Review of Tool Life Optimization Methods and their Effectiveness for Turning Inserts

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Abstract: - **The tool life prediction related detailed review has been done in the present work considering flank wear as the main criteria of tool failure. Taylor's extended tool life equation has been considered for the prediction. The different cutting parameters are considered and varied for optimization of tool life and to find the dominant affecting parameter amongst them. Different methods and approaches like Taguchi method, regression analyses have been considered here for tool life prediction. The areas for further required research of most optimized methods for tool life prediction with maximum accuracy have been discussed towards the end**

Keywords* — *Tool Life, Taylor's extended tool life equation, Taguchi method.

I. INTRODUCTION

Turning is one of the most basic and widely used metal cutting processes. The tool life of turning inserts greatly impact on the effectiveness and efficiency of the process. Tool failure leads to high inefficiency, High rework and rejection, and customer dissatisfaction. Significant improvements can be brought about in productivity by optimizing cutting parameters for best tool life.

Tool life: Tool life is defined as the cutting time or machining time or material removed satisfactorily before replacement or reconditioning. Modern tools usually fail by gradual wear like flank wear, crater wear etc. In research, tool life is defined as actual machining time by which fresh tool can work before attaining specific tool wear.

Flank wear: flank wear of the tool insert is one of the important factors which depend on tool geometry and the cutting conditions but more importantly the flank wear affects the surface roughness, tool life, and cost of the machining process.

The empirical relation for tool life is given by Taylor as VTn= c

By considering other cutting parameters like feed rate and depth of cut Taylor extended the above equation as T=Va*fb*dc

II. LITERATURE REVIEW

[1]Ali Reza motorcu has published experimental work on Tool Life Performances, their Mechanisms and Surface Roughness Characteristics when turning Austenised and Quenched AISI 52100 bearing Steel with different cutting tools at Indian Journal of Engineering and Materials Sciences in April 2011.

The author reports in his literature review that most of the machining study has been focused on hardened steels using ceramic or CBN cutting tools however a limited number of studies on the machining the steels using ceramic coated ceramic and CBN /TiC cutting tools have been reported with respect to surface roughness model. The author has also studied the whole surfaces of the cutting tools and examined them by scanning electron microscope (SEM) to find out the effective mechanism of wear. Furthermore, the effects of the cutting parameters and tools hardness on the tool life were also examined with these cutting tools. Materials used for the work AISI 52100 steels CNC machine used was John Ford 30 35 industrial type CNC lathe machine. Cutting tools of three types namely alumina ceramic tools coated ceramic cutting tools and CBN /TiC cutting tools were used. For the experimental procedure to types wears that are flank wear and crater wear flank wear being the most common tool wear compared with crater here because of its simplicity and is of measurement. The conclusions of both the criteria are presented in the publication. The numerical data about the surface roughness criteria is given. Qualitative conclusions about the relationship between various parameters and tool life are given for the flank wear criteria. Their behavior of Al2O3 ceramic tool in tool and CBN tool are given separately it is followed by the cutting tools hardness the effect. The qualitative relation tells that the surface roughness the cutting speed had the greatest effect on the optimal testing conditions. It is followed by the cutting tools hardness. The feed rate was also effective on to the life of the cutting tool it was shown that the tool life decrease with increasing cutting speeds in all cutting conditions what the longer to life was obtained for some tools than the others as given in the conclusion of the same publication. Among the cutting parameters the cutting speed was found to be more effective for to life and

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negligible effect for the surface roughness but the field rate was dominant for surface roughness.

The publication gives only a qualitative relation between cutting parameters and the tool life for the flank wear criteria; whereas quantitative relations are necessary in order to determine the values on the constant in Taylor's extended equation. Therefore need for establishing a similar method, but for numerical results is required. Similar qualitative results can be obtained by using the linear regression method on the quantitative results.

[2] Vikas B. Magdum optimized and evaluated machining parameters for turning on EN8 steel on a Lathe machine. This study investigates the use of tool materials and process parameters for machining forces for selected parameter range and estimation of optimum performance characteristics. Develop a methodology for the optimization of cutting forces and machining parameters. The analysis technique was investigated by turning with cutting parameters and analysis by the Taguchi method. One of the most commonly used methods for optimizing the turning process is the Taguchi approach with the cutting force most commonly selected as the target quality characteristic to investigate the effect of various process parameters on the product.

