IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684, p-ISSN: 2320-334X
PP 17-23
www.iosrjournals.org

OPTIMIZING THE TURNING FACTORS: TURNING IN 718 WITH LN_2 AS A COOLANT

T. Arunkarthik[1] , Dr. M. Nataraj[2]
[1]*(Mechanical Engineering, SVS College of Engineering, Coimbatore, India)*
[2]*(Mechanical Engineering, Government College of Technology, Coimbatore, India)*

ABSTRACT : *Most of the manufacturing industries are using Turning Process as their main Machining Technique. Tool Wear is a foremost problem for all the manufacturers while machining INCONEL 718 (IN 718) which is a Nickel based alloy. It is one of the hardest materials which is used in high temperature, corrosive and reactive eras. IN 718 is subjected to turning process in all situation most of the time in industries. The present paper attempts to investigate the new cooling approach of using Liquid Nitrogen (LN_2) while turning IN 718. Predominant Turning Factors like Cutting Speed, Feed Rate, Depth of Cut, etc., are simultaneously optimized during the investigation. Taguchi Optimization Technique is selected as the optimization tool for the effective experimentation. The effective experimentation finally gave good results for the attempt.*

Keywords :*Turning, Coolant, Cryogenic Cooling, Optimization, Tool Tip Temperature, Cutting force, Cryo gun.*

I. INTRODUCTION

Machining is an indispensable method in which jobs are produced to the preferred proportions with better surface finish by steadily eliminating the surplus objects from the predefined blank in the form of chips with the aid of cutting tool moved over the job surface. High material removal rate (MRR) is being keep on trying by the machining industries without compromising the product quality. [4, 5] High cutting temperature (Tool tip temperature) is one of the most important problems to achieve the high MRR while machining. Cutting tool failure and deviation of the dimension may occur during such high temperature. Recent research is trying to reduce the temperature by the optimum cutting conditions, proper cutting fluid selection with proper experimentation. IN 718 is categorized as a difficult to cut material and it is a high – temperature resistant alloy (HTRA) used in the applications that include space station: nickel hydrogen batteries, aerospace: gas turbines, space exploration: space shuttle engine, and for the cryogenic tanks and chemical industries [1, 2]. Cutting operations are the material removal machining practices. While IN 718 is imperiled to machining introduction of the paper should explain the nature of the problem, previous work, purpose, and the contribution of the paper. The contents of each section may be provided to understand easily about the paper.

it owes high material and work hardness tendency which leads to high temperature across the heat affected region. The high temperature in the heat affected zone will not be exposed or conducted to the neutral end of the material while turning, because of the low thermal conductivity of IN 718 [13]. Integration of cutting force during machining of IN 718 and the high temperature at heat affected region stereotypically prime the tool life to be petite and puff out the poor surface quality of the machined parts. The class of the exterior-surface is typically significant of the parts like aerospace engines, gas turbines, etc., after machining. As an outcome, machining apparatuses made from nickel centered alloys are usually allied with low cutting speeds, efficiency and extraordinary machining costs [14].Makarow in his book “Tribology of Metal Cutting” proposed the metal cutting laws. Law one states that the highest machinability i.e. low wear rate etc., is attained at a certain cutting temperatures identified as the optimal cutting temperature [15]. Tool tip temperature is increased while turning IN 718 because the cutting zone near the cutting edge is heated due to less thermal conductivity of IN 718. Generally the temperature on the tool tip is governed by affording flood cooling by soluble ecofriendly lubricants. In high feed machining, non-conventional cutting fluid are provided hence, the conventional cutting fluid fails in this process [6-8]. Extremely pressurized additives are usually provided in the cutting fluid that does not ensure penetration of coolant at the chip and tool crossing point affording lubrication to the machining process and the cool the process [9]. High pressure jet of soluble oil reduces cutting temperature and improves tool life to some extent when it is applied to the tool-chip crossing point [10, 11].

Surface roughness is a measure of the tool wear, since the surface roughness of the material will be increased by the rate of tool wear this lucidly enumerate that the tool wear is the major cause of the surface roughness increase while machining [12]. IN 718 is anticipated to have some relief from the machining complications at the greater cutting speeds. Therefore to understand the material behavior at higher cutting speeds, an analytical model that predicts specific shearing energy of the work material in shear zone has been investigated [16].Machining features of IN 718 with the aid of combining ultrasonic vibration with high temperature abetted cutting investigation which has been designed for the experiments used to clarify the influence of a number of machining parameters on the machining characteristics. Turning factors such as cutting speed, feed rate, in work temperature and power are concerned the investigation. Further, the machining characteristics investigated with the inclusion of surface roughness and cutting force [17]. The current paper deals with the goal of the investigation is turning the IN 718 with liquid nitrogen (LN_2) as a coolant and optimize the process factors in order to validate the cooling approach with the help of taguchi optimization tool.

