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Review Article

Optimization of Cutting Parameters of Tool Wear in Turning Operations: A Review

A. Adamu[1*], M. A. Bawa[1], A. M. Abioye[1]

[1]Department of Mechanical/Production Engineering, Faculty of Engineering and Engineering Technology Abubakar Tafawa Balewa University Bauchi, Bauchi State Nigeria

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***Corresponding author:** A. Adamu

Abstract

Tool wear is one of the major factors that contribute to surface quality, productivity and accuracy in machining. It also determines production flow by increasing the number of shutdowns for tools reshaping. Tool wear is related to cutting process parameters (depth of cut, spindle speed and feed rate), the surface nature of the metal (scaly or smooth), the cutting forces and thermal condition at cutting zone. This paper present review of various works on optimizing the tool wear rate during turning operation. Also, it presents techniques used in monitoring the processes and methods of determining the rate of tool wear with their results in an orthogonal machining operation on different type of materials.

Keywords: Tool Wear, process parameters, orthogonal machining.

INTRODUCTION

Tool wear can be described as the gradual failure of cutting tools due to regular operation. It is a term frequently associated with tipped tools, tool bits, or drill bits that are used with machine tools. Increasing productivity and reducing machining and tooling costs are prime objectives in any manufacturing activities. To achieve that, engineers need to select optimum process parameters during turning operations. Turning operation (Fig 1) is the most fundamental metal removal operation in the manufacturing industry (Sharma *et al.*, 2012).

Factors such as spindle speed, feed rate, and depth of cut that control the cutting operation can be setup in advance. However, factors such as geometry of cutting tool, tool wear, and joint material properties of both tool and work piece are uncontrollable (Kohli and Dixit, 2005).

The factors effecting tool life is a strong relationship between the rate of wear and the life span of a tool, this relationship can be largely affected by some influencing factors that are listed below; Types of surfaces on the metal (scaly or smoothness), Profile of the cutting tool, Speed, feed and depth of cut (axial or radial), material of cutting tool, microstructure of the material, type of material used, hardness of the material, type of machining operation being performed (Olufayo *et al.*, 2011).

According to Rout *et al.,* (2014), Tool Wear is one of the critical factors in machining process, affecting cost and productivity. The research on tool wear has improved the understanding of wear mechanisms for different work and tool materials in various machining operations. Machining is carried out under chatter conditions owing to very low dynamic rigidity of the machining system. This means that, in order to reduce the cycle time material removal rates higher than the stable limits are used. Tool wear includes: Flank wear in which portion of the tool in contact with the finished part erodes, can be described using the tool-life expectancy; and Crater wear in which contact with chips erodes the rake face. This is somewhat normal for tool wear, and does not seriously degrade the use of a tool until it becomes serious enough to cause a cutting-edge failure. Tool wear rate in machining is defined as the amount of volume loss of tool material on the contact surface due to the interactions between the tool and work piece. Mathematically, it is expressed by Kumar *et al.,* (2016).

$$TWR = \frac{T_i - T_f}{t} \text{ (mm/s)} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where T_i is the length of cutting tool before turning; T_f is the length of cutting tool after turning and t is the time taken for each experiment.

