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A Review on Models used for Prediction of Tool Life

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Abstract

Tool wear is an important factor that affects the quality and tolerance of machined parts. Having an accurate prediction of tool wear is important for machining industries to maintain the machined surface quality and can consequently reduce inspection costs and increase productivity. Many works has been done to achieve a suitable model for prediction of tool life. However, it has been found that many factors are there, which effects the suitability of prediction model for different methods used for machining operation. The objective of this paper is to exclusive review and sum up the model which is used for prediction of RUL of tool and rotating parts. Various research and analysis has been done for improvement and development of models which can analysis the vibration signals for predicting RUL of rotating parts. During machining operation there are many factors such as cutting parameters, machining condition, temperature, vibration etc which affect the life of the tool. Among which vibration is one of the important factor and if it will not be analysed then this leads to a tragic failure. Since tool is subjected to many factors during machining operation, due to which it possess great challenge to analyze the tool and predict its RUL.

Keyword: Cutting speed, Feed, Depth of cut, RUL

Introduction

In a machining process, the prediction of tool life is of crucial importance, and the factors that affect tool life can be divided in three categories: the machine tool, the machining parameters and the workpiece material. The parameters with a higher effect on tool life contain the cutting speed, the feed rate, the depth of cut and the cutting fluid. Tool life prediction is has a great influence on productivity in industrial activities. High material removal rate is intended to reduce the manufacturing cost and operation time, while the productivity in terms of machining cost and operation time for an expected workpiece quality strongly depends on tool wear and consequently is determined by tool life. The maximum utilisation of cutting tool is one of the ways for an industry to reduce its manufacturing cost. In order to maximise gains from a machining process an accurate process model must be constructed for a process with cutting speed, feed and depth of cut as input variables and tool life as the output variable. It is very difficult to predict tool life in end milling with sufficient accuracy on the basis of controllable process parameters. However, on the other hand, it is an essential part of a machining system in the automated factory to change tools automatically due to wear or damage. In general, a cutting tool fails either by gradual wear or by fracturing. Over more than two decade, huge emphasis is given to research on vibration based fault diagnosis methodologies. The objective of this paper is to sum up different prediction methods based on the vibration signal and to analysis the best method which dealt with non-liner non- stationery signals and find out the model which can give the best result.

PREDICTION MODEL

In 1997 M. Alauddin et. al built-in a mathematical models for tool life in end milling steel (190 BHN) using high-speed steel slot drills for dry conditions. This prediction models for tool life have been developed in terms of primary machining variables such as cutting speed, feed and axial depth of cut by response surface methodology. Contours were constructed in speed-feed planes and used for determining the optimum cutting conditions for a required tool life. The adequacy of the predictive models was tested by analysis of variance and found to be adequate. [1]

Tool wear prediction plays an important role in the tip geometry compensation during machining process. J.H. Lee and S.J. Lee 1999 developed a reliable method to predict flank wear during a turning process. In this method force ratio and increment values are applied to predict one-step-ahead flank wear. The results of this paper show that using force ratios, flank wear can be predicted to within 8 and 11.9%, and also using force increment, flank wear can be predicted to within 10.3% of the actual wear for various turning conditions. [2]

Degradation of working conditions of machinery and trending of fault propagation before they reach the alarm or failure threshold is extremely important in industry to fully utilize the machine production capacity. In 2008 Van Tung Tran et. al proposed a method to predict the future conditions of machines based on one-step-ahead prediction of time-series forecasting techniques and regression trees. The embedding dimension is firstly estimated in order to determine the necessarily available observations for predicting the next value in the future as shown in Figure 1. Real trending data of low methane compressor acquired from condition monitoring routine are employed. [3]

