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REVIEW ON PRIDICTION PARAMETERS OF TURNING OPERATION ON HARDENED STEEL

Sharawan Kumar Gendele, Anand Shrivas, Amit Kachhawa
Mechanical engineering department
Dr. C V R U, Bilaspur

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Corresponding Author
* Sharawan K. Gendele

The present work is to review the paper on performance of multi-layer coated tool in machining of hardened steel (AISI 4340 steel) under high speed turning. The influence of cutting parameters (speed, feed, and depth of cut) on cutting forces and surface finish has been analyzed. Under the different cutting conditions, forces were measured using dynamometer. Cutting force and MRR are mostly affected by speed and feed. Mathematical models were deduced by software design Expert in order to express the influence degree of the main cutting variables such as cutting speed, feed rate and depth of cut on cutting force components. The gap indicates that the depth of cut is the dominant factor affecting cutting force components. The depth of cut influences tangential cutting force more than radial and axial forces.

1. Introduction:

This method deposits thin films on the cutting tools through various chemical reactions. Most tool coatings were traditionally deposited using the CVD technique until the recent development of PVD. This method deposits thin films on the cutting tools through physical techniques, mainly sputtering and evaporation. The majority of cutting tools in use today employ chemical vapors deposition (CVD) or physical vapor deposition (PVD) hard coatings. The high hardness, wear resistance and chemical stability of these coatings offer proven benefits in terms of tool life and machining performance. The first technique is the CVD.AISI 4340 is a heat treatable, low alloy steel containing nickel, chromium and molybdenum. It is known for its toughness and capability of developing high strength in the heat treated condition while retaining good fatigue strength. Typical applications are for structural use, such as aircraft landing gear, power transmission gears and shafts and other structural parts.

Coated hard metals have brought about tremendous increase in productivity since their introduction. Since then coatings have also been applied to high speed steel and especially to HSS drills. Coatings are diffusion barriers, they prevent the interaction between chip formed during the machining and the cutting material itself. The compounds which make up the coatings used are extremely hard and so they are very abrasion resistant. Typical constituents of coating are Titanium Carbide(TiC), Titanium Nitride (TiN), Titanium

Carbonitride (TiCN) and alumina (Al2O3).All these compounds have low solubility in iron and they enable inserts to cut two le at a much higher rate than is or multi-layer.

Metal cutting process forms the basis of the engineering industry and is involved either directly or indirectly in the manufacture of nearly every product of our modern civilization. The cutting tool is one of the important elements in realizing the full potential out of any metal cutting operation. Over the years the demands of economic competition have motivated a lot of research in the field of metal cutting leading to the evolution of new tool materials of remarkable performance and vast potential for an impressive increase in productivity. An area of research interest in metal cutting is the analysis of cutting force, as minimum power consumption is a never-ending endeavor. Among the Cutting force, Thrust force and Feed force the former prominently influences power consumption and the most common equation available for the estimation of Cutting force parameter of research interest is Material removal rate of the workpiece produced.

Turning is a very important machining process in which a single point cutting tool removes unwanted material from the surface of a rotating cylindrical workpiece. The cutting tool is fed linearly in a direction parallel to the axis of rotation. Turning is carried on a lathe that provides the power to turn the workpiece at a given rotational speed and feed to the cutting tool at specified rate and depth of cut. Therefore three cutting parameters namely cutting speed, feed rate and depth of cut need to be optimized in a turning operation. Turning operation is one of the most important operations used for machine elements construction in manufacturing industries i.e. aerospace, automotive and shipping. Turning produces three cutting force components as shown in fig.1a,(the main cutting force i.e. thrust force, (FZ), which acts in the cutting speed direction, feed force, (FX), which acts in the feed rate direction and the radial force, (FY), which acts in radial direction and which is normal to the cutting speed).