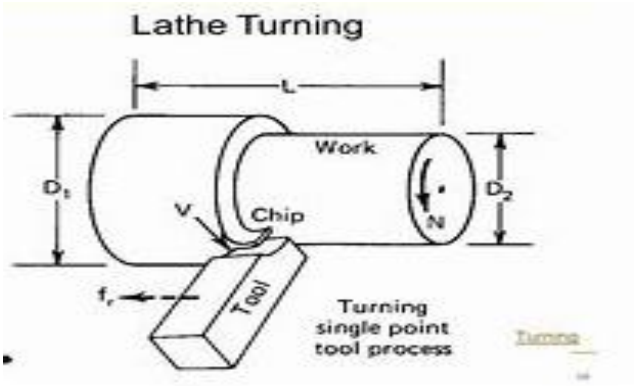

Fig 1: Turning operation

LITERATURE REVIEW

Mahesha *et al*., (2016) investigated the dry sliding wear behavior of 17-4 PH stainless steel, where they use a pin on disc tribometer by considering 3 factors of normal load, sliding distance and sliding velocity and they analyze the volume wear loss and specific wear rate using Taguchi. They conclude that the load has the most significant effect that affect the wear volume and specific wear rate then followed by sliding distance and then sliding velocity as statistically analyze by ANOVA: 55.423%, 8.130% and 29.999% for volume loss and 60.47%, 14.33% and 10.593% respectively for specific wear rate.

Nusrat *et al*., (2011) made a comparative study of tool wear and surface roughness by varying cutting parameters under dry and minimum lubrication while turning medium carbon steel using carbide tool insert. They develop a model to determine the surface roughness in terms of machine time and cutting tool wear functions in terms of time, feed rate, cutting speed and feed rate. The surface finish obtained with the use of min. lubricant is better because it reduces the auxiliary flank wear which causes rough surface roughness.

Fadhel *et al*., (2018) investigate the two ways of Calculating wear rate, by weight and by volume using aluminum sample through varying load of 500g to 1500g and a time of 300 to 900 second wear rate which gives 83%, 80% & 37%. Similarly, Same weight and same time was used to calculate by Volume which gives a higher percentage of 152%, 110% and 128% respectively and they concluded that calculating by volume gives better percentage of wear rate than by weight.

Aslantas *et al*., (2020) investigated the surface roughness and wear characteristic in micro turning of alloy Ti-6Ai-4V material, where they obtained a good surface finishing in micro turning process using the ideal cutting parameters and multi objective optimization of micro turning process through the use of response surface method. They also develop an empherical relations between cutting parameters and surface roughness (sa) & maximum surface roughness (sz) of the alloy using RSM for the micro turning process. They were able to established that as feed rate increases the sa & sz also increases while a mixed trend was observed from other cutting parameters, and finally at the end of their research they were able to come up with an optimize value for sa, sz and MRR obtained by the multi objective optimization approach which are 0.50µm, 4.16µm and 239.03mm3/mm respectively.

Al-Ahmari (2008) developed empirical models for tool life, surface roughness and cutting force for turning operation. The process parameters used in the study were speed, feed, depth of cut and nose radius to develop the machinability model. The methods used for developing aforesaid models were Response Surface Methodology (RSM) and neural networks (NN).

Barman and Mukherjee (2015) selected three level full factorial design of experiments. The experiments were conducted by considering three main influencing process parameters such as spindle speed, Feed Rate and Depth of Cut at three different levels namely Low, Medium and High. There results showed that the tool wear increases with increase of Spindle Speed. Also, it has been found that the tool wear is minimum at spindle speed of 250 rpm Feed Rate of 0.4 mm/rev and Depth of Cut of 0.8 mm. However, process reliability can be greatly influenced by crater wear as this factor leads to immediate breakage because of tool chipping. A failed cutting tool mostly causes problem with surface quality of work piece and it has been suggested and estimated according to literatures that a flank wear scar band width should be as high as 0.3 mm for experimental purposes.

The optimum condition of machining parameters of 80 m/min of cutting speed, 0.10 mm/rev of feed rate and a rotary tool speed of 45.7071 rotation/min was obtained using response surface method with Box- Behnken design for rotating tool turning process of magnesium AZ31. The turning process was carried out at low level cutting speed; low feed rate which gave a low temperature generation with a tool wear obtained at the optimum prediction was 0.27728 mm. The temperature generation between the work piece and rotary cutting tool was reduced using a pressurized air (Ibrahim *et al.*, 2019).