II. PRESENT WORK

The Strange cooling media LN2 is used to control the tool tip temperature in cut edge zone and special coated tools (Ti-AlN) are also used to turn IN 718 to avoid wear rate have to be used to overcome the difficult to machining problem. An attempt has been made in this paper work to bring optimum tool tip temperature and cutting force while machining Inconel 718 (IN 718) by way of optimizing machining variables through proper coolant selection. LN_2 is non-toxic, possess very low boiling temperature (-195.8ºC) and an eco-friendly liquid; so it has been selected as a coolant and used as cutting fluid to perform the turning operation on IN 718.Design of Experiment (DOE) approach was used to minimize experimentation and Taguchi L_{18} Orthogonal Array (OA) concept was used to find the optimum machining parameters. Control factors and its levels were fixed accordingly with L_{18} ($2^1 \times 3^7$) OA. The control factors considered are cutting speed (N, m/min), feed rate (f, m/rev), depth of cut (a_p, mm), tool nose radius (k, mm) and machining conditions (C_c, dry and wet) with LN_2 as a coolant. The influences of these control parameters on the responses such as tool tip temperature (T_t, °C), cutting force (F_x, N) of IN 718 after machining were investigated in this study. Simultaneous optimization technique was used for the interpretation results. To find the optimal condition of machining variables simultaneously, regression analysis was carried out. Cutting tool for three nose radius is used for this investigation the grade of the tool used is CNMG 120404 with Ti-AlN coating.

Ensuing components are used for this investigation.

[1] NAGMAT 175 Lathe Bharat Engineering
[2] Multichannel charged amplifier type 5070
[3] Kistler Piezo-Multicomponent Dynamometer Type 9253B23
[4] INCONEL 718 Nickel alloy
[5] MT 8 IR thermometer
[6] TR 100 Surface roughness Tester
[7] PMP009 Twin disc polisher
[8] HM 13 Micro hardness testing machine
[9] Cryogun (40 litre)- (*Courtesy Anna University, Chennai*)
[10] Air compressor
[11] Dynoware Software

III. RESULTS AND DISCUSSION

For the Taguchi Method parameter design, the basic method converts the objective parameter to the S/N ratio which is treated as the quality characteristics evaluation index. The least variation and the optimal design are obtained by means of the S/N ratio. The final step is to actually conduct the experiment to confirm whether or not the experiment is successful. The benefits of S/N ratio include increasing the factor weighting effect, decreasing mutual action, simultaneously processing the average and variation, and improving engineering quality. The higher the S/N ratio, the more stable the achievable quality. Depending on the required objective characteristics, different calculation methods can be applied as follows.

A. SN Ratio Calculation

The Smaller-the-Better (SB) where the objective optimal value is the smaller the better such as in cutting forces, Tool tip temperature and Surface roughness. Sum of squares (S_s), degrees of freedom (D_f), mean square (Ms), f value and p value are calculated. The f value decides the contribution of the particular factor on the total experiment. The control factor was expressed as the number called f value which is the deciding level of contribution than other factors. For example cutting force has the f value as 10, and then the cutting force is 10% contributing in the total response produced by the factors.The p value is less than F value, which is the probability number for denoting the significant and non-significant factor. In the table III the highlighted value denotes that the cutting factor F_x is significant for the responses.F value is deciding the significance of the factors accordingly to the responses. Correspondingly the important factors are pointed out in the trivial situation. From table III the nose radius performs the substantial role in the turning process. The noteworthy significance is recorded for the cutting condition also as shown in table III. The cutting condition's importance further validating the implementation of the new cooling approach. Further, the residual value is less said 3.01 hence it shows that the calculation part is quite worthy effort. It is clear that the legitimate flow of the experimentation is recorded at the time of experimentation. Cutting condition is mainly governed by the LN_2 in this investigation.Table IV authenticate that the cutting condition, that is the dry and wet mode of turning decides the temperature at the tool tip. It is because of the low thermal conductivity of the IN 718 material. Usually the steel material is having high thermal conductivity compared to other material. So, the temperature generated during the machining will distributed to the other end of the rod and dissipated to the exposed air. The ambient air temperature will made the heat produced into convection process and dissipated. The situation is different in the case of IN 718. It is having low thermal conductivity when compared to other materials. Since, the heat at the heat affected zone will not move to the other end of the material however the temperature will in progress to move back to the tool tip that is heat affected zone will be created on the tool. So, cutting condition afforded the very good cooling condition when compared to the other cooling method. This cooling condition is predicted by the taguchi tool further.

