Advances in Research

11(5): 1-11, 2017; Article no.AIR.36441
ISSN: 2348-0394, NLM ID: 101666096

Analysis of Carbide Tool Wear of EN38 Steel

C. H. Achebe[1], J. L. Chukwuneke[1*], T. D. Otobo[1] and P. S. Aguh[2]

[1]Department of Mechanical Engineering, Nnamdi Azikiwe University, Awka, Nigeria.
[2]Department of Industrial and Production Engineering, Nnamdi Azikiwe University, Awka, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Authors CHA and JLC designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors TDO and PSA managed the analyses of the study. Author TDO managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AIR/2017/36441
Editor(s):
(1) Siva Prasad Kondapalli, Department of Mechanical Engineering, Anil Neerukonda Institute of Technology & Sciences, India.
Reviewers:
(1) Serkan Islak, Kastamonu University, Turkey.
(2) Azuddin Mamat, University of Malaya, Kuala Lumpur, Malaysia.
(3) Yong X. Gan, California State Polytechnic University, Pomona, USA.
Complete Peer review History: http://www.sciencedomain.org/review-history/21012

Original Research Article

Received 28th August 2017
Accepted 12th September 2017
Published 15th September 2017

ABSTRACT

This research work analyzed carbide tool wear of the single point cutting tool used in the turning operation of EN38 steel. Sixteen experiments were conducted, to determine how feed rate, depth of cut and spindle speed of the tool, made of tungsten carbide, caused tool wear at varying machining parameters. Feed rate of 1.0, 1.5, 2.0, 2.5, and 3.0, rev/min and depth of cut of 0.2, 0.3, 0.4, 0.5, 0.6, mm and Spindle speed 400, 600, 800, 1000, 1200, rpm, were considered. Temperature and weight loss were equally measured during the experimental processes with a constant time of 15munites. With the data obtained, various graphs were plotted to show the variation of feed rate, weight loss, depth of cut, spindle speed and temperature. Regression analysis using partial least square method was used to determine the regression coefficient of temperature and weight loss. The probability value of 0.004 and optimal R-square value of 0.9957 were consequently obtained from the regression analysis. It was observed that temperature increase and weight loss depend on feed rate, spindle speed and depth of cut and also that an increase in feed rate, spindle speed and axial depth of cut had a significant effect on tool wear, revealing that the alpha value of 0.05 is greater than the probability value of 0.004 from the regression analysis.

**Corresponding author: E-mail: jl.chukwuneke@unizik.edu.ng;*

Keywords: Carbide; tool wear; EN38 steel; feed rate; depth of cut; spindle speed; temperature; coolant.

1. INTRODUCTION

In every machining system, one simply can't ignore the important role that cutting tools play as can be seen on various researches of the nature of cutting tool [1], the rate at which metal can be removed by the machine [2] and even the wear and tool life of these cutting tools [3]. Oftentimes, the quality of a finished product would rely on the quality of the cutting tools. The quality and the cutting performance of cutting tools would also directly affect a machining system's overall productivity. There are two types of cutting tools heavily favored in the machining industry: high speed steel (HSS) cutting tools and carbide cutting tools [4]. Cutting tool grades of carbides are further subdivided into two groups: cast–iron carbide and steel-grade carbide. The main carbide material used in its manufacture is tungsten carbide with a cobalt binder. Tungsten carbide is well known for its hardness and resistance to abrasive wear [5].

Turning is a form of machining, a material removal process, which is used to create rotational parts by cutting away unwanted material. The turning process requires a turning machine or CNC lathe, work piece, fixture, and cutting tool. The work piece is a piece of pre-shaped material that is secured to the fixture, which itself is attached to the turning machine, and allowed to rotate at high speeds. The cutter is typically a single-point cutting tool that is secured in the machine. The cutting tool feeds into the rotating work piece and cuts away material in the form of small chips to create the desired shape [6].

Cutting fluid (coolant) is any liquid or gas that is applied to the chip or cutting tool to improve cutting performance. Few cutting operations are performed dry. The cutting fluid is another agent that strongly influences the process of thermal crack formation. The use of a cutting fluid in turning process may be highly detrimental to the tool's life, depending on the cutting parameters, tool material and the type of damage involved. In the presence of thermal cracks, the cutting fluid will accelerate their nucleation process and reduce the tool's life regardless of the type of cutting fluid used [7].

