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Review on: Metal Cutting Tool Condition Monitoring using Machine Learning Approaches

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Abstract – *In a manufacturing industry it very important to maintain cost and production in a ratio such that overall productivity is always high. But as in machining operations a tool is required that performs cutting work by providing feed and speed to it, an undesired effect of wearing of tool with machining becomes unavoidable. To monitor tool life and condition Machine learning algorithms provide a modern solution to a very primitive problem. Many researchers have used ML techniques like Multi-layer perceptron, Support Vector Machine, Decision Tree, Random forest, K-NN, etc. to predict tool condition using signal processing generated by vibration of tool. In this paper a review of some of the techniques applied on single point cutting tool are discussed to throw light on this field.*

Key Words: Tool life, Machine learning algorithms, ML techniques, Multi-layer perceptron, Support Vector Machine, Decision Tree, Random forest, K-NN.

1. INTRODUCTION

The main purpose in the manufacturing is to enhance grade of products been manufactured from the machining process by reducing costs of production. In this case regulating the most favourable material cutting variable is very crucial.

Machining is an operation that improves the shape, size, surface finish and mechanical properties of a material by the approach of required tools and equipment.

This is generally carried out by machines where a cutting tool removes the material to improve the needed change to the work piece. There are various types machine been used for machining operation but in this paper, focus is on single point cutting machine tool like lathe.

A lathe machine is a flexible and multi-purpose machine tool which is used for removal of metal from the cylindrical surface of work piece material. There are various types of lathe machine namely centre or engine lathe, speed lathe, tool room lathe, bench lathe, automatic lathe, special purpose lathe, capstan or universal lathe, turret lathe and CNC lathe.

In India companies use both CNC Lathe and manual lathe machine but CNC lathe machines being very expensive are less preferred by small scale industries that contribute to less productivity. So, due to this many medium grades and low-grade company uses the manual lathe.

In manual lathe tool monitoring is a big problem as to do so machine have to be stopped which increases the lag time or ideal time of machine. This can be solved by using Machine learning techniques which can provide a real time monitoring system for tool condition monitoring.

Many researchers have worked and are working in the field of conjunction between mechanical and computer system-based condition monitoring of the tool.

2. LITERATURE REVIEW

In this section we have discussed some of the works of researchers in recent times on the given topic: Tool condition monitoring for single point tool using Machine Learning approaches.

O.Ryabov [1] in his research has proposed technique of laser displacement meter for direct multi-purpose sensing of milling tool conditions. He used laser sensing system consisting of laser sensors mounted on the main spindle of machine so that the rate of tool deterioration and the tool life of an individual tool can be diagnosed and monitored. He incorporated parameters namely bending, thermal expansion, and chatter characteristics. These data were analysed for obtaining the required outputs related to scanning time.

Jacob chi-Ming Chen [2] proposes an approach towards in-process tool wear monitoring systems based on multi linear regression (MLR-ITWP), artificial neural network (ANN-ITWP) and statistics assisted fuzzy-nets (S-FN-ITWP). Through these systems he has tried to put forward to provide a real time condition monitoring system that can be incorporated with CNCs for ITWP (In-process tool wear system).

Victor P. Astakhov [3] has described in his research paper about prediction of flank wear on the tool face. Prediction measured is by using the Makarow's law and prediction with the help of limiting amount of energy being transmitted through the cutting wedge till failure.

A.Siddhpura [4] has described in his research paper, about prediction of flank wear and tool breakage which has occurred during the turning operation in the flank face of the tool. In this paper author has done prediction of tool wear by using the tool condition monitoring system methods like TCMS (Tool condition monitoring system) named signal acquisition, signal processing, feature extraction and decision making. He used many parameters like cutting force, surface roughness, displacement, electrical resistance, optical, radioactive etc. and applied artificial intelligence techniques named Neural network, Fuzzy logic classifier, Neuro fuzzy methods, Hidden Markov models, support vector machine for the decision making.

N. Gangadhar [5] has described in his paper for prediction of tool wear by using tool condition monitoring system based on reduced downtime and excessive power use during the machining. Author has explained the quality of machining, surface roughness and tolerances by using machine learning algorithm such as decision tree.

C.K. Madhusudana [6] has done work in his research paper, for prediction of tool wear which has occurred during the milling process in the tool face. Tool wear measured was by using the online tool condition monitoring system method. He predicted the tool wear such as crater wear and flank wear using stereo vision method in the turning operation using parameters such as cutting force, current signal, acoustic emission signals, vibration signals etc. artificial intelligence techniques such as artificial neural network, support vector machine, Bayes-Sian network, fuzzy neural network, hidden Markov model, decision tree etc. machining has done many parameters used such as cutting speed, feed rate, depth of cut etc.

A. Gaurier [7] has explained in his research paper about identification of tool wears such as flank and crater wear on the rake face of tool. He predicted the tool wear and tool breakage occurred during the turning process. Prediction of tool wear was done by using the tool condition monitoring system, deep learning and machine learning algorithms such as artificial neutral networks and support vector machine etc. machining parameters used were cutting speed, feed rate, and depth of cut.

3. Case studies related to tool health prediction using Machine Learning approaches

In this section we have represented some of the work or researches in tabular form to present a more vivid picture of proposed work and type of ML techniques used.

Case studies using ML approaches on Lathe operations										
S no.	**Author (published year)**	**Implementation**		**Parameters****					**Model/ Techniques**	**Remarks**
		Milling	**Turning**	**DS**	**CS**	**FR**	**DC**	**CF**		
1	Oleg Ryabov (1998)	✓			✓	✓	✓		Laser sensing system	Implementation Of tool wear
2	Jacob chi-ming chen (2003)	✓				✓	✓		Used TCMS Method and ANN theory	Implementation Of tool wear Pre-process setting errors of cutting tool and predicted the tool wear TCMS method used for improvement in the process.
3	Victor P. Astakhov (2003)	✓	✓	✓				✓	Used the offline and online TCMS method	To predict the remaining tool life
4	A.Siddhpura (2012)		✓	✓				✓	Used the Tool condition monitoring system method.	TCMS method predicted the tool wear
5	N. Gangadhar (2014)	✓	✓		✓	✓	✓		TCMS and J48 algorithms are used.	J48 algorithm provided better accuracy with 84.38% for the prediction of tool wear.
6	C.K. Madhusudana (2016)	✓			✓	✓	✓	✓	K-Star algorithm and online TCMS. Naïve byes techniques and machine learning techniques	K-Star algorithm provided the better accuracy with range from 94 to 96% for prediction of tool wear. Naïve byes technique provided the better accuracy with 96.9%
7	A. Gouarir (2018)	✓	✓		✓	✓	✓		Used the Convolution Neural Network (CNN) and Makarov's law	Predicted the tool wear with 90% accuracy
Parameters are **Displacement(D), Cutting speed (CS), Feed Rate (FR), Depth of Cut(DC), and Cutting force(CF)										

Table -1: Case studies using ML approaches

4. CONCLUSIONS

Through the above discussion it can be deduced that work in the field of tool life monitoring is a very elaborative and exploring day by day. Researchers have shown a path to be followed in order to provide new and more innovative solutions in coming days to follow.

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