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Carbide tool life prediction and modeling in SiCp/Al turning process via artificial neural network approach

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Abstract. The experimental research and theoretical analysis of tool life and attached wear with the tool during turning operation of SiCp/Al 45%vol: fraction has been carried out. This research proposed the machining factors affecting the wear of carbide tool and the laws of wear affecting the life expectancy of the tool. Artificial neural network (ANN) was utilized for analyzing the cutting process, the training of ANN achieved by back-propagation on the basis of three input parameters such as cutting speed, feed and depth of cut. The wear and damage of cutting tools in the machining process of composite materials also depend on SiC reinforced particles size and volume. The effects of workpiece material components and different cutting process parameters on the tool wear mechanism were thoroughly analyzed and measured. The main wear form on the cutting tool and its major causes for different wear patterns were recognized as adhesive and abrasive, for such phenomena the cutting speed held as a most influencing factor.

Keywords: SiCp/Al Metal Matrix Composite; tool life; wear mechanism; turning process; Artificial Neural Network; Modeling.

1. Introduction

Metal matrix composites (MMCs) containing reinforced components, it is a fresh branch of composite materials. MMC materials have high specific strength and modulus along with the excellent physical and mechanical properties. MMC materials have high performance; contain low weight in comparison to volume with other metals [1]. Major applications of MMCs has found in the development of aerospace and automotive technology due to characteristics of the complex structure, and high precision. MMCs are also known as aerospace material due to its comprehensive performance in the development



of spacecraft structural parts. Metal matrix composite materials have achieved much more respect in both military and civilian industrial applications [2].

In spite of being composite materials exhibiting the wide range of application, however, their machining cost has not been affordable for general required dimensional accuracy of the component. Several researchers found that the MMCs machinability involves in sudden tool failure and high tool flank wear with an adverse effect on component surface quality due to the presence of SiC hard particles. It has revealed from the literature that several cutting tools fail to machine MMCs [3].

The material of the employed cutting tool should be more in hardness than metal matrix composite materials for the machining process. The cutting tool should be strong enough to endure the wear mechanism during the operation for a certain period to give suitable life to the cutting tools. From different studies, it has seen that the cubic boron nitride (CBN), tungsten carbide (WC), diamond coated carbide tools and polycrystalline diamond cutting tool (PCD), are decent in machining of composite material in accordance to their respective characteristics. It is also found out that these tools have performed well in a quality surface generation at moderate cutting conditions [3, 4, 5].

Yanming and Zehua study the metal matrix composite materials affecting features on the tool wear. From machinability outcomes, where it reveals that the harsh nature of MMC reinforced particle's size and volume fraction in a matrix are the most impelling aspects affecting tool life [5]. Similarly, Kilickap et al. have presented the results of titanium carbide (K10) tool wear in the cutting process of SiCp/Al MMC. The clarifications show the growth in tool wear during increasing the cutting speed and due to an adverse effect of hard SiC particles on the insert. However, the surface roughness effected by both increasing cutting speed and feed rate [6].

This attempted work conducted to understand the carbide tool wear mechanisms and behavior in CNC lathe turning of Al/SiCp45% vol: metal matrix composite. The wear model of carbide tool has established on the basis of artificial neural network data optimizing technique a general equation involving machining conditions cutting speed, feed rate and depth of cut.

2. Artificial Neural Network (ANN)

Artificial Neural Network (ANN) is an evolving information processing technique, which is studied by several scientists and employed in various research and technical fields. Features of ANN somehow resemble with the human brain, it mimics the information processing, storage and it's similar to the retrieval functions of the human brain [7]. ANN possesses intelligent processing functions of memorizing, learning and calculating, due to its ability of self-organization and adaptation. After several years of research and development, there are many numbers of neural network models in ANN, which roughly categories into three major sets such as self-organizing neural network, Feed-back neural network and feed-forward neural network. In the area of the metal cutting process, the ANN is employed to measure and understand the machine tool behavior and analysis the error. The core application of ANN in the metal cutting process is to evaluate the effect of machining parameters on tool wear, optimization of parameters and reduction of errors in machining operation [8]. In this experimental work, research is conducted on the lathe turning to measure and analyze the tool wear and its mechanisms in the cutting process of SiCp/Al reinforced metal matrix composite material.

In this specific research the architecture of 3-n-1, a feed forward back-propagation multi-layer neural network is employed for analysis of tool wear. The ANN model is developed in the ANN tool-box in MATLAB R2015a. Developing the productive ANN model with less number of data points are most challenging task. However, developing model with less data point determine the capability of this particular technique in formulating the ANN tool wear model. From the available 16 experimental data sets, randomly nominated 12 sets are taken to build the model and remaining of the 4 data sets are used for the validation of the developed model. Fig: 1 shows the ANN configuration used for training in this research.