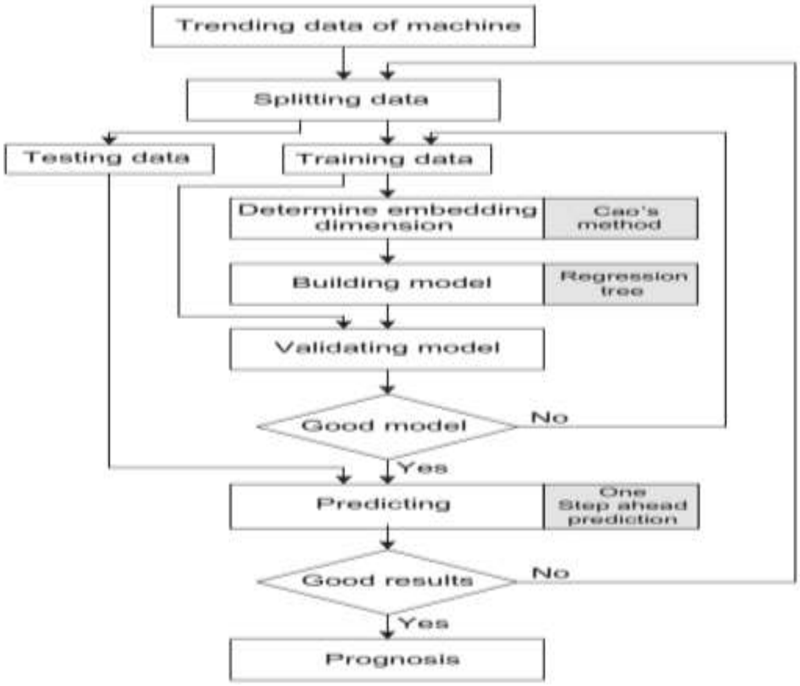

Figure 1 Proposed system for machine fault prognosis.

Van Tung Tran et. al 2009 presents an approach to predict the operating conditions of machine based on classification and regression trees (CART) and adaptive neuro-fuzzy inference system (ANFIS) in association with direct prediction strategy for multi-step ahead prediction of time series techniques. False nearest neighbour method and auto mutual information technique are incorporated for the number of available observations and the number of predicted steps are initially determined. The CART models and ANFIS models are validated by its ability to predict future state conditions of a low methane compressor using the peak acceleration and envelope acceleration data as shown in Figure 2. Hence results prove that the ANFIS prediction model can track the change in machine conditions and it has the potential for using as a tool to machine fault prognosis. [4]

