 718, The International Journal of Advanced Manufacturing Technology, 96(9-12), (2018) 3449-3458.

[9] M. Naresh Babu, N. Muthukrishnan, Experimental analysis in drilling of AA 5052 using copper nanofluids under minimum quantity lubrication, Australian Journal of Mechanical Engineering (2018) 1-10.

[10] Rapeti, Padmini, Vamsi Krishna Pasam, Krishna Mohana Rao Gurram, Rukmini Srikant Revuru. Performance evaluation of vegetable oil based nano cutting fluids in machining using grey relational analysis-A step towards sustainable manufacturing. Journal of Cleaner Production 172 (2018) 2862-2875.

[11] A. Thakur, S. Gangopadhyay, Dry machining of nickel-based super alloy as a sustainable alternative using TiN/TiAlN coated tool. Journal of cleaner production 129 (2016) 256-268.