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A REVIEW "EFFECTS OF CUTTING PARAMETERS ON CUTTING FORCES AND FLANK WEAR IN HARD TURNING OF ALLOY STEEL AND PREDICTION BYARTIFICIAL NEURAL NETWORK

KEYWORDS hard turning, cutting tool forces, flank wear, ANN model

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ABSTRACT *This paper describes a review of basic terms and visualizations of the major components of the hard turning cutting parameter in process. The parameters like cutting speed, depth of cut and feed rate are taken into account so as to predict their effects on cutting tool forces and flank wear. Hard turning can produce as good or better surface finish at significantly higher material removal rates without using coolant or special tooling. High accuracy achieved by hard turning. This process has been developed as an alternative to the grinding process in a bid to reduce the number of setup changes, product cost and lead time without compromising on surface quality to maintain competitiveness. Artificial neural network (ANN) approach is an accurate and powerful tool for machining process modeling. ANN approach permits to save much time and money generally spent in experiments. A large amount of works have been carried out on forces modeling which have shown that ANN approach is more accurate and faster than many other analytical and numerical cutting force modeling methods.*

INTRODUCTION

During the last decade, hard part turning has been shown capable of replacing grinding in many operations in different industrial areas like automotive, roller bearing and hydraulic industries due to the fact that the hard turning process offer better flexibility, lower production cost [3, 4, 5], short lead–time and better ecological aspects compared to grinding. The development of flank and crater wear is the main factor which contributes to geometric errors and thermal damage to the machined surface. Moreover, the tool wear also influence the cutting forces which causes instability in the tool motion which leads to inaccuracy.

During hard turning one of the most important factors is tool wear. The tools wear are classified as flank wear, crater wear, and nose wear etc. The primary tool wear are classified as flank wear, crater wear and nose wear, are important wear which will affect the smoothness of the product, cost of operation and performance. During turning tool wear is caused by the normal load generated by interaction between tool tip and work piece. It is very important to minimize tool wear, and optimizing all the cutting parameters like depth of cut, cutting velocity, feed rate, cutting fluids and cutting fluid application. The study of the wear behavior and predicting tool life of CBN during machining hard martensite stainless steel is needed.

The concept of an artificial neural network has emerged with the idea that it simulates the operating principles of a human brain. The first studies were made with mathematical modeling of biological neurons that make up the brain cells. An artificial neural network consists of a large number of interconnected processing elements. Artificial neural network processing elements are called simple nerves.

An artificial neural network contains a large number of interconnected nodes. A nerve is the basic unit of an artificial neural network. An artificial nerve is, thus, simpler than a biological nerve. All the artificial neural networks are derived from this basic structure. The differences in the structure of artificial neural networks result in different classification types.

The learning procedure can be affected by establishing correct correlations between the input and the output in artificial neural networks. This process falls below a certain value of the error between the foreseen output and the desired output. Artificial neural networks learn like a human. The more samples are used for learning, the more accurate is the obtained result. When a certain input is entered, the network can make changes to the data in order to give similarly accurate answers.

LITERATURE REVIEW

S.Thamizhmanii et al. [1] conducted study on a flank wear on CBN and PCBN tools due to cutting forces and develop the clear relation between them. Turning tests were carried using cutting speeds of 100, 125, 150, 175 and 200 m/min with feed rates of 0.10, 0.20 and 0.30 mm /rev and constant depth of cut of 1.00 mm. The performances of cutting tools were evaluated based on the flank wear and cutting forces. The wears were measured by scanning electron microscope and the cutting forces measured by a dynamometer. There is clear relationship between flank wear and cutting forces while turning hard martensitic stainless steel by CBN and PCBN tools.

During the study AISI 440 C as a workpiece material and CBN tool were used. The turning experiments were conducted using on NC Harrison 400 Alpha Lathe with 7.5 kW capacity and after the experiment develop the relationship between flank wear and cutting forces while turning hard martensitic stainless steel by CBN and PCBN tools. The lower the cutting force leads to low flank wear and low cutting force provides good dimensional accuracy of the work material including the surface roughness. Flank wear formation was more by abrasion. The built up edge formed reduced the cutting force and also the heat at cutting zone [4]. Flank wear and crater on the rake face and hard metal depositions on the cutting tool surface are the damage that takes place during turning process. If higher the values of flank wear area, the higher the friction of the tool on the work material and high heat generation produced [2,4].

Gaurav Bartarya et al. [2] investigated 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:

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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 [3]. The response surface analysis showed that forces first decreased and then increased with increase in cutting speed. The most energy efficient cut can be achieved for relatively lower and moderate cutting speeds with moderate depth of cut in the range of parameters selected for nearly all feed values selected in the range. It also showed a critical range of cutting speed when thermal softening responsible for reduction in the forces generated [1,4].

