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Implementation of Machine Learning Algorithms for the detection of cutting tool wear for automatic tool monitoring system

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Abstract - **This research deals with the development of automatic tool condition monitoring system which is used for monitoring the cutting tool to prevent it from damage /breakage and increasing the total productivity. An indirect method is required to measure the physical parameters during machining. A neural network inference system is proposed to estimate the tool wear from the cutting force parameter. To determine the state of the cutting tool there are various models available which are not available because of their higher costs and modifiable tool according to the requirement.**

Index Terms – Hidden Markov Model, Support Vector Machine, Anfis, TCM, Genetic algorithm.

I. INTRODUCTION

The main aim of developing Tool Condition Monitoring system (TCM) was to increase the productivity, reduce down time, maximizing tool life and prevention of damage. The automation industry is increasing in a very faster pace and so are its requirements for higher accuracy with lesser time. Due to continuous use of the heavy and expensive machines heat is generated which directly affects the cutting tool, leads to the wear of the cutting tool. Worn out cutting tool might also cause damage to the hub of the surface of the machine. Other factors affecting the productivity like human error is impossible to minimize. Hence techniques which monitor the cutting tool condition are really important to be worked on. Also, since the cutting tool is affected by the spindle speed, feed rate, heat generation and other factors, thus monitoring it is an important task to do. TCM consists of sensors, signal amplifiers, signal visualization system connected to machine control and a monitor.

The manual monitoring of the cutting tool is a difficult job to do. The worker has to observe the cutting tool continuously and in the presence of loud noise in the workshop. The worker should be really experienced in analyzing the sound of the cutting tool. But with such expensive machinery and the demand of high productivity, it is a little risky to be dependent on the worker. It is very necessary for every company to utilize its machine and human resource very efficiently. Hence automation comes into the picture and finding a stable method and a quality algorithm supporting with various machineries is necessary to be executed and found.

In the process of metal cutting, dimensional accuracy and surface roughness define the quality of the product. These two indexes directly effect on the quality of the cutting tool. Thus the TCM(tool condition monitoring) system needs to designed that must detect the following important factors (1) the collisions as fast as possible, (2) identifying of tool fracture and (3) abrasion caused of tool wear due to various reasons. The system must provide us with increase in the efficiency of the machine ensuring quality of the product, saving man power and minimizing the risk of damaging the machine or the cutting tool or even the product under manufacture. And lastly reducing the total cost.

Though there has been a progressive research on the tool monitoring systems, a lot of research work is still to be done. This field has a long way to go. The automatic cutting tool monitoring system is divided into basically two parts, viz, 1.Direct monitoring method and 2.Indirect monitoring method.

Direct monitoring basically takes into consideration the parameters such as the shape of the cutting tool, position of the cutting tool, etc. On the other hand in Indirect monitoring various normal parameters of the cutting tool such as cutting resistance, cutting temperature, cutting vibration, work-piece dimension, surface roughness, tensional moment, etc. are compared with the actual parameters. Direct monitoring can be done off-line whereas indirect requires to be done on-line i.e. comparing with the parameters discussed above with the parameters when the actual manufacturing is being done. The Online and indirect tool wear estimation using neural and fuzzy inference systems is the new modern approach to this system. It describes the influence of cutting condition on the measured process parameters. Even acoustic emissions were used to derive input features during machining operation and topography of the surface.

II. LITERATURE REVIEW

There have been a few contribution in monitoring systems and various methods like the Bayesian network, artificial neural network, multiple regression and stochastic methods. Hidden markov model, Support vector machine and Anfis method have been compared to analyze the best suitable system for tool monitoring.

Adaptive Neural Fuzzy Inference System (ANFIS):

ANFIS method was introduced which was a fuzzy inference system using fuzzy if then rules. Anfis uses back propagation algorithm. In some cases data is collected in a noisy environment which is difficult to extract, that is where this model validation comes into play. ANFIS was introduced to overcome the problems in the other learning models by joining the neural networks with fuzzy systems i.e. giving an inference model. Combining the if-then rules of the fuzzy system with weighted nodes in neural systems has given quite accurate novel architecture known as the adaptive neural fuzzy system. ANFIS combines the best features from both systems, from the fuzzy inference we consider the reduction of optimization search space by priory representing the knowledge domain and from the neural network adapting back-propagation so as to structure the network in order to automate the parametric tuning of the systems.

III. MODEL FORMULATION

As discussed above the main goal of designing a system is that it should be able to adapt the most useful information from the noisy data in a noisy environment. Getting an accurate solution out of the given sample is really important.

The Hybrid TCM is to be designed should be able to satisfy the following task:

- Should be able to adapt the most useful information from the noisy data in a noisy environment.
- Getting an accurate solution out of the given sample is really important.

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- Training the model with proper and appropriate set of data is necessary.

- Optimum utilization of the system.

- Feature extraction is one of the important object detection and recognition parameter. It is a type of dimensional reduction technique used to efficiently in extracting the necessary amount of data. The basic problems to be solved are:

a. Collision detection as fast as possible

b. Tool fracture identification

c. Estimation or classification of tool wear caused by abrasion other factors. Monitoring these problems are difficult because all the machining processes are non-linear and time variant in nature, the signals acquired from the sensors are dependent on factors like work-piece material, cutting tool geometry, machining condition, etc.