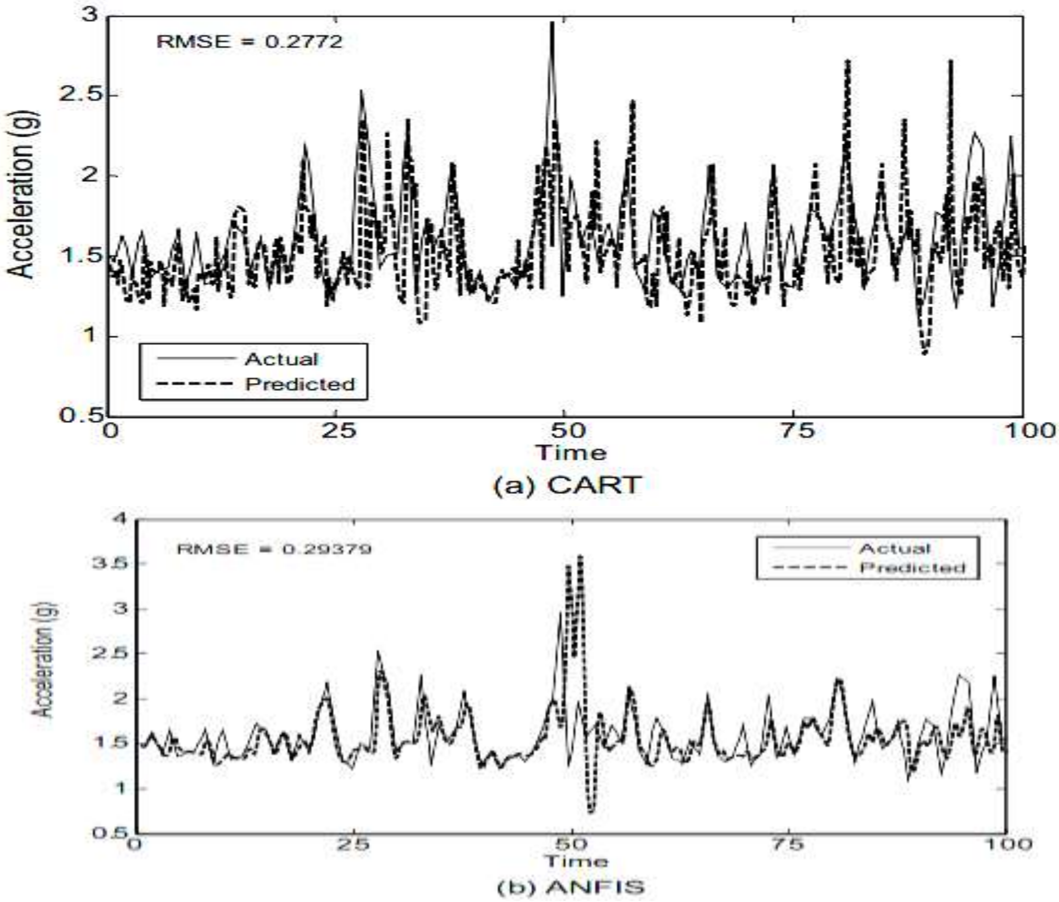

Figure 2 Predicted results of envelop acceleration data.

Jaydeep M. Karandikar et. al 2012 demonstrated a model where, tool wear is characterized by remaining useful tool life in a turning operation and is predicted using spindle power and a random sample path method of Bayesian inference. Turning tests are performed at different speeds and feed rates using a carbide tool and MS309 steel work material. The root mean square of the time domain power is found to be sensitive to tool wear. Sample root mean square power growth curves are generated and the probability of each curve being the true growth curve is updated using Bayes' rule. This method takes into account the uncertainty in tool life and the growth of the root mean square power at the end of tool life. [5]
J. Gokulachandrana et. al 2012 investigated a model for predicting tool life when end milling IS2062 steel using P30 uncoated carbide tipped tool under various cutting conditions. Based on Taguchi's method, three factors (spindle speed, feed and depth of cut) - three level orthogonal experiments are employed. A tool life model is developed from regression model obtained by using results of the experiments conducted. A second model is developed based on artificial neural network (ANN) for predicting tool life. The results obtained from ANN are compared with regression model. [6]
In 2012 Samir Khamel et. al examine effects of process parameters (cutting speed, feed rate and depth of cut) on performance characteristics (tool life, surface roughness and cutting forces) in finish hard turning of AISI 52100 bearing steel with CBN tool. Hence combined effects of the process parameters on performance characteristics are investigated using ANOVA. The composite desirability optimization technique associated with the RSM quadratic models is used as multi-objective optimization approach. The results show that feed rate and cutting speed strongly influence surface roughness and tool life. [7]
Muhammad Rizal et. al 2013 presents a model, based on the adaptive network-based fuzzy inference system (ANFIS), and anew statistical signal analysis method, the I-kaz method, were used to predict tool wear during a turningprocess. In order to develop the ANFIS model, the cutting speed, depth of cut, feed rate and I-kaz coefficient from the signals of each turning process were taken as inputs, and the flank wear value for the cutting edge was an output of the model. [8]
Man Shan Kan et.al 2015 focuses on prognostic techniques that can be applied to rotating machinery operating under nonlinear and non-stationary conditions. Hence challenges and opportunities in implementing prognostic systems and developing effective techniques for monitoring machines operating under non stationary and non-linear conditions. [9]
One of the important limitation to machining productivity and part quality is tool wear. In 2016 Cyril Drouillet demonstrated remaining useful life (RUL) prediction of tools based on the machine spindle power values usingthe neural network (NN) technique. Figure 3 illustrates methodology for an intelligent process monitoring system. The NN curve fitting approach with different MATLABTM training functions was applied to the root mean square power (P_{rms}) values. It was found that the value of P_{rms} in the time domain is sensitive to tool wear whereas results shows good agreement between the predicted and true RUL of tools as shown in Figure 4. [10]