D.I. Lalwani et al. [3] also reported that Effect of cutting parameters on cutting forces and surface roughness in finish hard turning of MDN250 steel. MDN250 steel as a Workpiece material and Coated ceramic inserts TNMA160408S01525 (Sandvik, Grade CC6050) were used in the experimental work with double clamp-type MTJNR 2525M16 (Mitsubishi Material Co.) tool holder. Rigid, high power precision NH22 (HMT, India) lathe equipped with specially designed experimental setup was used for experimentation. The machining experiments[2] were conducted based on response surface methodology (RSM) and sequential approach using face centered central composite design. After the experiment findings are Cutting speed has no significant effect on cutting forces and surface roughness. In Feed force model, the depth of cut is most significant factor with 89.05% contribution in the total variability of model whereas feed rate has a secondary contribution of 6.61% in the model. In Thrust force model, the feed rate and depth of cut are significant factor with 46.71% and 49.59% contribution in the total variability of model, respectively. In Cutting force model, the feed rate and depth of cut are the most significant factors affecting cutting force and account for 52.60% and 41.64% contribution in the total variability of model, respectively. The interaction between these two provides a secondary contribution of 3.85%.

S. Thamizhmnaii et al. [4] conducted study on Tool flank wear analyses on martensitic stainless steel during hard turning. Investigation of turning CBN tool in the machining of hard AISI 440 C material was carried out by turning process. The turning experiments were performed using N.C. Harrison 400 lathe. All experiment data were obtained on AISI 440 C hardened steel having hardness between 45 to 55 HRC. The conclusions after experiments were drawn that the higher flank wear occurred at low cutting speed with high feed rate and more depth of cut. i.e. at cutting speed of 125 m/min, feed rate of 0.125 mm/rev and DOC of 1.00 mm. The influence of tool flank wear was due to abrasive action between tool tip and cutting tool, hard carbides in the work piece material. At low cutting speed of 125 m/min. formation of built up edge was inevitable due to more contact time. The flank wear was also due to heat generated at low cutting speed [1].

M. Ibrahim et al. [5] carried out work on Wear development and cutting forces on CBN cutting tool during Hard turning of different hardened steels such as SS2244 (DIN 42CrMo4), SS2511 (DIN 16MnCr5) and SS2260 (DIN X100CrMoV51) using the cutting tool material used in this investigation is a high CBN content grade (88 % volume) with metallic binder and a grain size of 2 μm. According to the results of this experimentation, the conclusions can be obtained is that there is a clear relationship between the chemical composition, micro structure and machinability of hardened steel [4]. A combination of metallic binder and high CBN content results in rapid wear development in continuous turning of hardened steel. The analysis of the tool life, wear development, chip form and cutting forces clearly shows that the induction hardening gives the best machinability in terms of tool life, cutting forces, chip form and wear development. The influence of induction hardening and case hardening processes on the tool life is very similar.

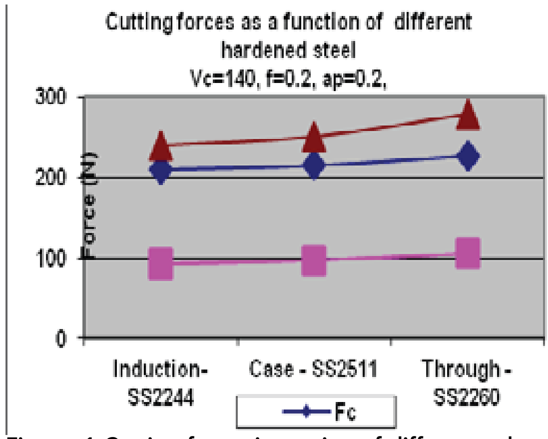

Figure: 1 Cutting forces in turning of different hard ened steels [5]

Souad Makhfi et al. [6] reported that a large number of interrelated machining parameters have a great influence on cutting forces so it is quite difficult to develop a proper theoretical model to describe efficiently and globally a machining process. In this paper, an artificial neural network (ANN) model is then proposed to predict cutting force components during hard turning of an AISI 52100 bearing steel using CBN cutting tools. This study was based on an experimental data set of cutting forces measured during hard turning. Cutting speed, feed rate , cutting depth and workpiece hardness (HRc, MPa) are taken as input parameters in the ANN model, while the three cutting force components (feed force Fa, radial force Fr and cutting force Ft, in N) are the output data. The ANN model of consists of a multi-layer feed-forward, trained by a back-propagation

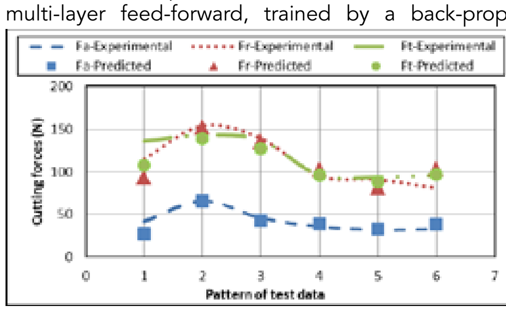

Figure 2. Experimental and predicted cutting force components in testing for the 4-11-3 structure [6]

The main objective of this study was to develop a robust numerical model to predict cutting force components in AISI 52100 bearing steel hard turning using CBN cutting tools using an ANN approach. The number of hidden layers has

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been tested. Neither using double hidden layer has shown advantage over single hidden layer. The type of transfer functions in hidden and output layers has been investigated. A sigmoid activation function has been chosen in hidden layer and a linear one in output layer. Levenberg–Marquardt (LM) algorithm has been compared to Levenberg–Marquardt using Bayesian Regularization (BR/LM). It has appeared that using Bayesian Regularization permits to avoid overfitting in training, which gives thus a major advantage over simple LM algorithm. And finally, a various number of neurons in hidden layer have been tested, from 1 to 35. It has been noticed first that the algorithm converges when this number reaches 11, and second that a minor overfitting appears when the number of neurons exceeded 13.