[3] CJ Rao et al. optimized process parameters for tool life during turning operation. In any metal cutting operation the features of tools, input work materials, machine parameter settings will influence the process efficiency and output quality characteristics. A significant improvement in cost efficiency may be obtained by process parameter Optimization that identifies and determines the regions of critical process control factors leading to desired outputs or responses with acceptable changes guaranteeing a less price of production. For turning process the cutting conditions i.e. speed feed and depth of cut plays an important role in the efficient use of machine tool. For this study, the tungsten carbide tool was chosen. Tungsten carbide is an organic chemical compound containing equal parts of tungsten and carbon atoms tungsten carbide is often simply called carbide. The CNC machine used for experimentation was MTAB CNC turning with a Fanuc controller. The machine is best suitable for machining aluminum ingots so aluminum is selected as work material. Cutting speed, feed and depth of cut were varied one at a time keeping other two constant and results for cutting force and tool life was recorded. Using the data recorded and MATLAB program process parameter i.e. cutting speed, feed and depth of cut were optimized for maximum tool life and surface finish.

[4] Puneet NP et al. studied the flank wear in turning of EN8 Steel. As flank wear largely affects the surface finish of components, they analyzed the effect of cutting parameters on flank wear during turning of EN8 Steel. They used three different turning inserts, two uncoated and one coated and using different cutting parameters they recorded for flank wear and made their conclusions that are cutting speed and feed together have compound effect on flank wear, to get minimum flank wear medium feed and medium cutting speed is to be used, coated turning inserts give better performance than uncoated ones in terms of flank wear and tool life in general.

[5] DS Sai Ravi Kiran et.al. worked on the project that deals with the optimization of tool life and machining cost while performing machining on CNC Milling machine. In many production contexts it is still necessary to rely on engineering judgment to optimize a multi-response problem, therefore uncertainty seems to prevail during the decision making process. The experiments are conducted through the Design of Experiments (DOE). The experiment has been carried out by using solid carbide flat end mill as a cutting tool and stainless steel (S.S-304) as a workpiece. The approach is carried out using a 3-level full factorial method and is performed using Minitab V15 package. The input parameters are taken as cutting speed, feed, and depth of cut while the responses are tool life and machining cost. The experimental results display that the cutting speed and depth of cut are the significant parameters that influence the tool life.

[6] Nexhat Qehaja et al. In their paper presented a methodology for the development of tool life prediction model for the first-order tool during turning of hardened 42CrMo4 steel at different levels of hardness. It is important to be able to predict and describe the tool life in regards to manufacturing costs during industrial production. Tool life is defined as the cutting time for which tool can be used. Cutting tools are used till they have not reached the tool life criteria and produce tools with required quality and accuracy. Flank wear of cutting tools is usually important because the tool life criterion as a function of it determines the accuracy of machining and stability. Tool wear is defined as a gradual loss of tool material at contact zones of workpiece and tool material, resulting in the cutting tool to reach its life limit. This paper investigates the tool wear of TiN coated inserts while dry cutting, utilizing the central composite way of experimental methodology (DoE) with 3 factors at 3 levels. By using the multiple linear regression analysis between cutting speed, feed rate and depth of cut, it determines the effects of cutting conditions on extended Taylor's tool life equation.

[7] Study by JA arsecularatne et.al. states that the tool life measurement and its controls are one of the very important factors in manufacturing processes like turning, milling, roughing etc. But in order to give an accurate relationship between tool life and cutting conditions, there is no such machining theory available. This is due to innumerable combinations and inadequate data and relationships to present these relationships. So we are compelled to use empirical relationship for this in which tool life equation proposed by Taylor is very popular and widely used. This research work has presented dominant mechanisms for tool wear using tool life, temperature and Taylor's standard

exponents. In the two types present that are catastrophic and progressive wears of the tool, the progressive tool life i.e flank wear can be considered as a success criterion for obtaining effective tool life as flank wear has a negative influence on dimensional accuracy, surface finish and stability of machining process. For the wear of WC type tool, the dominant tool wear will mostly depend on cutting parameters, tool-work material and majorly also on the temperature condition created due to these parameters. The work also contributes towards the explanation related to abrasive and adhesive wear with major reasons and temperature ranges of their way occurrence. The tools such as PCBN, PCD have a variety of different mechanisms responsible for the flank wear hence it is very difficult to understand the dominant mechanisms amongst them. The paper also says that cutting speed and cutting distance also have a really great impact on flank wear of tools like PCBN PCD tungsten carbide tools along with the temperature. For the tools with a variety of mechanisms for flank wear the tool material pairs such as WC- MMC, PCB-hardened steep, PCD- MMC were taken. Which concludes that for PCBN tool the wear is mostly due to continuous formation and removal of chemical compounds resulting from chemical reactions from tool material and atmosphere? For PCD the major conditions were found as microcracking, abrasion and adhesion concluding towards temperature control and tool parameter control