In metal cutting operations, there is always temperature increase between the work piece and the cutting tool interface. This is as result of the plastic deformation developed at the primary shear plane and friction at the interface [8]. During metal cutting, the heat generated is significant enough to cause local ductility of the work piece material as well as of the cutting edge. Although softening and local ductility are required for machining hard materials, such as EN38 steel, the heat generated can shorten the tool life and performance [9]. Therefore, the control of cutting temperature is required to achieve the desired tool performance. The cutting temperature is a key factor which directly affects tool wear, work piece surface integrity and machining precision according to the relative motion between the tool and work piece.

The cutting parameters especially cutting speed, feed rate and depth of cut influence chip-tool interface temperature. Temperature in the cutting zone depends on contact length between tool and chip, cutting forces and friction between tool and work piece material [10–11]. A considerable amount of heat generated during machining is transferred into the cutting tool and work piece. The remaining heat is removed with the chips; the highest temperature is generated in the flow zone. Therefore, contact length between the tool and the chip affects cutting conditions and performance of the tool and tool life. During the cutting process, greater cutting forces occur when increasing the feed rate. This, in turn will also increase tool wear [12].

For the purpose of increasing machining efficiency, this paper is therefore aimed at analyzing carbide tool wear in turning operation of EN38 steel. To achieve this aim, the following objectives have to be met; determining the spindle speed, depth of cut and feed rates, evaluating the variation of tool wear and determining the effect of increase in temperature on the cutter during operation for a given carbide tool.

2. MATERIALS AND METHODS

EN38 steel, whose mechanical and chemical compositions are outlined in Tables 1 and 2, was used for the experiment.

Carbon insert cutting tool with dimensions 16.02 mm × 8.02 mm, with nose radius of 0.4 mm was utilized for the experiment due to its ability to withstand high speed machining. The experiment was carried out on a precision CNC lathe (CK 6132) using a bar turning process under dry conditions.

Table 1. Chemical composition of EN38 steel (%)

C	SI	Mg	S	Ni	P
0.35-0.4	0.05-0.35	0.6-0.9	0.5	4.50-5.50	0.5%

Table 2. Mechanical properties of EN38 steel

Tensile strength, tones/sq. in. min. (Rm)	65 N/m^2
Elongation, %. Min. (A)	13 m
Izod impact value.	30 J/m^2

The Camry digital scale was used to weigh the mass of the tool before and after machining in order to determine loss of weight of the tool. A dial indicator having a 25.40 mm range and a calibration increment of 0.0254 mm was utilized for the operation, as well as a pyrometer which was utilized to determine temperature changes of the cutting tool and work piece. AME Optical Pyrometers was used which work on very sophisticated mechanism. This thermal device detect temperature of an object by reckoning the emitted, reflected and transmitted energy by means of optical sensors & detectors and show temperature reading on display panel and the temperature Range is 300º to 1100ºC).

The experiment was performed in three stages. In stage one, the spindle speed and depth of cut was kept constant at 800 rpm and 0.2 mm respectively, the feed was varied from 1.0 – 3. Rev/min with an interval of 0.5. In the second stage, the spindle speed and federate were kept constant at 800 rpm and 2.0 mm/min respectively and the depth of cut was varied from 0.2-0.6 mm with an interval of 0.1. In the final stage, the depth of cut and feedrate were kept constant at 0.2 mm and 2.0 mm/min respectively with the spindle speed varied from 400-1200 rpm in an interval of 200. For each of this experiment, the temperature is taken every 15 mins and the weight of the cutting is measured before and after the experiment.

3. RESULTS AND DISCUSSION

Fig. 1 is a graphical representation of spindle speed versus feed rate and weight loss. Here, at constant spindle speed and constant feed rate, the weight loss tends to increase but as the feed rate increases the wear also increases. This can be attributed to the time at which the cutting tool is in contact or is advancing along the work piece. There was a rapid contact with the work piece which caused the cutting tool to encounter weight loss. This shows that an increase in feed rate has a significant effect on the tool life since there will be an increase in the wear.

From the graph of feed rate versus temperature and weight loss as represented in Fig. 2, it can be seen that as feed rate increases, there is an increase in temperature which moves geometrically as the feed rate increases. However, the weight loss increased to a point and remained constant. From the experiment carried out, it could be seen that at the first contact the cutting tool had with the work piece, there was a chip from the cutting tool. When the machining process continued, the cutting tool retained its property and becomes steady and no wear occurred again showing the behavior of carbide tool at feed rate of 2 rev/min.

In Fig. 3, the values of these two responses are the same, but their calculated variances are different. This is a perfect correlation because the data points all lie exactly on a straight line and the slope of the graph is positive. Feed rate increases geometrically by 0.5.

Fig. 4, shows a minimum R-squared value of 0.96 at point 1, and an optimal value of 0.995786 at point 2, this is the best optimal R-squared value. The model selected the best optimal value of 0.995786 for the best fit. Since the p- value is less than 0.05 the model shows a good correlation and the response is linear.