2. Literature Review:

Increasing the productivity and the quality of the machined parts are the main challenges of manufacturing industries. This objective requires better management of the machining system. This literature includes information on hard materials, soft materials, and soft and abrasive materials used in turning, coating materials for cutting tools, wear observed during turning operations and surface finish of the machined workpiece. Machining of AISI 4340 steel to study the effect of cutting speed and wear land length on the surface damage produced during machining of quenched and tempered AISI 4340 steel under dry, orthogonal conditions was determined. The user of the machine tool must know how to choose cutting parameters in order to minimize cutting time, cutting force and produce better surface finish under stable conditions.

Anixter et al. [1] in turning process, they proposed a methodology of evaluating those uncertainty components of a single cutting force measurement that are related to the contributions of the dynamometer calibration and the cutting process itself. On the basis of the empirical model including errors from both the sources, the uncertainty for a single measurement of cutting force, and expressions for the uncertainty vs. cutting parameters are presented. For a defined range of cutting parameters, approach gives the possibility of evaluating cutting force uncertainty components, on the basis of few experiments.

Fang and Jawahir [2] predicted three important machining parameters, i.e. the cutting force ratio, chip thickness, and chip back-flow angle, on the basis of: the universal slip-line model, a maximum value principle in order to determine the state of stresses in the plastic region in restricted contact machining, Dewhurst and Collins' matrix technique and Powell's algorithm for non-linear optimizations and by correct implementation of these techniques it is found that the parameters cutting force, chip thickness, chip back-flow angle can easily be determined.

Shet and Deng [3] presented a finite element method to simulate and to analyze the orthogonal metal cutting process under plane strain conditions, with main attention on the residual stress and strain fields in the finished workpiece. Various modeling options have been employed. Considering material properties, the range of tool rake angle and friction coefficient values it has been found that thermal cooling increases the residual stress level whereas effects of the rake angle and the friction coefficient are nonlinear and the observed residual stress results were finally compared with experimental results.

Yen et al. [4] focused the effects of edge preparation of the cutting tool (round and chamfer edge) on-chip formation, cutting forces, and process variables like temperature, stress, and strain etc. in orthogonal cutting. With finite element method (FEM) simulations a fundamental understanding of the process mechanics with realistic cutting tool edges was provided, also it is possible to estimate the values of process variables that are very difficult to measure by experiment not measurable for cutting. On the basis of results carried out from the cutting simulation model, an analysis of tool wear is also possible as it is directly related to cutting temperature, stresses and chip sliding velocity.

Majumdar et al. [5] focused on the influences of the heat generation during metal cutting processes and its effects on cutting forces and tool wear. For this purpose, they developed a finite element based computational model in order to determine the temperature distribution in a metal cutting process on high-speed carbon steel. Results show that as cutting speed increases from 29.6 m/min to 155.4 m/min maximum temperature in the tool will also increase from 709.36 K to 1320 K. The model also describes the significant effect of conduction and convection losses in heat dissipation and temperature rise in the tool.

Son et al. [6] showed that because of large rake angle there is unstable cutting process without a continuous chip. In this investigation, they applied vibration cutting method for the possibility to reduce the minimum cutting thickness by changing the friction coefficient between tool and workpiece. The vibration cutting method is applied to increase the friction coefficient. On the basis of theoretical investigation and experimental verification results show that the cutting technology is efficient by decreasing the minimum cutting thickness and increasing the friction coefficient. Depending upon materials and vibration conditions the minimum cutting thickness was considerably reduced by 0.02–0.04 mm.

Akasawa et al [7] studied force variations and their effects in metal-deforming technological processes 14. They suggest that interaction of the energy waves propagating in the medium might affect the cutting force. They experimented and studied on the interaction between the deformation and the heat waves. The conclusions drawn from this paper reveals that the study of cutting force and the interaction between the deformation and heat waves can be very helpful in adopting the process which involves the least energy consumption.

3. Review Based on MRR

Krishnakant et al. [16] analyzed that an optimization of turning process by the effects of machining parameters applying Taguchi methods to improve the quality of manufactured goods, and engineering development of designs for studying variation. EN24 steel is used as the workpiece material for carrying out the experimentation to optimize the Material Removal Rate. It could be concluded that this method with its perfect amalgamation of statistical and quality control techniques was one of the effective and efficient methods of its kind to highlight the benefits of designing quality into products upstream rather than inspecting out bad products downstream. It offers a quantitative solution to identify design factors to optimize quality and reduce cost. Also, the application of this method is not confined to a particular domain but also to other fields like product and service sectors. It thus is a powerful method as compared to the other intuitive and more cumbersome methods encompassing a large number of fields in terms of application.

