International Journal of Engineering Applied Sciences and Technology, 2016
Vol. 1, Issue 9, ISSN No. 2455-2143, Pages 149-155
Published Online July – August 2016 in IJEAST (http://www.ijeast.com)

OPTIMIZATION FOR DRY TURNING OF AISI 304 AUSTENITIC STAINLESS STEEL WITH PVD COATED CEMENTED CARBIDE TOOL

Sathe Amol Vaijinath
JNEC, Aurangabad
Maharashtra, INDIA

Prof. Khedekar Dilip S
Associate Professor
JNEC, Aurangabad, Maharashtra, INDIA

Abstract. Austenitic stainless steels are considered as difficult for turning materials, due to their high Strength and low thermal conductivity. The low thermal conductivity results in concentration of heat at the tool cutting edge. The current study focuses on dry lubrication assisted machining which is economically and ecologically desired. The aim of this paper is to study and optimize turning parameters in machining of AISI 304 stainless steel with Dry lubrication conditions. Turning tests have been performed in five different feed rates (0.5, 0.10, 0.15, 0.20, 0.25 mm/rev) and cutting speeds of (200, 220, 240, 260 and 280 m/min) without cutting fluid. The cutting tool used is the fine grained uncoated cemented carbide (Sandwick made) coated with TiAlN hard coating by PVD technique. A design of experiments (DOE) is done with Response Surface Methodology (RSM) to determine the effects of each parameter on the surface roughness, cutting temperature and chip thickness. The cutting speed and feed are the most significant factors influencing the surface roughness, as cutting speed increases, the surface roughness gets decreased and as the feed rate decreases surface roughness also gets decreased. Dry turning resulted in superior surface finish at higher speeds. Also increases in cutting speed and feed results in increased cutting temperature. In Dry machining mostly brittle chips are produced which shows the increased work hardening of the workpiece.

Keywords: High speed machining, AISI 304 austenitic stainless steel, TiAlN Coating, RSM, Dry lubrication, Surface roughness, cutting temperature, Chip thickness

I. INTRODUCTION

Machining is the widely used metal shaping process in which a single point cutting tool is used to serve the purpose. The material from the workpiece is removed in the form of chip, which slides along the tool face, known as tool rake face. This leads to the formation of shear stresses and high coefficient of friction during chip formation. Large amount of the mechanical energy used to form the chip and becomes heat, which generates high temperatures in the cutting zone and because of which the tool wears at a faster rate. Thus to get the better workpiece quality a good control of the heat generation during machining is required. Generally cutting fluids are applied in the cutting zone to solve the above problem. Cutting fluids acts as a lubricant and coolant and hence referred as 'lubrocoolant'. Cutting fluid flushes chips out of the cutting area. The use of cutting fluids in machining processes reduces the cutting zone temperature, by lubrication and reduction of friction wear or through a combination of both functions. The use of cutting fluids is restricted due to their harmful health and environmental effects. The use of cutting fluid has severely affected the environment and human health. Disposal of cutting fluid is a high concern for industries as it is difficult and causes water, soil and also air pollution due to vapors of cutting fluids. Metal working fluids add up to the manufacturing cost. National institute of occupational safety and health [NIOSH] indicated that 1.2 million workers are exposed to the hazards of cutting fluids across the world. It is evident that workers are facing severe chronic, respiratory and skin problems. These diseases include chronic bronchitis, asthma, chest symptoms, airway irritation and skin problems. Knowing these negative aspect of cutting fluids there use should be minimized. Increasing productivity and reducing manufacturing cost are ever emphasized objectives in manufacturing industry. Many researchers are finding alternatives for the excessive use of cutting fluids without affecting machinability and productivity. A newly developed economical and environmental friendly alternative to flood lubrication is dry machining is a step towards 'Green manufacturing'. Thus by using dry machining technique in machining of AISI 304 use of lubricant can be eliminated. In this study, the effect of Dry lubrication techniques in machining of AISI 304 austenitic stainless steel is studied to understand the effects