An empirical second order equation was used to predict a model for surface roughness of machining EN24 through the use of Response surface methodology using Box-Behnken experimental design. The effect of dept. of cut, spindle speed and feed rate on surface roughness was quantified and result obtained shows that the feed rate remain the highest contributor to better surface finishing followed by the spindle speed and dept. of cut. They further come up with 0.1 mm/rev as feed rate, 111.5 m/min for cutting speed and depth of cut of 0.2 mm as the values of cutting parameters with which lowest surface finish is attained. The result also shows that the higher the speed the higher the surface quality roughness obtained (Babu *et al.*, 2011).

The effect of process parameters of spindle speed, feed rate and depth of cut in turning operation of Aluminum 6061 served as material work piece and coated carbide as cutting tool. A mathematical model using regression analyses with response surface methodology (RSM) and Box-Behnken as design expert was developed a long side genetic algorithms to determine the optimal solution of deferent cutting parameters (Basha *et al*., 2013).

Machining parameters of depth of cut, feed rate and spindle speed were investigated in relation to surface roughness while carrying out turning operation of mild steel material. The parameters were optimized for proper and effective machining of the materials using Box-Behnken experimental design method with ANOVA as result statistical analyzer. Furthermore, a mathematical model correlating the influence of machine parameters in relation to surface roughness Ra during machining was developed. A linear regression was carried out and the result shows feed rate as the parameter that determined a good surface roughness (Abdulkareem *et al*., 2011).

Okokpujie *et al.,* (2018) investigate tool wear on high-speed steel (HSS) during tuning operation of aluminum 1061 alloy and also developed mathematical models using least square method. They use cutting input parameters of cutting speed feed rate and radial depth of cut. They used scanning electron microscope (SEM) to measure the cutting tool in other to determine the tool wear through a model of prediction. The experimental result and the actual value, predicted value and percentage deviation of tool wear (TW max) where developed and a comparison between the experimental data and the predicted data and also the effect of the cutting parameters on the tool wear also carried out.

Ibrahim *et al.,* (2013) used Taguchi method to optimize parameter design that contributes to flank wear. They evaluate coated surface treatment, cutting speed and feed rate. The Usui's model was used to measure the flank wear size; where the ANOVA analysis was used to identify the influent factors contributed to tool wear. 0.18 mm/min of feed mate, 800 m/min of cutting speed and have coated surface treatment at TIN was found to be the best optimal parameters which has a significant effect to tool wear. Confirmation test was carried out and found 0.002 mm of tool wear.

Jadhav and Jadhav (2014) have studied the effect of cutting parameters on cutting force FC and feed force in turning process where (ANOVA) based on adjusted approach was used. They analyzed the cutting force and feed force to increase linearly with increase in depth of cut from 0.25 mm to 0.75 mm while optimum conditions are achieved for a feed mate value of 0.18 mm/rev and a depth of cut value of 0.5 mm. This shows that the cutting force is influenced by DOC, feed rate, interaction effect of feed and depth of cut and also interaction effect of speed, feed and depth of cut. They further analyzed the insignificance of speed in relation in cutting in relation to cutting force while the feed mate has significant influence on both the cutting force and surface roughness. DOC has significant influence on cutting force, but insignificant on surface roughness. They finally studied that in turning process, optimization with respect to power consumption, appropriate combination of feed rate and depth of cut should be chosen while optimum surface roughness can be achieved through selecting relatively higher values of speed, DOC (>65.37 m/min) and (>0.75 mm) and lower feed rate of (<0.10 mm/rev).

Owolabi *et al.,* (2016) evaluate the effect of welding current on mechanical properties of weldment particularly on carbon steel and mild steel, where they discovered that the hardness of the weld increases with current of 115 A and 116c A for mild steel and low carbon steel respectively but show decrease with further increase in welding current and that of ultimate tensile strength decreases with increase in welding current but increases at welding current of up to 200cA for mild steel. They further discovered that the yield strength and impact strength and shows a decrease with an increase in welding current.