Nicoleta Lungu and Marian BORZAN [17], performed the finite element simulation to study the effect of cutting speed and feed rate on tool geometry, temperature and cutting forces. The AISI 1045 carbon steel used as a workpiece material and tungsten carbide coated with a TiCN layer used as a tool. The Deform 2D machining software used for finite element simulation. The results show that the temperature value increases with the increase in cutting speed but at that time the value of cutting forces decreases and cutting forces increases with increase in feed rate.

Gaurav Bartarya et al. [18] investigated the effect of cutting parameters on cutting force and surface roughness during finish hard turning AISI52100 grade steel. The turning of hardened EN31bearing steel (60±2 HRC) which is equivalent to AISI52100 was performed on a stiff heavy duty lathe (Make: HMT). CBN insert (Make: Seco, type TNGA160408 S01525) of chamfered edge geometry was used on Seco tool holder (type PTGNR 2020 K16). A full factorial design of experiments procedure was used to develop the force and surface roughness regression models. To test the quality of fit of data, the ANOVA analysis was used. After the experiment depth of cut was found to be the most influential parameter affecting the three cutting forces followed by the feed. Cutting speed was least significant in case of axial and radial force models but was not significant for the regression model of cutting force.

Chomsamutr et al. [19] objective of the research is to compare the cutting parameters of turning operation the workpieces of medium carbon steel (AISI 1045) by finding the longest tool life by Taguchi methods and Response Surface Methodology: RSM. This research is to test the collecting data by Taguchi method. The analyses of the impact of the factors are the depth of cut, cutting speed and feed rate. This research found that the most suitable response value; and tool life methods give the same suitable values, i.e. feed rate at 0.10 mm/rev, cutting speed at 150 m/min, and depth of cut at 0.5 mm, which is the value of longest tool life at 670.170 min, while the average error is by RSM at the percentage of 0.07 as relative to the testing value.

Chandrasekaran et al. [20] have investigated the effects of process parameters on surface finish and material removal rate (MRR) to obtain the optimal setting of process parameters. Taguchi method was used for studying the machinability of AISI 410 on CNC lathe for surface roughness. L27 orthogonal array, analysis of variance are used in this investigation And the analysis of Variance (ANOVA) is also used to analyze the influence of cutting parameters during machining. In this work, AISI 304 stainless steel workpieces are turned on a conventional lathe by using tungsten carbide tool. The results revealed that the feed and nose radius is the most significant process parameters on workpiece surface roughness.

However, the depth of cut and feed are the significant factors on MRR.

Atul Kulkarni et al. [21] used Taguchi method to optimize cutting parameters during dry turning of AISI304 austenitic steel with AlTiCrN coated tool. They have discussed an application of the Taguchi method for optimizing the cutting parameters in turning operations. The Taguchi method provides a systematic and efficient methodology for the design optimization of the cutting parameters with far less effect than would be required for most optimization techniques. It has been shown that tool life and surface roughness can be improved significantly by turning operations.

4. Review based on ANOVA

Nayak et al. [22] have presented in the paper the multi-response optimization of turning parameters for Turning on AISI 304 Austenitic Stainless Steel. Experiments are designed and conducted based on Taguchi's L27 Orthogonal array design. This paper discusses an investigation into the use of Taguchi parameter Design and Regression analysis to predict and optimize the Surface Roughness, Metal Removal Rate and Power Consumption in turning operations using CVD Cutting Tool. The Analysis of Variance (ANOVA) is employed to analyze the influence of Process Parameters during Turning. This work also remarks the advantages of multi-objective optimization approach over the single-objective one. The useful results have been obtained by this research for another similar type of studies and can be helpful for further research works on the Tool life and Vibration of tools etc.