The residual normal plot in Fig. 5, shows that there is a good correlation within the boundary. The response is a linear plot which shows the standardized residual boundary limit. Since the values of percent falls within this boundary, the response plot shows that the linearity is 100% with confidence level of 95%.

3.1 Surface Response Plots for Depth of Cut

The tool wear was observed using different, depth of cut for the operation of EN38 steel. For a carbide tool cutter, the following results were plotted in a graph.

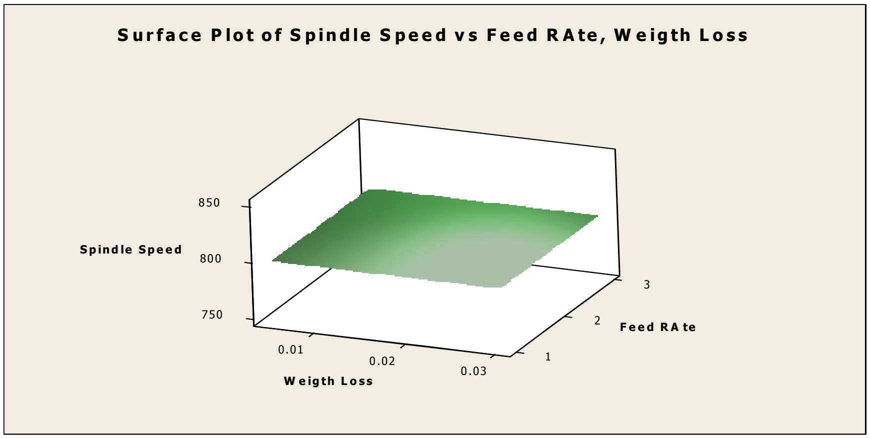

Fig. 1. A graph of spindle speed versus feed rate and weight loss

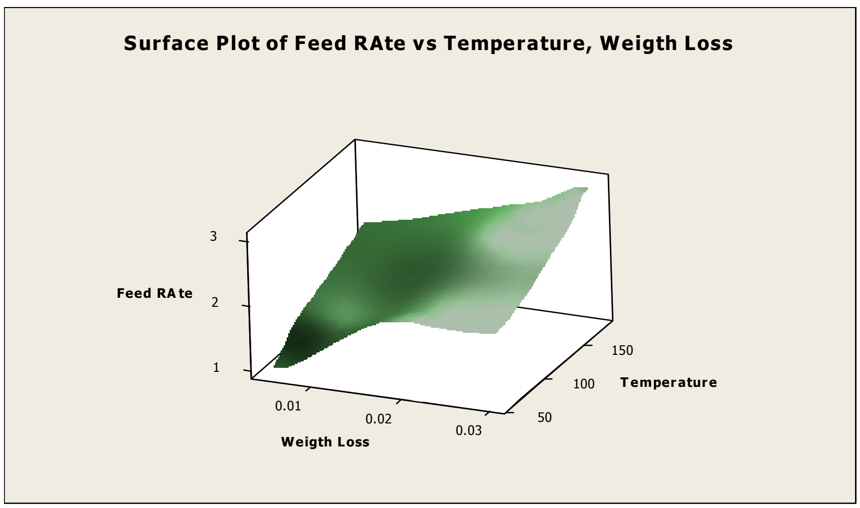

Fig. 2. A graph of feed rate versus temperature and weigh loss

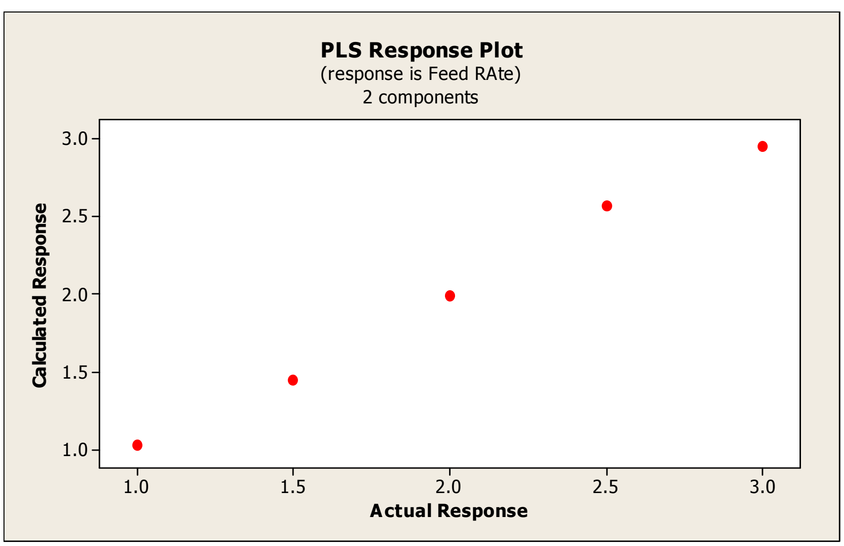

Fig. 3. Calculated response versus actual response for feed rate

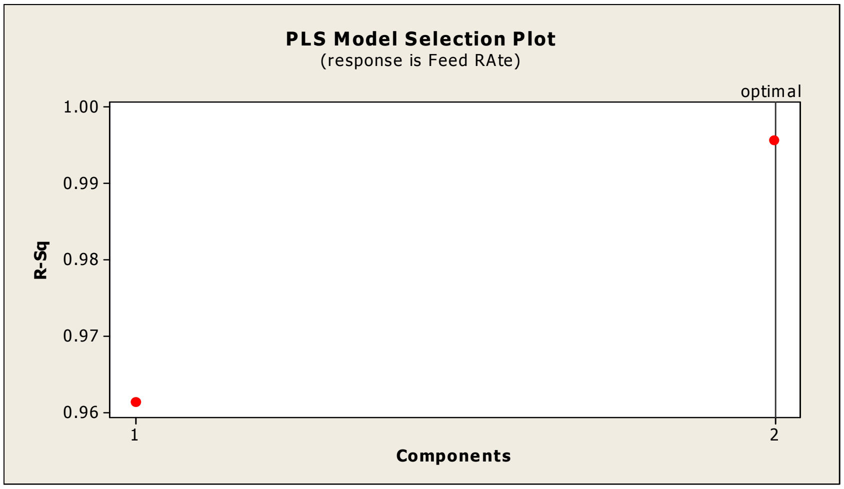

Fig. 4. Graph showing model selected plot response for feed rate

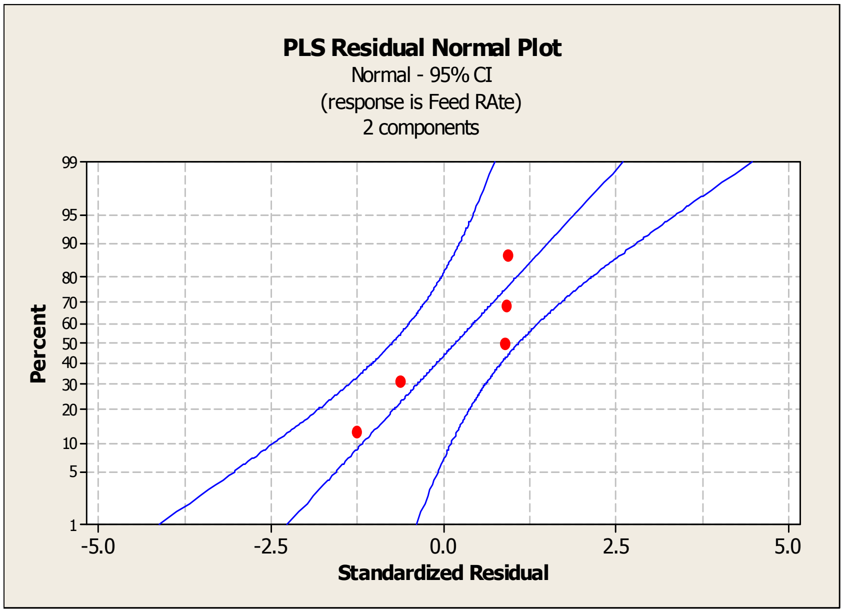

Fig. 5. Graph showing residual normal plot response for feed rate

Table 3. Regression analysis using partial least square method

3a. Analysis of variance for feed rate

Source	DF	SS	MS	F	P
Regression	2	2.48947	1.24473	236.32	0.004
Residual error	2	0.01053	0.00527		
Total	4	2.50000			

3b. Model selection and validation for feed rate

Components	X variance	Error	R-Sq
1	0.89623	0.0965085	0.961397
2	1.00000	0.0105344	0.995786

3c. Coefficients

	Feed rate	Standardized
Constant	0.5597	0.000000
Temperature	0.0026	0.188964
Weight loss	64.1493	0.841310

At constant spindle speed, a steady increase in temperature and a slight increase in weight loss of the cutting tool were observed as shown in Fig. 6. This temperature and weight loss increase was also observed to be linear.

From Fig. 7, as depth of cut increases there is an increase in weight loss which moves linearly. It can also be seen that temperature increases as the depth of cut increases. This shows that depth of cut has a strong significant effect on both weight loss and temperature when using carbide cutting tool.

