Review on Monitoring of surface roughness in CNC end milling

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***Abstract*—The general manufacturing problem can be described as the achievement of a predefined product quality with given equipment, cost and time constraints. Unfortunately, for some quality characteristics of a product such as surface roughness it is hard to ensure that these requirements will be met. This paper aims at presenting the various methodologies and practices that are being employed for the prediction of surface roughness. The resulting benefits allow for the manufacturing process to become more productive and competitive and at the same time to reduce any re-processing of the machined workpiece so as to satisfy the technical specifications. Each approach with its advantages and disadvantages is outlined and the present and future trends are discussed. The approaches are classified into those based on machining theory, experimental investigation, designed experiments and artificial intelligence (AI).**

***Keywords*— ANN, Surface roughness, offline monitoring, online monitoring.**

I. INTRODUCTION

There are two main practical problems that engineers face in a manufacturing process. The first is to determine the values of the process' parameters that will yield the desired product quality (meet technical specifications) and the second is to maximize manufacturing system performance using the available resources. The decisions made by manufacturing engineers are based not only on their experience and expertise but also on conventions regarding the phenomena that take place during processing.

In the machining field, many of these phenomena are highly complex and interact with a large number of factors, thus preventing high process performance from being attained. To overcome these problems, the researchers propose models that try to simulate the conditions during machining and establish cause and effect relationships between various factors and desired product characteristics. Furthermore, the technological advances in the field, for instance the ever-growing useCNC end milling which is commonly used in manufacturing industry for machining of Inconel 718. Mahesh, Muthu and Devadasan [2] focused on surface roughness as it denotes the product quality. There are several theoretical approaches are proposed to model roughness. Zain, Haron and Sharif [3] used AI technique like ANN to model roughness. Analytical and experimental models are developed using ANN and response surface methodology to calculate roughness. Zhong, Khoo and Han [4] discussed the application of ANN for modelling of surface roughness. In order to investigate how capable the ANN technique is at estimating the prediction value for surface roughness.

II. CLASSIFICATION OF APPROACHES

The classification of the selected papers was not easy due to two main reasons. First, there are many papers that do not strictly follow a certain methodology in its entirety, they rather select some of its basic principles and combine them into a 'new' approach. Secondly, there are many cases where researchers blend different strategies into a single approach and therefore no single classification would be entirely accurate.

Taking into account the above, four major categories

were created to classify the selected papers. These are:
(i) approaches that are based on machining theory to develop analytical models and/or computer algorithms
to represent the machined surface; (ii) approaches thatexamine the effects of various factors through the
execution of experiments and the analysis of the results;
(iii) approaches that use designed experiments; and (iv)
artificial intelligence (AI) approaches.

3. Machining theory based approach

This category includes approaches that place emphasis
on certain aspects from the theory of machining such as
process kinematics, cutting tool properties, chip formation
mechanism etc. Computer-aided design (CAD) methods and tools are utilized so as to achieve the goal
of building a model that will be able to simulate the creation of the machined surface profile, thus visualizing
surface topography and assessing surface roughness.
In general, geometric model development forms the basis of the approach through rigorous mathematical equations. This model is then implemented by a computer
algorithm in order to handle the complex calculations. Also, there are some theoretical models that
relate surface roughness to cutting conditions such as the
feed rate [2]. These models are generally not accurate so their improvement with the introduction of additional
parameters is examined by researchers.

IV. Experimental investigation approach

The experimental approach may be thought of as the most 'obvious' method: experiments with the factors that
are considered to be the most important are conducted
and the obtained results are used to investigate the effect
of each factor as well as the influencing mechanism on
the observed quality characteristic. Regression analysis
is often employed in order to build models based on the
experimental data. The researcher's intuition and insight
play a great role in this approach but a high understanding
of the examined phenomenon is also necessary for the experiment to yield any meaningful results. The experimental approach is mainly adopted in cases where
there can be no analytical formulation of the cause and
effect relationships between the various factors.

V. Artificial neural networks overview

An ANN is an information processing system that displays
similar behavior to that of its biological analog. It is essentially a mathematical model that mimics the human reasoning and neurobiology and that is based on
the following assumptions [35]:
_ Information processing occurs in a number of simple
elements called neurons.
_ Signals are transmitted between neurons over connection
links.
_ Each connection link has an associated weight that multiplies the signal transmitted.
_ Each neuron applies an activation function to the incoming signal to determine its output signal (Fig. 2).
ANNs are mostly used for pattern recognition, pattern association and classification, constrained optimization
and systems modeling with applications ranging from
simple signal processing to medical diagnosis.
The two main characteristics of an ANN are: (i) the pattern of arrangement of the neurons, namely the architecture
of the network, which generally dictates what
type of problems can be dealt with; (ii) the method of determining the weights of the connections, either using
a training algorithm generalizing the relation of input to
output vectors-examples (supervised training) or inferring
classifications that are inherent to the data and generating
an exemplar vector for each class that is created (unsupervised training).

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I. CONCLUSION

The current work presented a review of the different approaches that are used for predicting the surface roughness and certain remarks concerning each approach
can be found in the respective sections. As is evident from the referenced papers, in recent years there has been a great deal of research activity in the field and the
results that have been produced are good. The trend that
is formed encourages more automated systems building
for on-line monitoring, measuring or control and is mainly driven by the fact that the processes themselves
have been automated to a great extent. All the methodologies
that are presented here can exhibit advantages and disadvantages when compared to one another, but
given this trend the most promising seem to be the theoretical and the AI approaches. A comparison of these two approaches reveals that AImodels take into consideration the particularities of the equipment used and the real machining phenomena, information that is stored in the experimental data used to develop the models. On the other hand, the theoretical approach is based on conventions and idealizations, which are responsible for errors and limitations. Surprisingly enough, a combined effort that would involve both AI and analytical modeling so as to validate, refine or correct the theoretical models was not found in the literature. Other advantages of the AI approach are that the models created seem to be the most realistic and accurate, they probably exhibit the highest level of integration with computers and that this approach can be used in conjunction with other more conventional techniques. With these facts taken into consideration, it can be concluded that there are not so many efforts as would have been expected. The same applies to the existing number of hybrid AI research approaches, such as the neurofuzzy systems. The advantages that they offer
(knowledge representation in the form of if-then rules, ANN assisted parameter determination) should be more than enough to encourage researchers to adopt these techniques, yet this has not been the case. Optimization of cutting conditions for a certain surface roughness is another field that has not received too much attention. GAs and other optimization algorithms could be ideally used in conjunction with the developed models for the prediction of surface roughness but as is evident from the above, very few similar approaches have been found.

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