Atul P. Kulkarni et al. [23], experimentally investigated the effects of machining parameters on the surface finish, cutting force, tool wear, chip thickness, and tool life. The AISI 304 austenitic stainless steel used as a workpiece and AlTiCrN coated insert produced by High Power Pulsed Magnetron Sputtering (HPPMS) used for dry turning. The experiment was carried out at different cutting speed and feed with a constant depth of cut. The results show that the surface roughness value increases with increase in feed and low at the high cutting speed. The flank wear was prominently affected by cutting speed and feed.

H Aouici et al. [24], experimentally investigated the effect of cutting conditions on surface roughness and cutting forces in hard turning of X38CrMoV5-1 with CBN tool. The results show that the effects of cutting speed on surface roughness and on cutting forces at various feed rates and also show that the analysis of variance(ANOVA) of the data with the surface roughness parameters and cutting forces components. They concluded that the depth of cut has a maximum effect on the cutting force component as compared to the feed rate and cutting speed.

Sunil Kumar Sharma et al. [25] have analyzed that Taguchi optimization technique pair with grey relational analysis has been adopted for evaluating parametric complex to carry out acceptable surface roughness lower is better, material removal rate higher is better of the AISI 8620 steel during turning on a CNC Lathe Trainer. After identifying the optimal process parameters setting for turning operation, ANOVA is also applied for finding the most significant factor in turning operation. In this study, it is concluded that the feed rate is the most significant factor for the surface roughness and material removal rate together, as the P-value is less than 0.05. Cutting speed and depth of cut is found to be insignificant from the ANOVA study

Awadhesh Pal et al. [26], experimentally investigated the effect of workpiece hardness and cutting parameters on the different responses which were analyzed by performing analysis of variance (ANOVA) technique. The AISI 4340 steel used as a material and TiC mixed alumina ceramic tool used for soft and hard turning.

From the experiment, they observed that all the components of cutting forces increases with the increase in depth of cut and the magnitude of the cutting forces increase with the increase in workpiece hardness. The results also show that surface roughness decreases with increase in hardness level of the workpiece and the average value of the chip-tool interface temperature increases with increase in cutting speed.

Sudhansu Ranjan Das et al. [27], experimentally investigated the effect of cutting speed, feed and depth of cut on the cutting force and surface roughness. The AISI 52100 bearing steel used as a material and CNB tool used for an experiment. The analysis of variance (ANOVA) technique was used for identifying the factors significantly affecting the cutting force and surface roughness. Their results show that the feed rate and cutting speed strongly influence on the surface roughness. Also, the cutting force increases with the increase in feed rate and depth of cut and decreases with cutting speed.

5. Review based on feed rate

Sharma et al. [28] focused on the assessment of metal machining process parameters and on the development of adaptive control, shows that machine performance, work-piece and tool material selections, tool life, quality of machined surfaces, the geometry of cutting tool edges, and cutting conditions are closely related to the cutting forces. The paper deals with checking the design of lathe tool dynamometer under the capacity of 500 kg and optimization of their cutting force measurement. In this, mechanical gauges were replaced by resistance strain gauges which are being utilized to sense the cutting forces during machining and give the necessary information of cutting forces in terms of resistances which is the measure of cutting and feed forces. The data is obtained using the technique of force measurement in metal machining processes. In particular for turning process the results are analyzed, leading to an appraisal of the current status of the cutting force measurements w.r.t. Feed rate, depth of cut and feed/revolution.

Gupta & Sood [29] investigate cooling method influences the deformation mechanism, which is related to the cutting forces, tool wear and surface finish of the parts. The deformation mechanism of AISI 4340 sheets of steel machining conditions are known to be very different from that of commonly used industrial materials. Therefore, the effect of cutting parameters and cooling methods on cutting forces, tool wear and surface roughness in machining of AISI 4340 steel is of particular interest. This paper investigates experimentally and analytically the influence of various process parameters, given as cutting speed (*v*), feed rate (*f*) and different cooling conditions (i.e. dry, wet and cryogenic in which liquid nitrogen used as a coolant) using uncoated tungsten carbide insert tool on three major characteristics (cutting force, tool wear and surface roughness) of a turned AISI 4340 steel part. The Taguchi's L9 orthogonal array, analysis of variance (ANOVA) and grey relational analysis (GRA) are executed to study the effects, significance, percentage contribution and optimum settings of given process parameters. The results obtained show that the machining performance can be improved by this approach.