The values of the calculated response and actual response were observed to be the same using partial least squared response plot for depth of cut as seen in Fig. 8, but their calculated variances are different. This is a perfect correlation because the data points all lie exactly on a straight line and the slope of the graph is positive. Depth of cut increased geometrically by 0.1.

Fig. 9, shows a minimum R-squared value of 0.96 at point 1, and an optimal value of 0.995786 at point 2, this is the best optimal R-squared value. The model selected the best optimal value of 0.995786 for the best fit. Since the p-value is less than 0.05 the model shows a good correlation and a linear significant response.

In Fig. 10: the residual normal plot response shows a good correlation within the boundary. The response is a linear plot which shows the standardized residual boundary limit. Since the values of percent falls within this boundary, the response plot shows that the linearity is 100% with confidence level of 95%.

3.2 Surface Response Plots for Spindle Speed

The tool wear was observed varying the spindle speed for the operation of EN38 steel and results obtained were ploted in the graph of Figs. 11 and 12.

In Fig. 11, at a steady feed rate, the spindle speed and temperature remained. As the feed rate increased there was an increase in spindle speed and temperature, showing that feed rate and spindle speed has a significant effect on the temperature.

Fig. 12 shows that as spindle speed increases there is an increase in weight loss and a rapid increase in temperature. The weight loss increases linearly and becomes almost steady at 800 rpm showing the stability of the cutting tool at that point.