International Journal of Engineering Applied Sciences and Technology, 2016
Vol. 1, Issue 9, ISSN No. 2455-2143, Pages 149-155
Published Online July – August 2016 in IJEAST (http://www.ijeast.com)

of turning parameters like speed, feed and depth of cut on surface roughness, cutting temperature and chip thickness. Mahdavinejad and Saeedy [7] studied the influence parameters of machining of AISI 304 with and without cutting fluid. They founds that cutting speed has the main influence on the flank wear and as it increases to 175 m/min, the flank wear decreases. The feed rate has the most important influence on the surface roughness and as it decreases, the surface roughness also decreases. Also, the application of cutting fluid results in longer tool life and better surface finish. In another work Asiturk and Neseli [8] studied the multi response optimization of CNC turning parameters via Taguchi method-based response surface analysis in the machining of AISI 304 austenitic stainless steel under dry condition with coated carbide insert. They founds that the feed rate is the dominant factor affecting surface roughness, which is minimized when the feed rate and depth of cut are set to the lowest level, while the cutting speed is set to the highest level. Kaladhar et al [16] studied the performance evaluation of coating materials and process parameters optimization for surface quality turning of AISI 304 austenitic stainless steel. The experimental result shows that, the improvement in average surface roughness is obtained when machining with PVD coated insert (1.13 µm).The nose radius have greater contribution (62.88%) when turning with PVD coated insert. Atul Kulkarni et al 2013 studied dry turning at high speeds of AISI304 by using coated carbide inserts at high cutting speeds up to 260m/min. The author directed study by using fine grained carbide tool insert coated with AlTiCrN using physical vapor deposition (PVD) technique.

II. EXPERIMENTATION

Turning experiments were carried out on AISI 304 austenitic stainless steel round bar of Ø45 × 450 mm dimensions. The chemical composition of test sample is shown in the table 1.

Table 1 Chemical composition of AISI 304

C	Mn	Cr	Ni	Mo	S	P	Si	Fe
0.031	1.72	19.20	8.36	0.27	0.019	0.027	0.17	70.203

The experiments have been carried out on a powerful and rigid CNC lathe of HAAS ST 10, 15hp, at different cutting speeds and feeds under Dry condition. For the experimentations, the fine grained uncoated cemented carbide (Sandwick made) turning tools were coated with TiAlN hard coating by PVD technique. The TiAlN coating service is provided by Ion Bond India Pvt. Ltd. The ranges of the cutting velocity (*Vc*) and feed rate (*f*) were selected based on the conducted study and intended to study the cutting performance at higher cutting speed. To study the effect of cutting speed and to examine machining performance at higher speeds it is taken as 200 to 280 m/min. The feed also varied from 0.05 to 0.25 mm/rev to study the machining performance at very fine as well as very rough feeds. The table below shows the range of cutting parameters. Depth of cut, as a least influencing parameter, taken constant equals to 1 mm as shown in the table 2.

Table 2 Cutting parameters and their levels.

Sr. No.	Parameter	Level 1	Level 2	Level 3	Level 4	Level 5
1	Cutting Speed	200	220	240	260	280
2	Feed	0.05	0.10	0.15	0.20	0.25
3	Depth of cut	1	1	1	1	1

Machining of steels involves more heat generation due to their ductility and production of continuous chips. The cutting temperature increases with the increase in strength and hardness of the steels which requires more energy. Keeping these factors in view austenitic stainless steel (AISI 304) is selected for the investigation. The surface roughness, cutting temperature and chip thickness were taken as output parameters. Surface roughness is measured by Mitutoyo surface roughness tester, temperature is measured by infrared non-contact type optical pyrometer and chip thickness is measured with optical microscope.

The experimental investigations were conducted with a view to explore the effect of dry lubrication on the machinability of AISI 304 austenitic stainless steel in terms of surface roughness, cutting temperature and chip thickness.

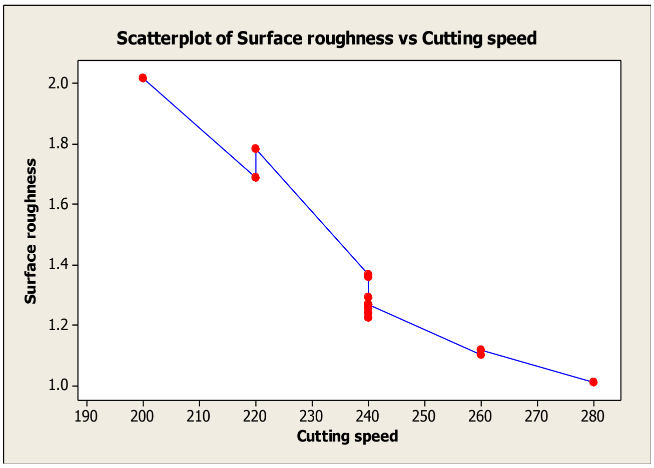
III. DESIGN OF EXPERIMENTS

The experiments are design according to the central composite design (CCD) of Response surface methodology as follows. Different combinations of speed and feed are obtained so that the most accurate results can be obtained.