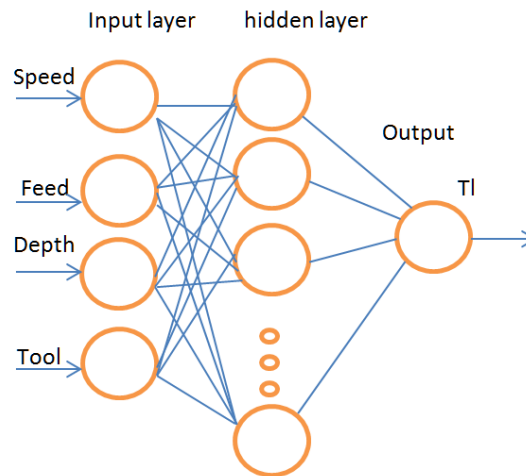


Figure 1. ANN configuration used for training

3. Experimental conditions

In this experiment, the orthogonal machining progression is accomplished on composite materials with three different cutting responses namely cutting speed, feed rate and depth of cutting. The experimental sample containing the different size such as measured length of 98.9 mm and measured diameter possess 48.2 mm. wear progression on cutting tool was measured after completing every single cutting operation for all number of cutting operation. There are 16 sets of cutting operations were performed in dry cutting conditions with the non-coated carbide tools. The average height 0.3 mm is counted as an of the flank wear to be considered as a worn edge with respect to ISO 3685 (ISO, 1993).

The machining parameters utilized in this operation for turning workpiece are detailed in Table 1. However, the experimental setup for turning operation on SiCp/Al is illustrated in fig: 2.

Table1. Cutting Parameters

| | | | | |
|-----------------------|-------|--------|-------|--------|
| Cutting speed (m/min) | 6.283 | 12.566 | 18.85 | 25.133 |
| Feed rate (mm/r) | 0.01 | 0.015 | 0.02 | 0.025 |
| Depth of cut (mm) | 0.2 | 0.5 | 1 | 1.5 |

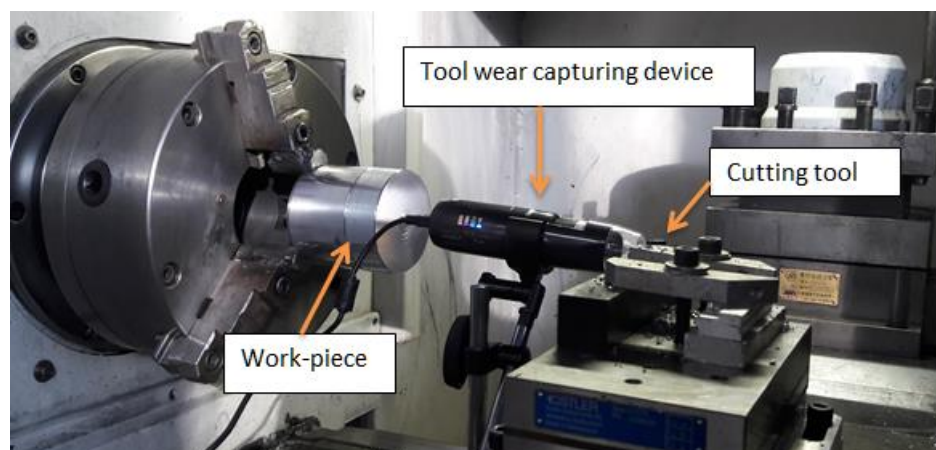


Figure 2. Experimental setup of turning of SiCp/Al

4. Estimation of carbide tool wear in turning process of SiCp/Al

4.1 Effect of SiCp/Al workpiece material properties on tool wear

It has been clarified in several studies that the more appropriate tool material for processing SiCp/Al metal matrix composites is a PCD cutting tool. PCD cutters wear mechanisms and amount are much less than cemented carbide tools, however, carbide tools have good economic machining performance, which can be used as tool materials at lower cutting parameters for MMCs, and are also very suitable for rough machining of particle reinforced aluminum matrix composites [4].

When machining SiCp/Al used to performed, the tool wear and wear mechanism are related to the volume and size of the reinforcing particles in the material. The greater the particle content and size in the composite, the more severe the tool wear. It can be seen from the experimental results that in the processing of particle reinforced aluminum matrix composites, the tool wear phenomenon varies with different component materials due to the difference in internal particle size and particle content [9].

The following fig: 3 shows the different patterns of carbide tool wear, and on the other hand fig: 4 show the comparisons between the experimental values and ANN calculated values of the tool life. The fig: 5 shows the tool life error percentage of ANN calculated values with respective to obtained experimental data.