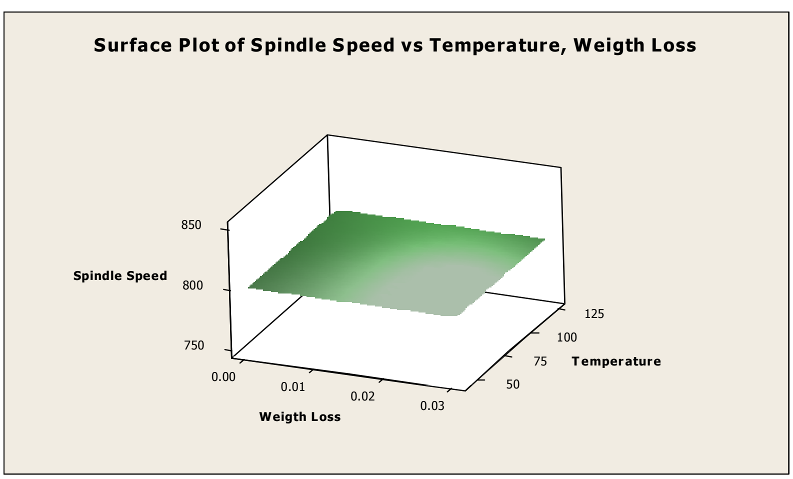

Fig. 6. Spindle speed versus temperature and weight loss

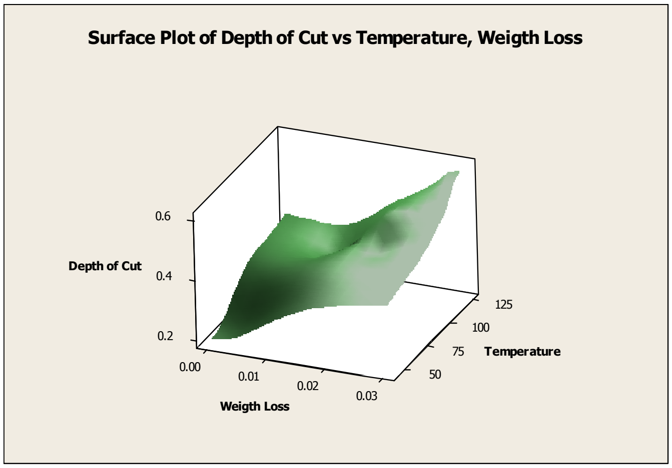

Fig. 7. Depth of cut versus temperature and weight loss

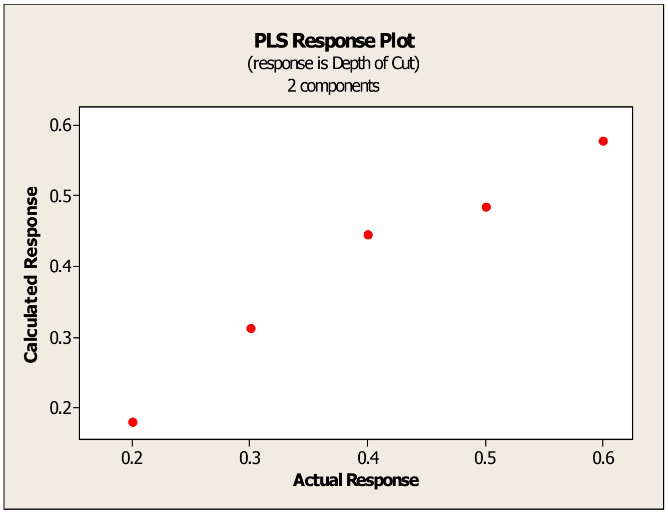

Fig. 8. Calculated response versus actual response for depth of cut

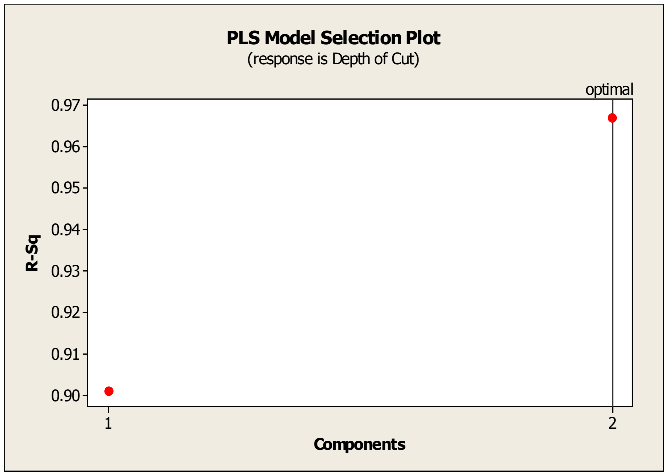

Fig. 9. Graph showing model selected plot response for feed rate

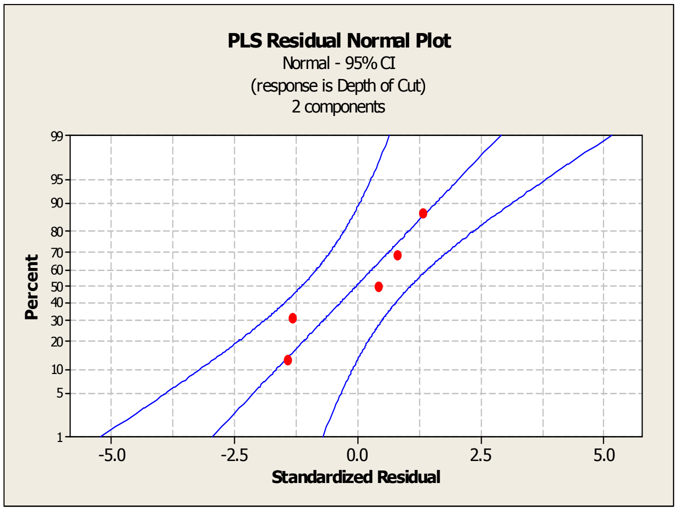

Fig. 10. Graph showing PLS residual normal plot

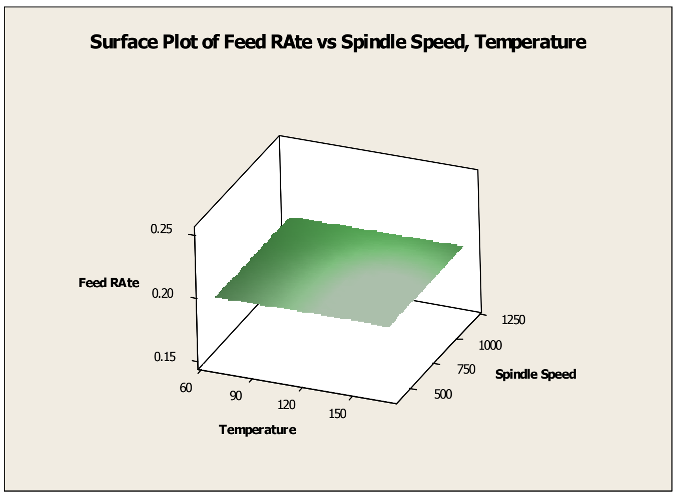

Fig. 11. Feed rate versus spindle speed, temperature

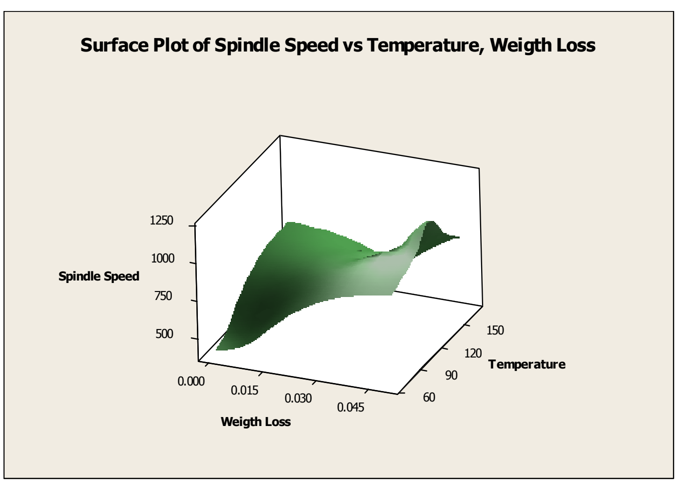

Fig. 12. Spindle speed versus temperature and weight loss

The value of calculated response and actual response were observed and discovered to be the same as shown in Fig. 13, but their calculated variances are different. This is a perfect correlation because the data points all lie exactly on a straight line and the slope of the graph is positive. Spindle speed increases geometrically by 100 rpm.

Fig. 14, shows a minimum R-squared value of 0.75 at point 1, and an optimal value of 0.95 at point 2, this is the best optimal R-squared value. The model selected the best optimal value of 0.95 for the best fit. Since the p-value is less than 0.05 the model shows a good correlation. The model shows a significant response and the response is linear.

In Fig. 15, the residual normal plot shows that there is a good correlation within the boundary. The response is a linear plot which shows the standardized residual boundary limit. Since the values of percent falls within this boundary, the response plot shows that the linearity is 100% with confidence level of 95%.

