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# A State of the Art Review of Online Condition Monitoring Tools using NDT as Principal Testing Technique

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**Abstract**

The non-destructive techniques are the suitable solution for testing and quality control but in present cut-throat scenario where margin of companies are decreasing and pressure for providing good quality is increasing day by day. Therefore offline condition monitoring techniques are losing their importance. Now the most suitable answer is on-line condition monitoring techniques. In online condition monitoring, machine or a component is constantly observed while it is in operating condition by taking help of sensors. This research paper aims to cover the research work related to online condition monitoring giving emphasis on those research papers which uses NDT as principal condition monitoring tool.

**Keywords-** Non destructive testing (NDT); Online Condition Monitoring; Fault Detection; Corrective Actions

## INTRODUCTION

Excessive maintenance works results [1, 2] in reduction of performance, efficiency and reliability of machine component. It is fruitful to go towards early fault detection [2, 3 & 4] & corrective action. Non destructive testing (NDT) as the name suggest is a Inspection or measurement of surface or internal flaws without destructing it. NDT is an effective technique [5, 6] and reduces Mean Time to Repair (MTTR) due to timely fault detection & Increases Mean Time between Failure (MTBF) due to pre-planned corrective action well before the breakdown. These techniques [7, 8] can be applied in online/offline condition monitoring of machine component or in a manufacturing processes such as welding, casting, forging, surface treatment, etc. in which flaws or defects are prominent.

In offline condition monitoring the component is either periodically or non-periodically observed with the help of suitable condition monitoring equipments. Therefore there is chance of neglecting the minor changes in performance of machine or some catastrophic failure.

In online condition monitoring, machine or a component is continuously observed while it is in running condition by taking help of sensors. This section will cover the research work related to online condition monitoring.

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## ONLINE CONDITION MONITORING TOOLS USING NDT AS PRINCIPAL TESTING TECHNIQUE

Abd Halim Suhaila et al. excellently gives overview of various authors for findings in detail about an automated detection system [9] to inspect and evaluate the existence of weld defect on radiographic image. Basically, there are four stages in development of automation analysis: image digitization, image processing, feature extractions and classification. Automated inspection of weld defect gives advantages in term of results and time. It avoids the limitation of manual examination by improving the objectivity, consistency, accuracy and efficiency at faster inspection rates.

E. Mendel et al. present vibration analysis techniques for problem revealing in oil extraction rigs [10] of rotating machines. Rolling element bearing faults inside a motor pump is the theme of study. Signal processing techniques, like frequency filters, Hilbert transform, and spectral analysis are utilized to extract features used afterward as a base to classify the condition of machines. Also, pattern recognition techniques are used to the obtained features to get better the classification precision. Furthermore, on others faults, such as unbalance, misalignment, flow turbulence, and cavitations can be investigated.

B. Sick state the reason for not been able to develop appropriate monitoring systems [11] up to now. In order to describe this 138 publications covering on-line and indirect tool wear monitoring in turning through artificial neural networks are evaluated. In this article, the methods used at the digital pre-processing level, the feature extraction level, the wear model level, and the decision level are investigated. The article compares the methods applied in these publications as well as the methodologies used to select certain methods, to carryout simulation experiments, to evaluate and to present results, etc. Furthermore, as author discussed focus on the development of the analytical process models for force signals, keep in evolutionary algorithms for structure optimizations, centre of attention on the development of measures for an automatic resolve of the optimal length of a reference (observation) time interval for local temporal information (short- or long-term information), the straight measurement of a wear area at a tool's flank by means of a CCD camera can be utilized with other applications. The figure 1 shows Force signal normalization by means of analytical process models.

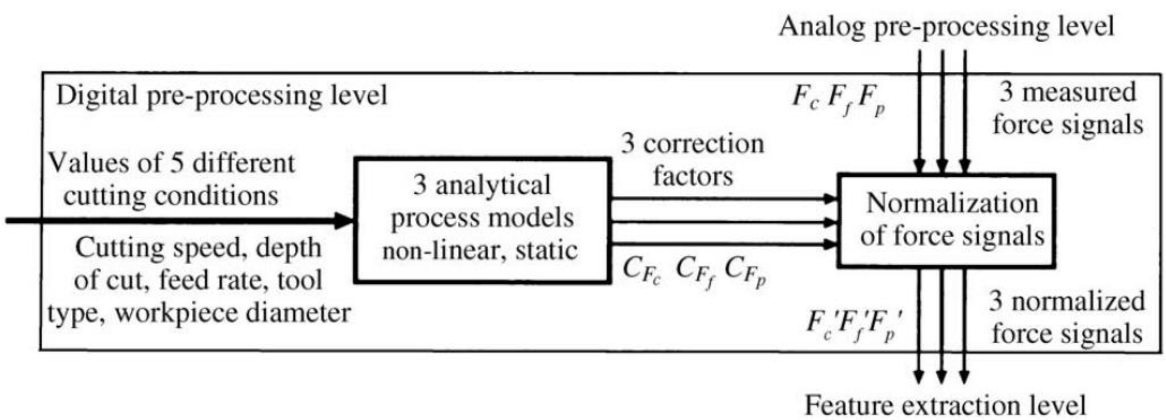


**Figure 1 Force signal normalization by means of analytical process models.**

D.E. Dimla et al. demonstrates an experimental and analytical method for one such technique concerning the use of three mutually perpendicular components of the cutting forces (static and dynamic) and vibration signature measurements [12]. The resulting analyses in time and frequency domains showed some components of the measured signals to correlate well to the accrue tool wear. Concept is explained with multiple graphs, flow charts. The figure 2 shows experimental test rig.