IV. PROPOSED ALGORITHM

While modelling the anfis system the data usually divided into training and testing data sets. The training data is used for finding the initial parametric conditions whereas the testing set is used in comparing the computed model with actual system. A threshold value is determined which is the error between actual and desired output, this value is found for each of the data pair. Using least-square methods the consequent parameters are achieved, this value is compared with the threshold value. When the value is larger than the threshold value the premise parameters are updated using gradient decent method $Q_{next=}Q_{nov+}\eta_d$ (Q= parameter that reduces the error, η=learning rate and d=direction vector). And if the value is less than the threshold value then the process is terminated. *Fig 1* explains the anfis model

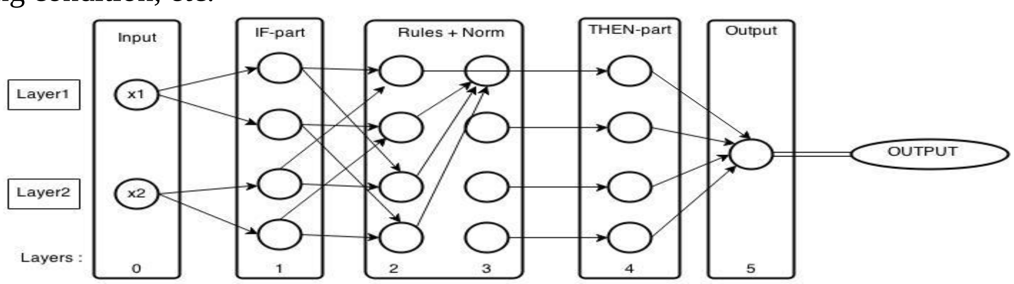

Fig 1

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	Hidden Markov Model	Support Vector Machine	Anfis System
Used for	Determining the underlying and consequent and sequence of observation with probabilistic data analysis	Analyzing infinite, non-linear data and for good generalized performance. They differ radically from the comparative approach of the neural networks.	Solving ill-defined equation which involve automatic elicitation of the knowledge represented by its 'if-the rules.'
Equations	$P_{r[x_t \mid x_{1:t-1}]} = \frac{b_\infty . B_{xt} . b_t}{\sum_x b_\infty . B_{xt} . b_t}$	***D*(x) = ∑*iαiyi*g(*xi*)*t* g(x) + *b*.**	$E_k = \sum_{i=1}^{N\ (L)} (d_t - x_L)^2$
Advantages	Its computation is simple and easy to implement, good for generating alignment.	It has capacity to model complex problems, gives good performance where the attributes of data are large. Training a svm is easy and the quality of generalization is its uniqueness.	They give dynamic response under different critical machining condition. Helps to achieve high accuracy. It has significantly lower cost
Disadvantages	The observations are mostly having single dimensional features and also they are not independent.	Discrete data cannot be analyzed, the speed and size of the training and testing data is a problem and the choice of the kernel.	The training time required is longer. Comparatively less accurate results for unstructured data**.**

V. ARCHITECTURE

The various parameters are considered before the testing of the iven data set. Some factors are pre-assumed and some are calculated during the experimentation. Following some of the factors needed to know before the training and testing is performed.

A. NOMENCLATURE:

A - Depth of cut (mm).
Cw - The edge force constant (N/mm2).
Fx - Axial force (N).
Ks - Specific cutting pressure of workpiece material (N/mm2).
St - Feed rate per tooth (mm/tooth).
Vb - The flank wear width (mm).
Kt - The crater wear depth (mm).
Vf - Feed speed (m/min).
Vc - Cutting speed (m/min).
Ss - Spindle speed (rpm).

B. PARAMETERS:

Table 2

Parameter	*value*	
Spindle speed	*300-450*	*Rpm*
Cutting depth	*1-1.5*	*Mm*
Feed rate	*100-120*	*Mm/min*

C. OBSERVATION

Table 3

Cutting depth (mm)	Feed rate (mm/min)	Spindle speed (rpm)	Neuron structure	Error
1	100	300	[4,4]	0.001197
1	100	300	[4,8]	0.001318
1	100	300	[8,8]	0.00099
1.5	120	450	[4,4]	0.00199
1.5	120	450	[4,8]	0.00099
1.5	120	450	[8,8]	0.00099

VI. RESULT

The time series used in ANFIS is chaotic and the period is not clearly defined. Study proves that the anfis method is best suggested method for predicting the result. . The neural networks gives the flow of nodes gives the best training sample. It gives the connection between various links of data and gives you optimum result. The performance of anfis is quite good and gives prediction result nearly accurate.

Since the literature suggested that there exists a correlation between cutting force (static and dynamic) and the tool wear therefore we analyse this system considering the parameter of cutting force. The given data was fed into anfis editor tool and unsupervised training was performed and tested. The results showed that the network was able to classify a breakage up to 0.3mm with a reliability of 98%. The method was able to estimate wear from the given parameters (Ks, a, Cw, D, Vc, St, z) with NN (8 neural in input layer-5 neural in hidden layer and 1 neural in output layer).

VII. CONCLUSION

The hybrid technique proposed is useful to lower the intrusiveness than traditional monitoring, more efficient and flexible. It can be infeasible due to large scale distribution of data and diversity in the application environment. Many authors have suggested the importance of maintaining a database that carries information of different cutting tools and their materials. This will allow in computing the models by knowing their complete domain in all the machining process. A TCM designed should fulfil all task discussed i.e. of collision detection, tool fracture, estimation of tool wear and feature extraction. The cutting tool monitoring system provides with many benefits, it enhances the machine efficiency, the quality of the hub is maintained, breakage and other damage to the equipment is saved and also the man power required to scrutinize or monitor the tool is reduced and is very cost effective. The duration of the working condition of tool is increased and thus it positively affects the production.

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