Sr. No	Cutting speed	Feed	Depth of cut	Ra	Temp	Chip thickness
1	220	0.1	1	1.689	59.8	0.3002
2	260	0.1	1	1.102	67.5	0.1612
3	220	0.2	1	1.782	60.9	0.3277
4	260	0.2	1	1.119	63.6	0.2913

International Journal of Engineering Applied Sciences and Technology, 2016
Vol. 1, Issue 9, ISSN No. 2455-2143, Pages 149-155
Published Online July – August 2016 in IJEAST (http://www.ijeast.com)

5	240	0.05	1	1.367	66.1	0.1460
6	240	0.25	1	1.359	65.4	0.2639
7	200	0.15	1	2.016	56.7	0.3220
8	280	0.15	1	1.011	70.6	0.1671
9	240	0.15	1	1.268	65.4	0.2589
10	240	0.15	1	1.292	63.5	0.2494
11	240	0.15	1	1.254	63.7	0.2510
12	240	0.15	1	1.224	63.1	0.2601
13	240	0.15	1	1.239	64.8	0.2788
14	240	0.15	1	1.268	63.9	0.2701



IV. RESULTS AND DISCUSSION

IV.I Surface Roughness

From the results and ANOVA below it is inferred that, in dry assisted turning surface roughness is mostly affected by cutting speed and feed. Surface roughness gets decreased by increasing the cutting speed and by decreasing the feed rate. It is due to the fact that, as cutting speed increases, there is increase in the temperature at cutting zone which softens the material which results in formation of continues chips without built-up edge and surface roughness get reduced. Ra value increases with the increase in the feed rate. This might be attributed that, with increase in feed rate the cutting time reduces and the new abrasive particles enters in the region of cutting zone so more removal of material takes place and material may remain uncut due to the impact of the abrasive particles for the short period of time.

The table below is the ANOVA of surface roughness.

Table 4 ANOVA of Surface Roughness

Source	DF	Square SS	Adj.SS	Adj.MS	F	P
Regression	5	0.99776	0.997756	0.199551	51.25	0.000
Linear	2	0.88637	0.142847	0.071423	18.34	0.001
Speed	1	0.88563	0.124377	0.124377	31.95	0.000
Feed	1	0.00074	0.000110	0.000110	0.03	0.871
Square	2	0.10994	0.109942	0.054971	14.12	0.002
Speed* Speed	1	0.09019	0.105988	0.105988	27.22	0.001
Feed* Feed	1	0.01976	0.019755	0.019755	5.07	0.054
Interaction	1	0.00144	0.001444	0.001444	0.37	0.559
Speed* Feed	1	0.00144	0.001444	0.001444	0.37	0.599
Residual error	8	0.03115	0.031148	0.003893		
Lack of fit	3	0.02826	0.028260	0.009420	16.31	0.005
Pure error	5	0.00289	0.002888	0.000578		
Total	13	1.02890				

R-Square = 96.97% R-Square (adjusted) = 95.08%

Also as feed increases friction between workpiece and tool interface gets increased which eventually increases the surface roughness. In addition to this as feed increases a radial cutting force gets increased which results in more friction between the newly generated surface and the flank face which results in the increased surface roughness. Along with the cutting speed, feed rate have shown the most significant influence on the surface roughness (Ra). Built-up-edge formation is in relation with cutting speeds and feed rates. So that, at higher speeds and higher feed rates, built-up-edge phenomenon results in poor surface finish.

IV.II Cutting Temperature

From the results and graph it is inferred that, in dry lubrication assisted turning cutting temperature is mostly affected by cutting speed and feed both. As the cutting speed and feed increases cutting temperature also gets increased.