B. Interaction Plots

Interactions plots are used to visualize the interaction effect of two factors on the response and to compare the relative strength the effects. Minitab draws an interaction plot for two factors, or a matrix of plots for three or more factors. For each combination of process variables, Minitab plots the response mean and connects the points for the low and high levels of the factor plotted on the x-axis. Look at the lines connecting the levels to determine whether or not an interaction is present. You should only view the interaction effects plots for interactions that are significant according to the analysis to the analysis of variance table. An interaction is present when the change in the response mean from the low to the high level of a factor depends on the level of a second factor. If the lines are parallel, there is no interaction. The change in the response mean from the low to the high level of a factor does not depend on the level of a factor. If lines are not parallel to each other, there may be an interaction. The change in the response mean from the low to the high level of a factor depends on the level of a factor. The greater the degree of departure from being parallel, the stronger the effect. Make sure to determine whether interaction is significant.Interaction plot for the force parameter F_x is illustrated by the Fig. 1. The main interactions for the force are integrated as the lines and values for the response F_x in order to visualize. The main interactions of the process factors are computed and accumulated for the responses. Tool tip temperatures are shown in Fig. 2.

FIGURES AND TABLES

TABLE I
CUTTING PARAMETERS AND THEIR CHOSEN VALUES

Factor	Level 1	Level 2	Level 3
Cutting Speed(N) m/min	44	64	102
Feed Rate (f) mm/rev	0.5	0.1	0.15
Depth of cut (d) mm	0.5	1.0	1.5
Nose Radius (k) (mm)	0.4	0.8	1.2

TABLE II

EXPERIMENTATION AND MEASURED RESPONSES

Runs	N	f	d	C_c	k	T	F_x
1	44	0.050	0.5	dry	0.4	200	800.4
2	44	0.102	1.0	dry	0.8	55	8.569
3	44	0.159	1.5	dry	1.2	83	429.9
4	64	0.050	0.5	dry	0.8	52	64.99
5	64	0.102	1.0	dry	1.2	132	891.2
6	64	0.159	1.5	dry	0.4	65	67.1
7	102	0.050	1.0	dry	0.4	120	340.9
8	102	0.102	1.5	dry	0.8	78	59.23
9	102	0.159	0.5	dry	1.2	125	354.1
10	44	0.050	1.5	wet	1.2	130	82.7
11	44	0.102	0.5	wet	0.4	60	573.9
12	44	0.159	1.0	wet	0.8	105	128.9
13	64	0.050	1.0	wet	1.2	85	203.5
14	64	0.102	1.5	wet	0.4	130	126
15	64	0.159	0.5	wet	0.8	80	113.1
16	102	0.050	1.5	wet	0.8	79	58.43
17	102	0.102	0.5	wet	1.2	180	289
18	102	0.159	1.0	wet	0.4	105	48.29

TABLE III

SN RATIO FOR CUTTING FORCE F_X

Factor	S_s	D_f	M_s	F	P
(C_c)	10.13	1	10.13	9.53	0.021
(N)	244.09	2	122.04	0.93	0.3636
(f)	3.27	2	1.63	11.18	0.0048
(d)	612.61	2	306.31	0.15	0.8634
(k)	65.80	2	32.90	28.06	0.0002
Residual	87.34	8	10.92	3.01	0.1058
Total	1023.24	17			

TABLE IV
SN RATIO FOR CUTTING FORCE TOOL TIP TEMPERATURE

Factor	S_s	D_f	M_s	F	P
(Cc)	16.88	1	16.88	7.89	0.0229
(N)	9.64	2	4.82	2.25	0.1674
(f)	2.65	2	1.32	0.62	0.5626
(d)	13.36	2	6.68	3.12	0.0995
(k)	6.17	2	3.08	1.44	0.2919
Residual	17.11	8	2.14		
Total	65.81	17			