Sharma *et al.,* (2012) proposed a neural network base approach to complex optimization of cutting parameters; they used a neural optimization algorithm in developing a simple, fast and efficient optimization of all important optimum cutting parameters during machining where there is less time for deep analysis. Mild steel was used as work material and HSS/cemented carbide tipped as cutting tool under a dry environment surface roughness measuring instrument. The coefficient (R) of test performance of HSS is 0.91 while that of cemented carbide is 0.92 both on mild steel while their R value is 0.821 and 0.864 respectively. The valuation in percentage obtained of 82% and 86% shows the linear relationship between experimental and network predicted values, while the remaining percentage of the total variation in network predicted values remain unexplained. R^2 increases up to hidden neuron 25 then decreases in terms of testing cases. At the end, they selected the network consisting of 25 hidden neurons as optimum value of their work.

Adnan *et al.,* (2013) use particle swarm optimization (PSO) method to study and optimize the cutting temperature separated at both the primary heat zone and the secondary heat zone of weldment. Their study showed a major amount of energy is converted in to heat in the primary heat zone while the heat generated at the secondary heat zone is due to the rubbing at that interface. They also studied that the heat distribution pattern is dependent on the sizes and the thermal conductivity of the tool, work material and the cutting conditions. They also come up with a conclusion that the cutting force, feed rate and depth of cut greatly influence the shear zones temperature at the same time chip thickness and frictional forces have lower effect. They also reached that the secondary heat zone temperature increases with increase in feed rate and the cutting force at the same time decrease with increase in depth of cut.

Boumerzong *et al.*, (2010) studied the effect of arc welding on micro structures and mechanical properties mild steel (0.19wt. %). They analyzed the micro structure of the weld using optical microscopy and EBSD where it shows the effect of direction heat flow on elongation of ferrite grains. They further analyzed the micro structure of the center of weld zone to be different from heat affected zone (HAZ). The HAZ contains wild manstatten ferrite, large grains of ferrite and colonies of pearlite. They also observed that bonds of coarse grains grow along a certain preferred crystallographic direction and the max hardness values were found to be situated in the area of weld metal and HAZ which indicates its specification.

SUMMARY

This paper reviewed various researches that used soft computing techniques to developed optimization models for machining functions (tool life, cutting force and surface roughness) and parameters (cutting speed, feed rate and depth of cut). It has been established that process functions are greatly influenced by process parameters.

FUTURE WORK

Turning is one of the most widely cutting operations in production of new component and repair of failed ones. Failed shafts are mostly repaired because the cost of replacement is higher. Shafts are usually repaired through welding and subsequently machining process such as turning operation to obtain required dimensions. Machining weldment mostly results in excessive cutting tool wear due to difference in properties of the base metal and that of the weldment that is always harder due to metallurgical processes with consequential increase in cost of production. Optimizing Cutting Parameters of carbide tool wear in turning operations on mild steel shaft weldment using Box Behnken design of expert would be of economic value in industries.