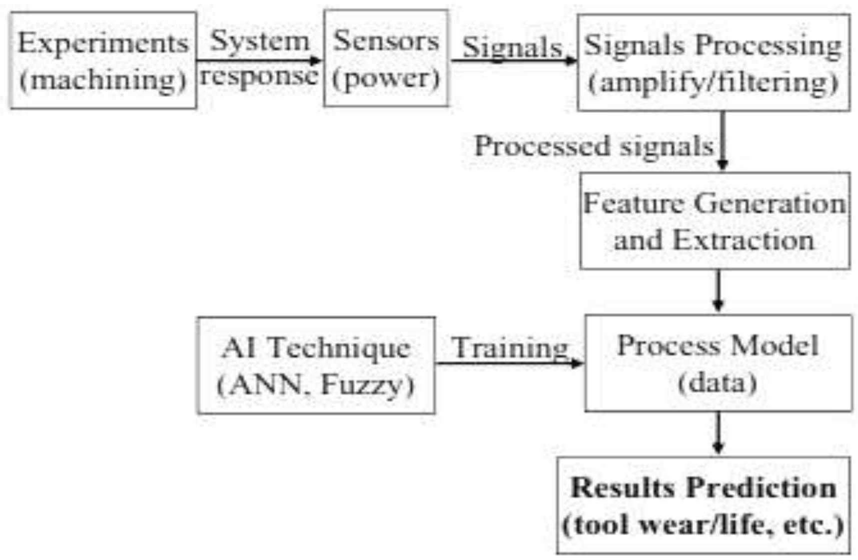

Figure 3 Methodology for an intelligent process monitoring system.

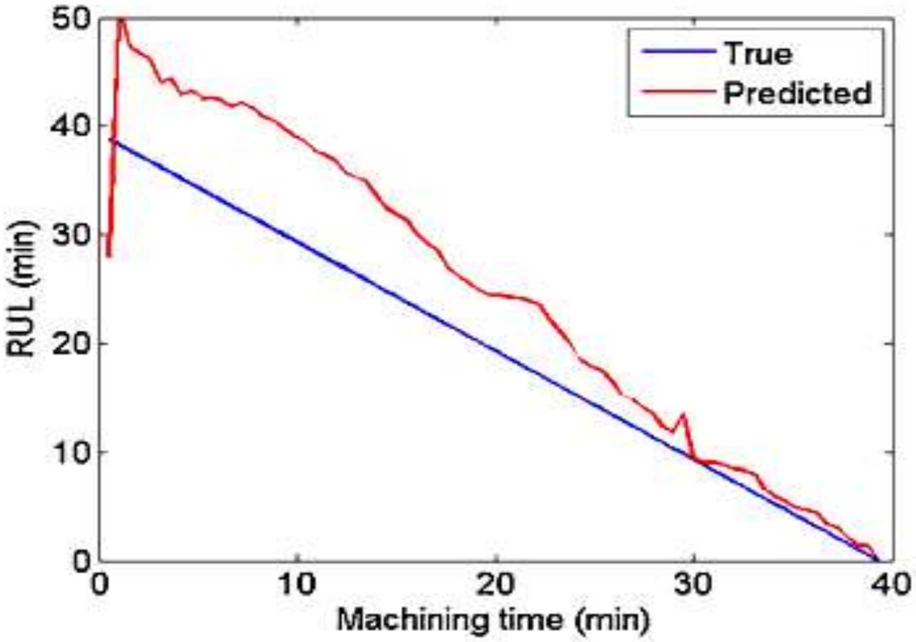

Figure 4 Prediction of the RUL at 2700 rpm with the training at 1800 rpm.

Chi Zhang et. al 2016, proposes a hybrid model based on autoregressive (AR) model and Gaussian process regression (GPR) for probabilistic wind speed forecasting. In the proposed approach, the AR model is employed to capture the overall structure from wind speed series, and the GPR is adopted to extract the local structure. Additionally, automatic relevance determination (ARD) is used to take into account the relativeimportance of different inputs, and different types of covariance functions are combined to capture thecharacteristics of the data. The forecasting results indicate that the proposedmethod can not only improve point forecasts compared with other methods, but also generate satisfactory prediction intervals. [11]

Conclusion

Prognosis is a necessary activity in industries to predict the remaining useful life and optimise the usage of machines. The service lifetimes of machine components or the entire system can be predicted so that downtime, reliability and productivity of the enterprise can be increased. Unpredicted failure in these industries can be catastrophic and can result in extended downtime, which in turn can lead to economic loss. Effective prediction can alleviate this shortcoming by predicting failure occurrence in advance so that maintenance actions can be undertaken before components fail and subsequently avoid catastrophic failure.

Summing up the review on prediction model for determining the remaining useful life (RUL) of cutting tools and rotating parts, over the past two decades, much time for research has been devoted to analysis different models which can be used to analysis vibration signals to determine the RUL. Literature has been surveyed and it has been found that in order to calculate the RUL the most commonly used method is Gaussian Mixture Model(GMM) to calculate the degradation pattern and Gaussian Process Regression(GRP) based one step ahead prediction method is used to predict the RUL.GMM and GRP have a wide application in prediction of RUL of gear box, bearing, wind speed, gear fault etc.

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