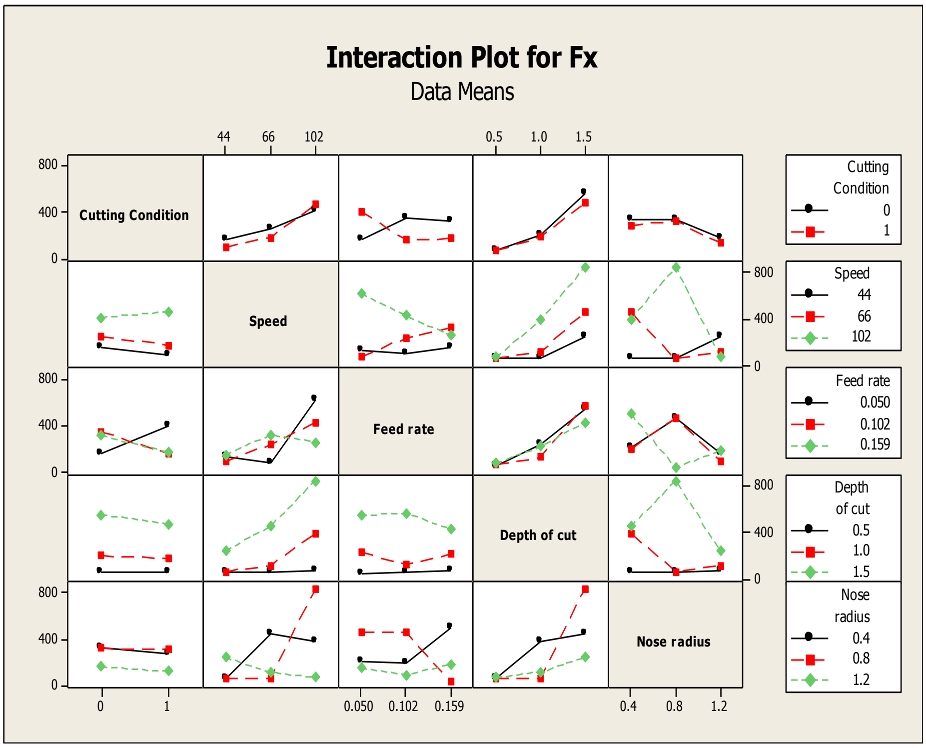

Fig. 1. Interaction plot for F_x for different turning parameters. The symbols shown in the right side of the figure. The corresponding line color and the symbol are distinguished the different interactions within the parameters and their manner of affection on the responses are expounded with aid of Fig. 1.

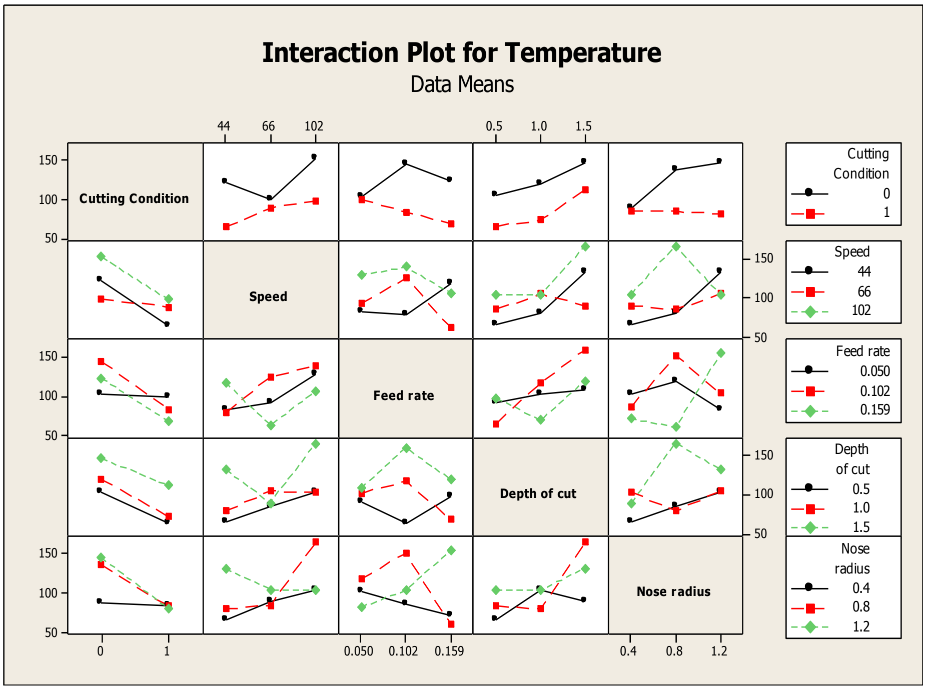

Fig. 2. Interaction plot for tool tip temperature at different turning parameters. The symbols shown in the right side of the figure. The corresponding line color and the symbol are distinguished the different interactions within the parameters and their manner of affection on the responses are expounded with aid of Fig. 2.