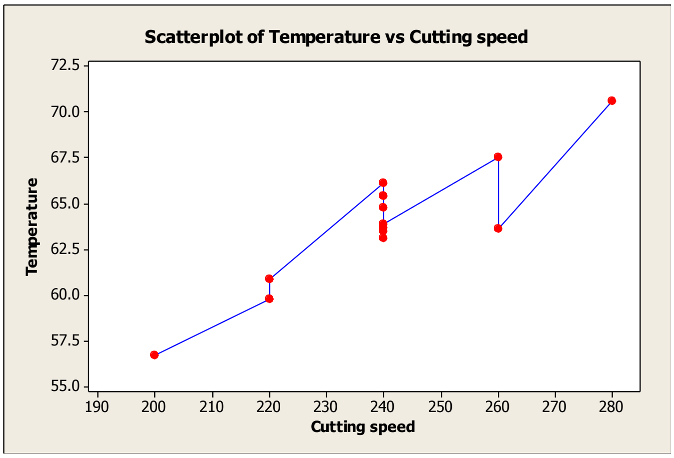
The table below is the ANOVA of Cutting temperature.

Table 5 ANOVA of Cutting Temperature

Source	DF	Square SS	Adj.SS	Adj.MS	F	P
Regression	5	134.258	134.258	26.8516	17.45	0.000
Linear	2	123.073	6.186	3.0930	2.01	0.196
Speed	1	121.603	4.171	4.1710	2.71	1.138
Feed	1	1.470	4.078	4.0778	2.65	1.142
Square	2	4.934	4.934	2.4672	1.60	0.260
Speed* Speed	1	1.467	0.518	0.5177	0.34	0.578
Feed* Feed	1	3.467	3.467	3.4670	2.25	0.172
Interaction	1	6.250	6.250	6.2500	4.06	0.079
Speed* Feed	1	6.250	6.250	6.2500	4.06	0.079
Residual error	8	12.311	12.311	1.5388		
Lack of fit	3	8.577	8.577	2.8592	3.83	0.091
Pure error	5	3.733	3.733	0.7467		
Total	13	146.569				

R-Square = 91.60% R-Square (adjusted) = 86.35%

International Journal of Engineering Applied Sciences and Technology, 2016
Vol. 1, Issue 9, ISSN No. 2455-2143, Pages 149-155
Published Online July – August 2016 in IJEAST (http://www.ijeast.com)



In Dry lubrication assisted turning as the cutting speed and feed increases cutting temperature also gets increased. This is because, as the cutting speed increases, cutting force gets increased which results in more energy to remove material from the workpiece which increases the temperature in cutting zone. Also at higher feed rate cutting temperature get increased because due to increase in the feed rate friction between material being removed and the cutting tool gets increased which causes increase in the temperature.

IV.III Chip Thickness

Nature of chips indicates that whether it is ductile or brittle and gives us the idea about the chip generation process. In dry turning mostly brittle chips are produced.

From the results and graph below it is inferred that, as cutting speed increases and feed rate decreases thinner chips are produced. It is due to fact that, increase in the cutting speed reduces the tool-chip contact area and simultaneously increases the shear angle which results in shorter shear plane which leads in the production of thinner chips. As the cutting speed decreases chip thickness gets increased, because decrease in the cutting speed increases the tool chip contact area and decreases the shear angle, which results in formation of thick chips.

Also as the feed rate decreases, the friction between work-tool gets decreased due to which cutting temperature also gets decreased, leads to plasticization and shrinkage of the shear zone takes place which results in the reduction in the friction at cutting zone which results in the reduced chip thickness.

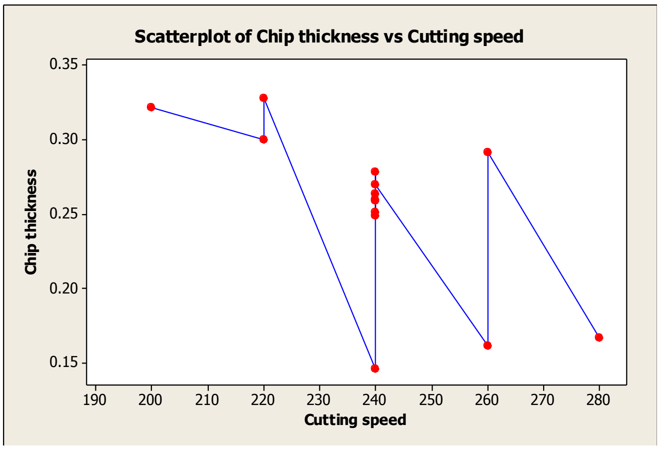
Table 6 below shows the ANOVA and the contribution of each parameter for chip thickness in Dry lubrication assisted turning of AISI 304 austenitic stainless steel.