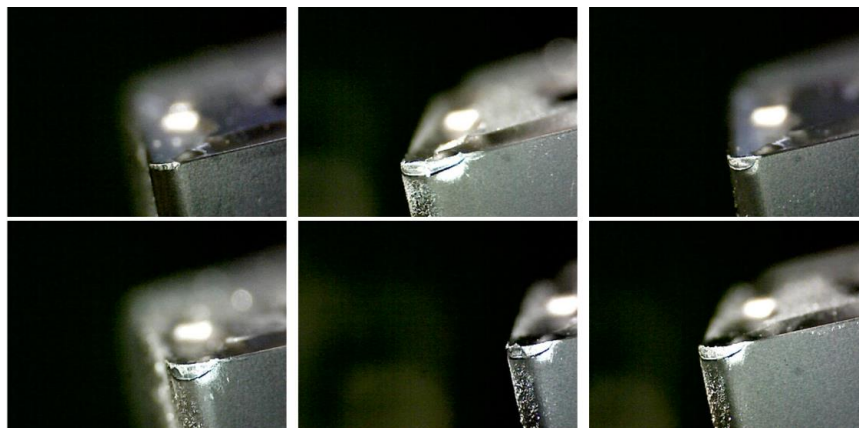


Figure 3. Different tool wear patterns

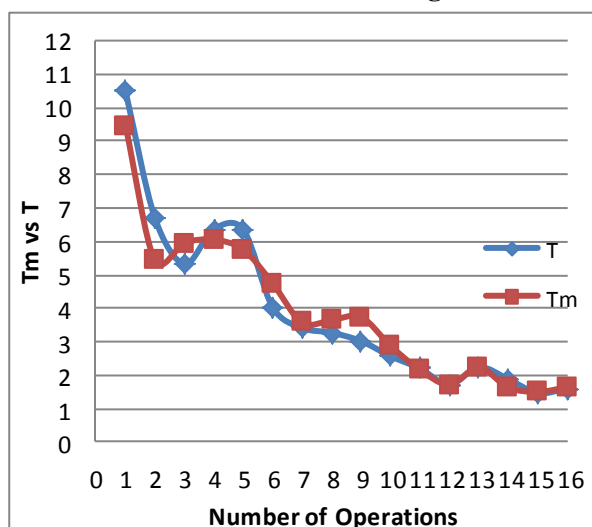


Figure 4. Experimental Tool life (T) vs ANN Tool life(Tm)

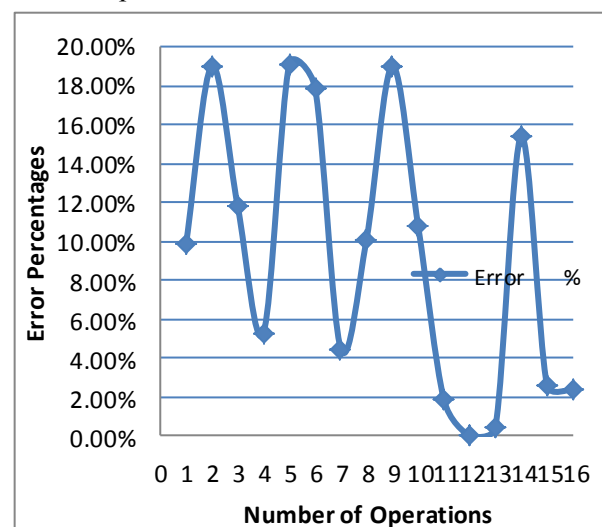


Figure 5. ANN measured Error %

5. Conclusions

This experimental research thoroughly analysis the tool wear law, mechanism and morphology in the cutting process of SiCp/Al reinforced metal matrix composites.

When using carbide cutting tool in turning operation of SiCp/Al reinforced metal matrix composites, the tool wear shows the increasing phenomena with the higher cutting speed.

Tool wear morphology reveals that the flank wears of the carbide tool is severe and most common during the turning process of composite material. The different damage mechanisms were studied on the flank of the tool; the core causes which affect the flank wear is the adhesive and abrasive wear patterns. Reason for the tool flank wear is due to the low strength of tool surface after doing some machining that produces microcracks, and SiCp/Al materials particles bonded to the rack face of the tool and therefore damaged the carbide tool.

The calculated results of ANN model of tool life are very close to the experimental results. The ANN model successfully predicted the experimental results with minimum error.

For future research work employing the sensors for gathering tool wear data should be the effective as compare to and analyze the obtained data. There is a necessity of effective tools, techniques and methods for gather data during operation. It can provide more precise and accurate results as well as fruitful for analyzing data.

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