IV. CONCLUSION

This study revealed that the cutting speed is a vital factor in turning of INCONEL 718 that affects cutting forces and Tool tip temperature, under cryogenic cooling. Tool worn out occurred at higher depth of cut under wet machining, whereas this was the case not so in dry machining. Further tool wear study shall be done in future. Depth of cut has to be carefully selected. The optimum value of depth of cut was 0.5 mm feed rate value was 0.159 under this experimental condition.Confirmation test were also carried out to confirm the optimal solution with 97% of confidence level. The responses recorded were very close to the predicted optimum values. The F_x value is 13 N, and Tool tip temperature is 51.23 ºC.

REFERENCES

[1] Ezugwu, E., Bonney, J., and Yamane, Y., “An overview of the machinability of aeroengine alloys,” Journal of Materials Processing Technology, vol. 134, no. 2, pp. 233-253, 2003.

[2] Arunachalam, R. and Mannan, M. A., “Machinability of nickel-based high temperature alloys,” Machining Science and Technology, vol. 4, no. 1, pp. 127-168, 2000.

[3] Dhar, N. R., Paul, S. and Chattopadhyay, A. B., “The influence of cryogenic cooling on tool wear, dimensional accuracy and surface finish in turning AISI 1040 and E4340C steels,” Wear, vol. 249, no. 1, pp. 932-942, 2002.

[4] Leskovar, P. and Grum, J., “The metallurgical aspects of machining,” Ann. CIRP, vol. 35, no. 2, pp. 537-550. 1986.

[5] Tonshoff, H. K., and Brinkomeier, “Determination of the mechanical and thermal influences on machined surface by microhardness and residual stress analysis,” Ann. CIRP, vol. 29, no. 2, pp. 519-532, 1986.

[6] Shaw, M. C., Pigott, J. D., and Richardson, L.P., “Effect of cutting fluid upon chip–tool interface temperature,” Trans. ASME, vol. 71 no. 2 pp. 45–56, 1951.

[7] Merchant, M. E., “The physical chemistry of cutting fluid action,” Am. Chem. Soc., vol. 3, no. 4A, pp. 179–189, 1958Preprint.

[8] Paul, S., Dhar, N. R., and Chattopadhyay, A. B., “Beneficial effects of cryogenic cooling over dry and wet machining on tool wear and surface finish in turning AISI 1060 steel,” in International Conference on Advanced Manufacturing Technology, ICAMT-2000, Malaysia, 2000, pp. 209-214.
[9] Cassin, C., and Boothroyed, G., “Lubrication action of cutting fluids,” Journal of Mechanical Engineering and Science, vol. 7 no. 1, pp. 67–81, 1965.
[10] Mazurkiewicz, M., Kubala, Z., and Chow, J., “Metal machining with high pressure water-jet cooling assistance — a new possibility,” J. Eng. Ind., vol. 111 pp. 7–12, 1989.
[11] High Pressure cooling available at http://www.pe.chalmers.se/projects/cool/ advantages.html
[12] Sharman A., Dewes, R. C., and Aspinwall, D. K. “Tool life when high speed ball nose end milling INCONEL 718,” Journal of Materials processing technology, vol. 118 pp. 29-35, 2011).
[13] Dudzinski, D., “A review of developments towards dry and high speed machining of Inconel 718 alloy,” International Journal of Machine Tools and Manufacture, vol. 44, pp. 439-56, 2004.
[14] Leshock, C. E., and Kim J. N., “Plasma enhanced machining of Inconel 718: modeling of workpiece temperature with plasma heating and experimental results,” International Journal of Machine Tools and Manufacture, vol. 41 pp. 877-97, 2001.
[15] Astakhov, V. P., Tribology of Metal Cutting (Elsevier Science, Rochester Hills, Michigan. 2006).
[16] Pawade, R. S. Harshad, A., Sonawane, and Suhass. Joshi, “An analytical model to predict specific shear energy in high-speed turning of Inconel 718,” International Journal of Machine Tools & Manufacture, vol. 49 979–990, 2009.
[17] Hsua, C. Y., Linb, Y. Y., Leeb, W. S., and Lob, S. P., “Machining characteristics of Inconel 718 using ultrasonic and high temperature-aided cutting,” Journal of materials processing technology, vol. 198, pp. 359–365, 2008.