The table below is the ANOVA of Chip Thickness.

Table 6 ANOVA of Chip Thickness

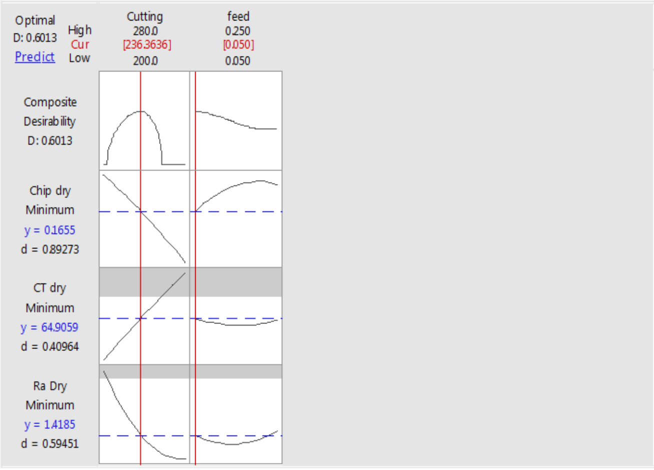
Source	DF	Square SS	Adj.SS	Adj.MS	F	P
Regression	5	0.039433	0.039433	0.007887	20.79	0.000
Linear	2	0.032515	0.001029	0.000514	1.36	0.311
Speed	1	0.019618	0.000048	0.000048	0.13	0.731
Feed	1	0.012897	0.01013	0.001013	2.67	0.141
Square	2	0.004286	0.004286	0.002143	5.65	0.030
Speed* Speed	1	0.000001	0.000282	0.000282	0.74	0.141
Feed* Feed	1	0.004285	0.004285	0.004285	11.30	0.010
Interaction	1	0.002632	0.002632	0.002632	6.94	0.030
Speed* Feed	1	0.002632	0.002632	0.002632	6.94	0.030
Residual error	8	0.003035	0.003035	0.000379		
Lack of fit	3	0.002396	0.002396	0.000799	6.25	0.038
Pure error	5	0.000639	0.000639	0.000128		
Total	13	0.0242468				

R-Square = 92.85% R-Square (adjusted) = 88.39%



V. OPTIMIZATION

Optimization of the input parameters and input variables is to be carried out to find the optimal machining condition which will give the best results. In this study the obtained results were optimized by using response optimizer of response surface methodology with MINITAB 17 software. Response Optimizer helps to identify the factor settings that optimize a single response or a set of responses.



From observing the optimization plot we can conclude that, at cutting speed of 236.3636 m/min and feed of 0.05 mm/rev we will get the minimum optimized values of surface roughness (Ra) = 1.4185 µm, cutting temperature (t) = 64.9059°C and chip thickness = 0.1655µm.

VI. VALIDATION

The optimized values of input parameters and output responses are needed to verify by performing the validation experiment under optimized conditions. By comparing the optimized and verified values it is clear that, the variation in the optimized and verified values is below 5 % which indicates that, the model designed is valid and adequate. These results demonstrated that the optimization method used was efficient and greatly reduced the machining cost and the design process. The prediction models can be applied to determine the appropriate cutting conditions, in order to achieve desired surface roughness, cutting temperature and chip thickness.

VII. CONCLUSIONS

The main objective of this experimentation is to check the viability of the Dry lubrication technique in turning of AISI 304 austenitic stainless steel at higher cutting speed to study the effect of input parameters on responses. The results were observed and statistical analysis is made and studied to draw the following conclusions