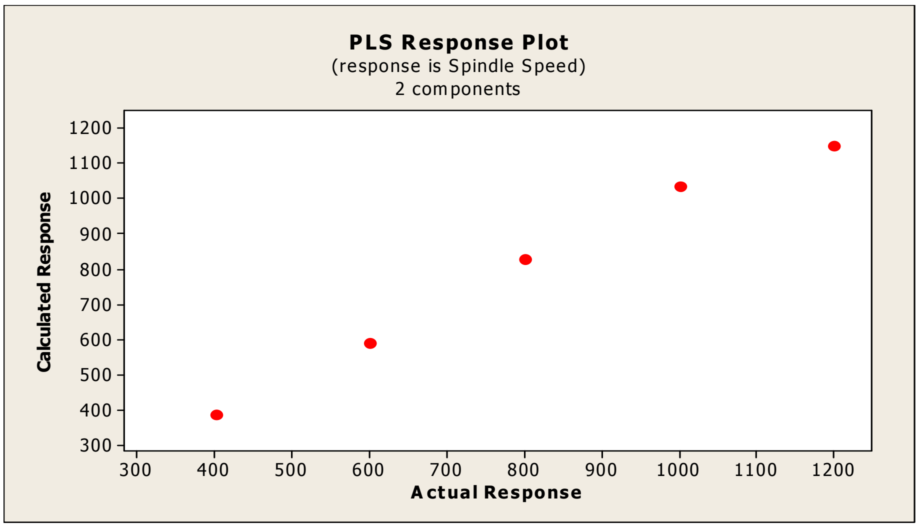

Fig. 13. Graph showing PLS response plot for spindle speed

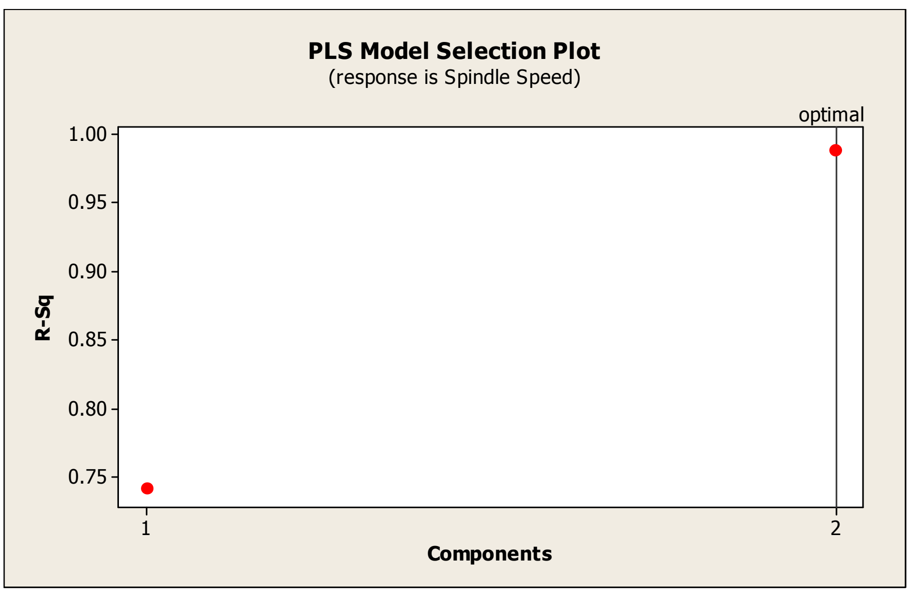

Fig. 14. Graph showing PLS model selection plot

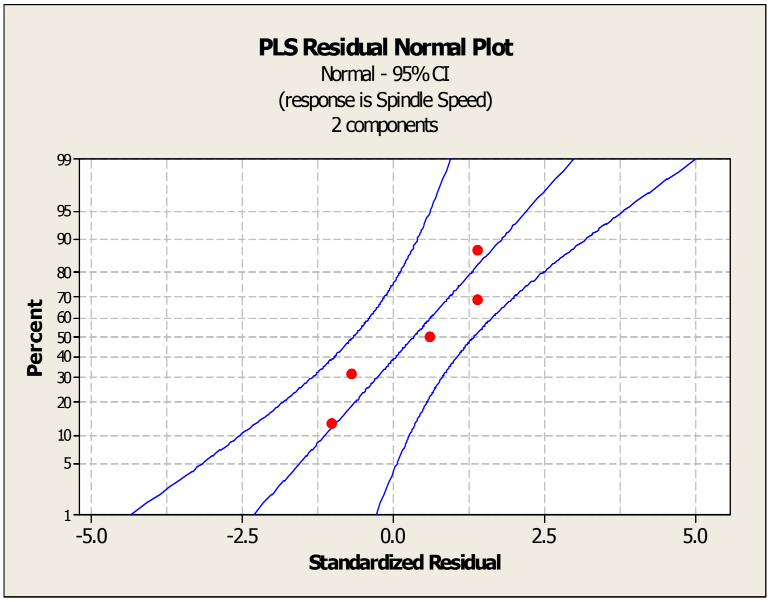

Fig. 15. Graph showing PLS residual normal plot

4. CONCLUSION

From the experiments carried out as stated in the methodology above, a probability value of 0.004 and optimal value of 0.0995786 were consequently obtained. At a constant spindle speed 800 rpm, steady feed rate 2 rev/min, and depth of cut 0.2 mm it was seen that the weight loss was steady showing the stability of the cutter. It was seen that carbide tool experiences break-in as a result of tool coming in contact with the work piece during the first depth of cut. This is due to an increase in feed rate and spindle speed for the operation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Viktor P. Astakhov. Effect of the cutting feed, depth of cut, and work piece (bore) diameter on the tool wear rate. International Journal Advance Manufacturing Technology. 2007;34:631-640.
2. Sexton JS, Milne RD, Stone BJ. A stability analysis of single point machining with varying spindle speed. Applied. Mathematics. Modeling. 2008;1:310–318.
3. Arsecularatne AJ, Zhanga LC, Montrossb C. Wear and tool life of tungsten carbide, PCBN and PCD cutting tools. International Journal of Machine Tools & Manufacture. 2006;46:482–491.
4. Akhil CS, Ananthavishnu MH, Akhil CK, Akhilesh R, Rahul Rajan. Measurement of cutting temperature during machining. Journal of Mechanical and Civil Engineering. 2016;13(2):108–122.
5. John M. Benefits of Carbide Cutting Tools; 2014. Available:www.streetdirectory.com/travel-guide-cutting-tools-html
6. Custompart. Turning Process, Defects, Equipment; 2009. Available:www.custompartnet.com/wu/turning
7. Anderson C. A. de Melo, Julio Cesar G. Milan, Marcio B. da Silva, Alisson R. Machado. Some observations on wear and damages in cemented carbide tools. Journal of the Brazilian Society of Mechanical Science and Engineering. 2006;28:269.
8. Bagheri M, Mottaghizadeh P. Analysis of tool-chip interface temperature with FEM and empirical verification. World Academy of Science, Engineering & Technology. 2012;69:434–443.
9. Ajay Goyal, Suresh Dhiman, Shailendra Kumar, Rajesh Sharma. Analysis of Cutting Force with respect to cutting

parameters when EN-38MS is machined with PCBN Insert. Jordan Journal of Mechanical and Industrial Engineering. 2014;8(2):82–93.

10. Fata A, Bagheri M, Mottaghizadeh P. Tool temperature prediction during machining by FEM with experimental validation. Journal of Basic and Applied Scientific Research. 2012;2(12):12606–12610.

11. Manu Dogra, Josminder S. Dureja. Wear analysis of coated carbide tools in hard turning. International Journal of Research in Mechanical Engineering & Technology. 2014;4(2):163–167.

12. Ashish B. Optimization of different performance parameters. International Journal of Engineering and Science. 2013; 2:103-113.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/21012