Murat Tolga Ozkan et al. [7] studied the influences of the machining parameters (cutting speed, feed rate, depth of cut and cutting-tool material) on the cutting forces and surface roughness. In this experimental study, the 50CrV4 (SAE 6150) steel was subjected to the machining tests with coated carbide and cermet cutting tools in a turning operation. A multiple regression analysis and experimental design were performed statistically. The measured surface-roughness values were used for the modeling with an artificial neural network system (ANNS). After the experimentation, The statistical-analysis results were: RMSE = 0.004291, R2 = 0.999963, MEP% =0.006097. The predicted surface-roughness values using the ANN model are in good agreement with the experimentally obtained surface-roughness values. The ANN based on the calculation can be used to predict the surface roughness depending on the machining parameters. These results can be used to predict the cutting forces and surface roughness in machining the 50CrV4 (SAE 6150) steel using the coated carbide and cermet cutting tools. In conclusion, a surface-roughness prediction not requiring an experimental study with ANN models can provide both simplicity and fast calculation. It is shown that an ANN model can be used as an effective and alternative method of experimental studies improving both the time and economical optimization of the machining.

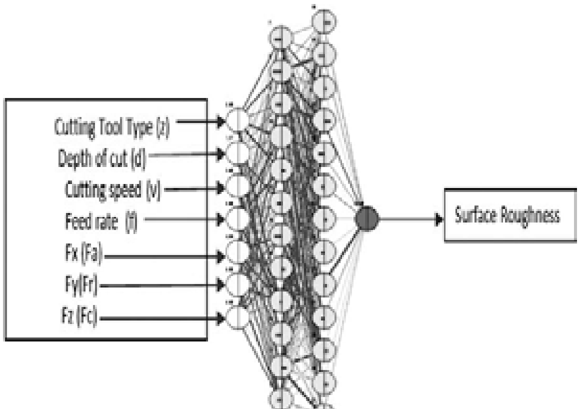

Figure: 3 ANN model [7]

Djordje Cica et al.[8] working on an Artificial Intelligence Approach for modeling of the Cutting Forces in Turning Process Using Various Methods of Cooling and Lubricating. The workpiece material used in the experiment was carbon steel Ck45E. Machining experiments have been carried out on the universal lathe VDF Boehringer Prvomajska which is equipped with a standard system dosing of cooling and lubrication fluid in the cutting zone. The MATLAB's Neural Network Toolbox [6] was used as a tool for the design, implementation, and simulation of neural networks. The proposed ANN used for mathematical modeling of cutting forces is a three-layer feed forward back propagation neural network. In this study, two different methodologies, namely, ANN and ANFIS based modeling as a potential modeling technique for developing optimal cutting force prediction model are compared and discussed. During the research focus is placed on modeling cutting forces in different cooling and lubricating conditions (conventional, minimal quantity lubrication, and high pressure jet assisted machining). Despite the fact that different cooling and lubricating conditions significantly affect the cutting force components, primarily the values of feed and passive force, the predicted values from ANN and ANFIS models and measured values are fairly close, which indicates that both models can be used effectively to predict the forces in turning operations.

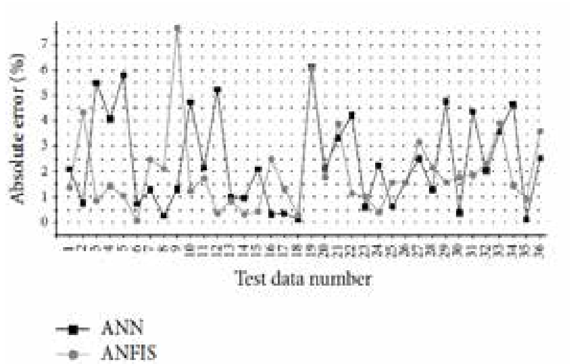

Figure: 4 Error profile of estimated feed forces ( ) obtained using ANN and ANFIS models [8]

CONCLUSIONS

Cutting forces and flank wear calculation and modeling are major concerns in hard turning. The accurate determination of cutting forces is essential for process performance and for developing machinability criteria. For the modeling of the cutting forces and flank wear, various artificial neural networks are very important for development and testing. The suggested neural networks are possible to train with experimental data acquired from actual experiments with the neural network toolbox of Matlab®. The best performance is obtained from the ANN with FFBP architecture, one hidden layer and seven neurons on the hidden layer. There is clear relationship between flank wear and cutting forces while turning hard martensitic stainless steel by CBN and PCBN tools. The lower the cutting force leads to low flank wear and low cutting force provides good dimensional accuracy of the work material including the surface roughness.

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