[8] R. Vinayagamoorthya and M. Anthony Xaviorb in 'Parametric Optimization on Multi-Objective Precision Turning Using Relational Analysis' stated that the objective of the paper is to analyze the performance of precision turning under dry working conditions. Various parameters that affect the machining processes were identified and a conclusion was reached regarding its values. In order to perform machining under the selected levels of conditions and parameters and to estimate the, cutting temperature and surface roughness generated as the result of the machining process. Based upon the experimental values, Analysis of Variance was conducted to understand the influence of various cutting parameters on, surface roughness, cutting force, tool wear and cutting tool temperatures during precision turning of titanium alloy. Optimal levels of parameters were identified using relational analysis, and significant parameter was determined.

The time and cost for doing the experiment are very high in order to find the optimal parameters for machining. The number of readings increases as multiple parameters are involved. It concludes that for finding optimal parameters in an efficient and optimal method it is necessary to select an orthogonal array using the Taguchi approach.

[9] S.E. Arabia and D.R. Hayhurstb in 'Tool life determination based on the measurement of wear and tool force ratio variation stated that non-linear regression analysis techniques can be used to establish models for wear determination in terms of the variation of a magnitude relation of various forces acting the tool tip. Wear and tool life determination in terms of the variation of a ratio of force components acting at the tool tip. Predictions of the model have been compared with the results of experiments, and with predictions of an extended Taylor model. Techniques for describing tool wear and failure are based mostly either on the utilization of databases with interpolative and extrapolative techniques or on the utilization of specific mathematical relationships. In case, the random nature of tool wear provides obstacle to the accomplishment of best production conditions.

The model which is developed in the paper by S.E. Orabya, D.R. Hayhurstb 'Tool life determination based on the measurement of wear and tool force ratio variation which describes initial force ratios as a function of feed happens to be of secondary importance. The determination by these models does not give an accurate prediction of tool life. Extended Taylor's model has a good predictive capability which relates a measure of wear with the other cutting parameters

III. RESEARCH GAP

Ref. No.	Authors	Research gap found
1.	Ali Reza Motorcu	Qualitative relations between cutting parameters and tool life are given but quantitative results are needed to generalize the process using Taylor's extended equation
3.	CJ Rao	Feed rate and depth of cut coefficients have to be calculated experimentally for each tool and workpiece material pair.
4.	Puneet N P	Flank wear and tool life are greatly influenced by cutting parameters so the study of flank wear is important and can be used to calculate experimental tool life.
7.	JA Arsecularatne	As there are a variety of mechanisms for flank wear of tools the more focus should be given on finding a dominant cutting parameter for improvement/optimization of tools life. Some experimental work is necessary for the area of Taylor's extended tool life empirical equation for the different constant.
8.	R.Vinayagamoorthya	More amounts of Time and cost are required for calculating the tool life by the conventional method of experiment. The equation is a combined function of various parameters. The multi parameters are difficult to analyze in order to find accurate optimal parameters
9.	S.E.Oraby	This paper gives a model for tool life prediction based on tool force ratio and feed. But as forces on the tool on each point are difficult to find this model is of secondary importance

IV. Conclusion

Various studies reviewed show that tool life improvement can be achieved by various factors such as optimizing cutting parameters, using coated inserts, using better cutting fluids, etc. But amongst them, all cutting parameters are very important as they affect all other parameters related to tool life. Therefore to find out the optimized values of cutting parameters is very important and as studied above in various works method like experimentally optimizing the cutting parameters for individual tool-workpiece material pair using Taylors extended equation is quite significant. This method uses experimentation using Taguchi array and then using the observations in regression analysis to calculate feed rate and depth of cut constants and hence the tool life.

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