REFERENCES

- Aslantas, K., Mohd, D., Ahmet, H., Mozammel, M., Munish, G., Turnad, G., & Hassan, I. (2020). Investigation on surface roughness and wear characteristic in Micro- turning of Ti-6A1-4V Alloy. *www.mpdi.com/Journal/materials. 13. 1-20*
- Abdulkareem, S., Rumah, U. J., & Adaokoma, A. (2011). Optimizing Machining Parameters during Turning Process. *International Journal of Integrated Engineering*, 3(1), 23-27.
- Al-Ahmari, A. M. A. (2008). Prediction and optimisation models for turning operations. *International journal of production research*, *46*(15), 4061-4081.
- Babu, V. S., Kumar, S. S., Murah, R. V., & Madhava, R. (2011). Investigation andValidation of Optimal Parameters for Least Surface Roughness in EN24 with Response Surface Method. *International Journal of Engineering and Technology*, 3(6), 146-160.
- Barman, M., & Mukherjee, S. (2015). Optimization of Process Parameters of Tool Wear in Turning Operation**.** *International Journal of Engineering Research and Application*, 5(4), 19-23.
- Basha, N. Z., Mahesh, G., & Muthuprakash, N. (2013). Optimization of CNC Turning Process Parameters on Aluminum 6061 Using Genetic Algorithms. *Journal of Science & Mordern Engineering*, 1(9). 43-46.
- Boumerzoug, Z., Derfouf, C., & Baudin, T. (2010). Effect of Welding on Microstructure and Mechanical Properties of an Industrial Low Carbon Steel. *Journal of Scientific Research in Engineering*, (2) 502-506.
- Fadhel, A. A., Mader, M. M., Ehsan, S. A. (2018). Calculation of wear rate by weight and volume for Alminium Sample. *Journal of university of Babylon for Engineering science*, 26(7).
- Ibrahim, G. A., Hamni, A., Burhanudin, Y., & Nadhira, W. (2019). Optimization of Cutting Parameters on Tool Wear Using Box-Behnken Design**.** *International Journal of Engineering and Technology*, 6(1), 2462-1269.
- Ibrahim, M. R., Abdulkadir, A. R., Omar, M. S., Sulaiman, S., & Osman, H. (2013). Optimization 0f Parameter for HSS Tool Wear by Using Taguchi Method and Finite Element *Method. Applied Mechanics and Material*, (315), 151-155.
- Kohli, A., & Dixit, U. S. (2005). A Neural-Network-Based Methodology for the Prediction of Surface Roughness in a turning process. *International Journal of Advance Manufacturing Technology*, 25, 118–129.
- Kumar, U., Singh, A., & Kumar, R. (2016). Optimization of Machining Parameters for Tool Wear Rate and Material Removal Rate in CNC turning by Grey Relational Analysis. *International Journal of Applied Engineering Research*, 11(4), 973–4562.
- Mahesha, N. S., Hanumantharaya, R., Mahesh, B. D., Ramakrishna, D. P., & Shivakumar, K. M. (2016). Investigation of the Dry Sliding Behavior of 17-4PH Stainless Steel. *American journal and material science*, 6(4A), 6-14.
- Chowdhury, N. T., & Dhar, N. R. (2011).

Experimental analysis and modeling of tool wear and surface roughness in hard turning under minimum quantity lubricant environment. *Operations Management*, *68*, 326-330.

- Olufayo. O. K., El-Hossein, A., & Niekerk, T. V. (2015). *Tool Wear Monitoring, Robotics and Mechatronics.* Conference of South Africa ROBMECH.
- Rout, I. S., Padhi, S. S., Biswal, J. N., & Panda, T. K. Optimization of cutting tool material in lathe machine by T-test. *International Journal of Modern Engineering Research*, 4(9), 32.
- Okokpujie, I. P., Ohunakin, O. S., Bolu, C. A., & Okokpujie, K. O. (2018). Experimental Data-Set for Prediction of Tool Wear During Turning of AL-1066 Alloy by High High-Speedle Cutting Tools. *Journal of Data in Brief*, 4(3), 2352-3409.
- Sharma1, P., Raju, S., Gopichand, A., & Subbaiah, K. V. (2012). Optimization of Cutting Parameters On Mild Steel with HSS and Cemented Carbide Tipped Tools Using ANN. *International Journal of Research in Engineering and Technology*, 1(3), 226-228.
- Owolabi, O. B., Aduloju, S. C., Metu, C. S., Chukwunyelu, C. B., & Okwuego, E. C. (2016). Evaluation of the Effect of Welding current on Mechanical properties of Welded Joints between Mild Steel and Low Carbon Steel. *American journal of materials science and application*, 4(1), 1-4.
- Jadhav, J. S., & Jadhav, B. R. (2014). Experimental Study of Effect of cutting parameters on cutting force in turning process. *IJIRAE*, *1*, 240-248.
- Jameel, A., Minhat, M., Nizam, M., MOSTAFA, B., CHAKKOR, S., ABDERRAHMANE, H., ... & ALI, A. A. A. (2013). Optimal Parameters Selection to Reduce Cutting Temperature of Mild Steel Using Particle Swarm Optimization Intelligent Technique. *Journal of Theoretical and Applied Information Technology*, *53*(3), 324-333.