- ➢ The results indicate that the process parameters of cutting speed and feed rate have significant effects on the quality of turning of AISI 304 stainless steel.
- ➢ In Dry turning at higher speed and lower feed surface roughness gets reduced, as the speed decreases and feed increases surface roughness gets increased.
- ➢ Analysis of variance (ANOVA) demonstrates that, cutting speed is the most significant factor affecting the surface roughness.
- ➢ From the experimental readings and graphs we can conclude that, cutting temperature gets increased with increase in cutting speed and feed.
- ➢ Analysis of variance (ANOVA) demonstrates that, cutting speed and feed both are significant factors affecting the cutting temperature.
- ➢ Mostly brittle chips are produced in turning of AISI 304 with Dry lubrication, which indicates the increased work hardening of the workpiece.
- ➢ It is observed from the experimental readings and graphs, that chip thickness gets reduced with increase in cutting speed and reduced feed rate.
- ➢ From ANOVA it is clear that, feed is the most significant factor affecting the chip thickness.
- ➢ The optimal combination of process parameters for minimum surface roughness (Ra), cutting temperature and chip thickness is obtained at 236. 3636 m/min cutting speed, 0.05 mm/rev feed, 1 mm depth of cut.
- ➢ The validation experiment is carried out which deduced that the obtained optimized results are accurate up to 95 % of confidence level.

VIII. REFERENCES

[1] Vishal S. Sharma, Manu Dogra, N.M. Suri, "Cooling techniques for improved productivity in turning" Journal of Materials Processing Technology,vol.152, pp.199-214, 2003
[2] Nourredine Boubekri, Vasim Shaikh "Minimum Quantity Lubrication (MQL) in Machining: Benefits and Drawbacks " Journal of Industrial and Intelligent Information Vol. 3, No. 3, September 2015
[3] Murat Sarıkaya , Abdulkadir Gullu, "Taguchi design and response surface methodology based analysis of machining parameters in CNC turning under MQL" Journal of Cleaner Production, vol. 65, pp. 604-616, 2014
[4] N.R. Dhar, M. Kamruzzaman, Mahiuddin Ahmed, "Effect of minimum quantity lubrication (MQL) on tool wear and surface roughness in turning AISI-4340 steel" Journal of Materials Processing Technology,vol.172, pp. 299–304, 2006
[5] Sathe Amol Vaijinath, Khedekar Dilip S "A Review Study of MQL and Dry Turning of AISI 304" International Journal of Engineering Applied Sciences and Technology, 2016 Vol. 1, Issue 8, ISSN No. 2455-2143, Pages 235-240
[6] Upadhyay V, Jain, P. K., Mehta N. K. "minimum

quantity lubrication assisted turning - an overview" International Scientific Book 2012 pp. 463-478 Chapter 39

[7] R.A. Mahdavinejad and S. Saeedy, "Investigation of the influential parameters of machining of AISI 304 stainless steel", Indian Academy of Sciences, Vol. 36, pp. 963-970, 2011

[8] Ilhan Asiltürk, Suleyman Neseli,"Multi response optimization of CNC turning parameters via taguchi method-based response surface analysis", Measurement, vol. 45, pp.785–794, 2012

[9] Asier Gandarias, Luis Norberto López de Lacalle, Xabier Aizpitarte , Aitzol Lamikiz, "Study of the performance of the turning and drilling of austenitic stainless steels using two coolant techniques", International Journal of Machining and Machinability of Materials, Vol. 3, Nos. 1/2,2008

[10] Atul P. Kulkarni ,Girish G. Joshi , Vikas G. Sargade," Dry turning of AISI 304 austenitic stainless steel using AlTiCrN coated insert produced by HPPMS technique", International conference on design and manufacturing, Procedia Engineering, vol. 64, pp. 737-746, 2013

[11] Atul P. Kulkarni ,Girish G. Joshi , Vikas G. Sargade, "Design optimization of cutting parameters for turning of AISI 304 austenitic stainless steel using taguchi method", Indian journal of engineering and material sciences, Vol. 20, pp.252-258, 2013

[12] Shreemoy Kumar Nayak Jatin Kumar Patro, Shailesh Dewangan, Soumya Gangopadhyay,"Multi-objective optimization of machining parameters during dry turning of AISI 304 austenitic stainless steel using grey relational analysis", Procedia Materials Science,vol.6, pp.701-708, 2014

[13] D. Philip Selvaraj, P. Chandramohan,"Optimiztion of surface roughness of AISI 304 austenitic stainless steel in dry turning operation using taguchi design method", Journal Of Engineering Science and Technology, Vol.5,pp. 293-301, 2010