Dogra et. al. [30] performed experiments by using material specimens of EN8 to know the effect of different machining parameters on tool wear. The main objective of this study was to investigate the effect of cutting parameters and the workpiece on the tool wear during a machining of EN8 material. The quality of workpiece material is a main contributing factor as spindle speed, depth of cut and feed rate which may be influenced by tool wear through cutting operation. The experimental design was formed based on Taguchi's Technique. An orthogonal array L(3)9 and

Analysis of Variance are employed to investigate the turning conditions and machining was done using coated tool insert with specific density of 7.8 Kg/m3

Rashid et. al. [31] investigated on finding the current attainable limits of hard turning using a CNC turret lathe. Accordingly, this study aims to contribute to the existing literature by providing the latest experimental results of hard turning of AISI 4340 steel (69 HRC) using a CBN cutting tool. An orthogonal array was implemented using a set of judiciously chosen cutting parameters. Subsequently, the longitudinal turning trials were carried out in accordance with a well-designed full factorial-based Taguchi matrix. The speculation indeed proved correct as a mirror finished optical quality machined surface (an average surface roughness value of 45 nm) was achieved by the conventional cutting method using a CBN cutting tool. Furthermore, signal to noise (S/N) ratio analysis, analysis of variance (ANOVA), and multiple regression analysis were carried out on the experimental datasets to assert the dominance of each machining variable in dictating the machined surface roughness and to optimize the machining parameters. One of the key findings was that when feed rate during hard turning approaches very low (about 0.02 mm/rev), it could alone be most significant (99.16 %) parameter in influencing the machined surface roughness (Ra). This has, however, also been shown that low feed rate results in high tool wear; so, the selection of machining parameters for carrying out hard turning must be governed by a trade-off between the cost and quality considerations.

Kharea & Agarwal [32] research on cryogenic turning process involves the modeling and optimization of the process parameters affecting the machining performance and value-oriented sustainable manufacturing. In the present work, the machining parameters namely the cutting speed, feed rate, depth of cut and rake angle are optimized for the minimum surface roughness of AISI 4340 steel. The experimentation was planned based on the orthogonal array (L9), the signal-to-noise (S/N) ratio, and the Qualitek-4 were employed to the study the surface roughness in the turning of AISI 4340 steel under cryogenic condition. It was observed that cutting speed and depth of cut was the most influential factors on the surface roughness. To validate the study, confirmation experiment has been carried out at an optimum set of parameters and predicted results have been found to be in good agreement with experimental findings. The results have revealed that cryogenic machining has yielded better surface finish.

Kamble et al. [33] investigated by applying principal component analysis with Taguchi method. Five process parameters, viz cutting environment, nose radius, feed rate, depth of cut and tool type are used to optimize multi-quality characteristics namely surface roughness, MRR, cutting force, tooltip temperature. Also to make the design robust, experimentation is performed under the different levels of spindle vibration. Due to the limitation of Taguchi method for multi optimization, the principal component analysis is hybrid used to solve this problem. Image processing in Matlab, the unconventional method of measuring tool wear is used. Coated(CVD & PVD) and un-coated cutting tools and the latest lubrication method (Minimum quantity lubrication) are also considered to match the current scenario of the manufacturing system. PCA is used to change multiple objectives to a single objective.

Conclusion:

From the available literature, it can be seen that though some work has been reported on the influence of turning parameters on surface roughness and cutting forces measurement of the machined surface, no attempt has so far been made to systematically to optimize the process variables with a view to obtain favorable responses. Moreover, cutting forces cannot be characterized as a single response since it typically includes cutting force on turning process. Therefore, there should be research endeavor to apply multi-objective optimization techniques in order to achieve a reasonably low value of SR and high value of cutting forces.

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