[14] M. Huseyin Cetin , Babur Ozcelik , Emel Kuram, Erhan Demirbas, "Evaluation of vegetable based cutting fluids with extreme pressure and cutting parameters in turning of AISI 304L by Taguchi method" , Journal of Cleaner Production, vol.19, pp. 2049-2056, 2011

[15] Babur Ozcelik, Emel Kuram , M. Huseyin Cetin , Erhan Demirbas, "Experimental investigations of vegetable based cutting fluids with extreme pressure during turning of AISI 304L", Tribology International, vol. 44, pp.1864–1871, 2011

[16] M. Kaladhar, K.Venkatasubbsish, Ch. SrinivasaRao, "Performance evaluation of coating materials and process parameters optimization for surface quality during turning of AISI 304 austenitic stainless steel", International Journal of Engineering, Science and Technology Vol.3, pp.89-102, 2011

[17] K.P. Sodavadia and A.H. Makwana, "Experimental Investigation on the Performance of Coconut oil Based nano fluid as lubricants during turning of AISI 304 austenitic stainless steel", International Journal of Advanced Mechanical Engineering. ISSN 2250-3234 Vol.4, pp. 55-60, 2014

[18] Luciano de Souza, Izabel Fernanda Machado, Joao Paulo Pereira Marcicano, "Characterization of the surface generated during the turning of annealed and aged AISI303, 304 and 310 austenitic stainless steel", 18^{th} International congress of Mechanical Engineering, Ouro Preto, MG, 2005

[19] M. Anthony Xavior and M. Adithan," Evaluating the performance of cutting fluids in machining of AISI 304 austenitic stainless steel", Int. J. Machining and Machinability of Materials, Vol. 7, Nos. 3/4, 2010

[20] Nithyanandhan. T, Manickraj. K and Kannakumar. R, "Optimization of cutting forces , tool wear and surface finish in machining of AISI 304 stainless steel material using taguchi method", International Journal of Innovative Science , Engineering and Technology , Vol.1 Issue 4,June 2014

[21] M. Anthony Xavior,"Experimental investigations on the machinability of AISI 304, AISI 52100 and AISI d2 steel materials", middle-east journal of scientific research vol.21 pp.1550-1560, 2014

[22] W. Grzesik," Experimental investigation of the cutting temperature in turning with coated indexable inserts", International Journal of Machine Tools & Manufacture, vol.39 pp. 355–369, 1999

[23] F. Klocke, T. Maßmann, K. Gerschwiler, "Combination of PVD tool coatings and biodegradable lubricants in metal forming", Wear, vol. 259,pp.1197–1206, 2005

[24] F. Klocke, K. Gerschwiler, R. Fritsch, D. Lung," PVD –coated tool and native ester – an advanced system for environmentally friendly machining", Surface and Coating Technology, vol. 201, pp.4389-4394, 2006

[25] Ahmad Hamdan and Ahmed A. D. Sarhan and Mohd. Hamdi," An optimization method of the machining parameters in high-speed machining of stainless steel using coated carbide tool for best surface finish", International Journal of advanced manufacturing and technology, vol.58, pp. 81–91, 2012

[26] Muammer Nalbant, Hasan Gokkaya, Ihsan Tokas, Gokhan Sur," The experimental investigation of the effects of uncoated, PVD-and CVD- coated cemented carbide inserts and cutting parameters on surface roughness in CNC turning and it's prediction using artificial neural networks", Robotics and computer integrated manufacturing, vol.25, pp.211-223, 2009

[27] Shane Y. Hong, Mark Broomer," Economical and ecological cryogenic machining of AISI 304 austenitic

stainless steel", Clean Products and Processes, vol.2, pp.157–166, 2000
[28] Ahsan Ali Khan, Mirghani I. Ahmed, "Improving tool life using cryogenic cooling", Journal of materials processing technology, vol.196, pp.149–154, 2008
[29] M. Dhananchezain, M. Pradeepkumar, and T. Sornakumar, "Cryogenic turning of AISI 304 stainless steel with modified Tungsten carbide tool inserts", Material and manufacturing processes, vol.26, pp. 781-785, 2011
[30] M.A. Xavior, "Evaluating the machinability of AISI304 stainless steel using alumina inserts", Journal of Achievements in Materials and Manufacturing Engineering volume 55 issue 2 December 2012