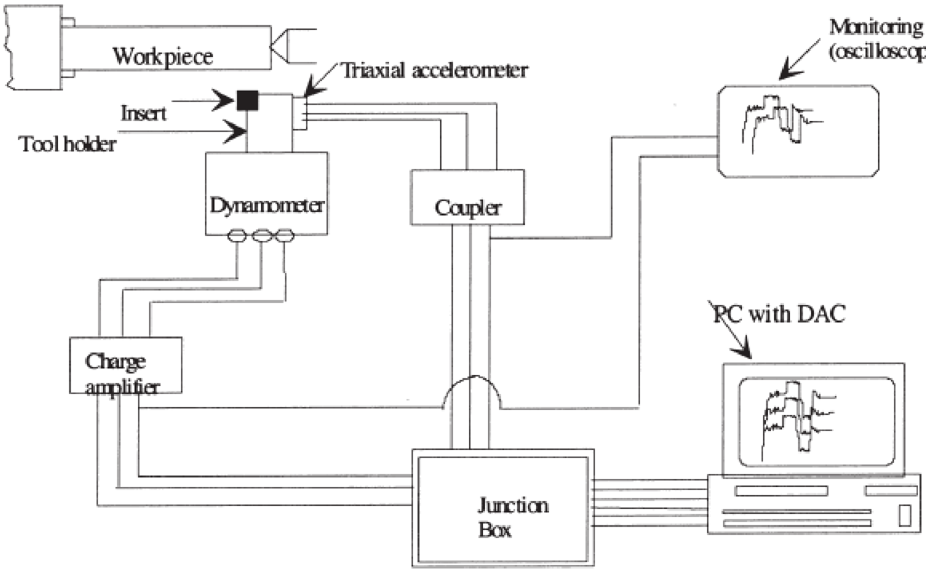


**Figure 2 The experimental test rig.**

Y. Amirat et al. stated status of diverse types of faults, their signatures and their analytical schemes in wind energy conversion systems [13]. This paper has briefly reviewed state of art of wind energy conversion systems condition monitoring and diagnosis.

M Jurevichius et al. presented automated system for vibrations measurement and algorithms for examination of vibration signal [14]. The vibration measurement system comprise accelerometers or displacement sensors, amplifier for sensor signal amplification and signal integrator for apparatus calculation of vibration speed and displacement, data acquisition device and personal computer. The vibration signals are analyzed in frequency and in time domain by estimating spectral distribution, statistics, RMS for different time intervals of vibration signal. The illustration of results of vibration measurement and data analysis in buildings and machines with rotating parts are included also. The software used for data acquisition is ebiol'LT and for data analysis it is Origin 7.0. It is found in multiple papers that use of two or more NDT techniques as a combination gives higher reliability in terms of fault detection. In this paper only one technique was used

A.A. Carvalho at al. presented pattern nonlinear classifiers were applied using artificial neural networks, to make sure the possibility to become aware of and classify defects in pipelines examine through magnetic pigs (MFL technique) [15]. More than a few tests were performed on specimens with defects artificially inserted (internal and external corrosion and lack of penetration). This work may be continued fulfilling more tests in new pipelines, to inc rease the classifier robustness as well as increasing the scope of the defects to be classified

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such as excessive penetration, root bead misalignment, and hollow bead. Besides, it is possible to apply new filters and methods to reduce the signal magnitude to turn the process still faster and more efficient.

A. Runnemalm et al. suggests a single-sided setup of a thermography system using a flash lamp as excitation source [16]. The analysis algorithm aims to find the spatial region in the acquired images corresponding to the successfully welded area, i.e., the nugget size. Experiments show that the system is able to detect spot welds, measure the nugget diameter, and based on the information also separate a spot weld from a stick weld. This paper covered a single-sided set up of a thermography system for spot weld inspection. The set-up is arranged to be possible to mount on an industrial robot in order to achieve a fully automatic inspection system. The analysis algorithm aims to find the spatial region in the acquired images that corresponds to the successfully welded area (the nugget size). The presented system is capable to inspect more than four spot welds per minute. The results were compared to the results from a peel test for each piece. In order to avoid uncertainties in the comparative measurement, the peel tests were performed by a skilled person with experience of measuring spot weld diameters. As discussed in paper itself, Even if the extracted characteristics of the welds most of the times are correct, the analysis is sometimes confused by the physical deformations of the surface created by the welding process. The presented system is capable to inspect more than four spot welds per minute. The set-up is arranged to be possible to mount on an industrial robot in order to achieve a fully automatic inspection system. The most common method for inspection of spot welds is ultrasonic testing, but experience shows that the reliability of the test is often depending on the time, place, testing situation, and skill of the operator. With the suggested setup of an automated thermography system, the inspection can be operator-independent, and with a stationary inspection cell, as suggested here, the time, test place and situation can be controlled. In this paper, the analysis is based on the variation in measured infrared radiation with respect to time. Therefore the absolute temperature, which requires exact knowledge about the emissivity, is not needed. Furthermore,

– *Bias as a function of material properties* The currently implemented system seems to give a bias towards smaller spot weld sizes. This bias is probably dependent on the material properties (heat conductivity and thickness) and should be systematically studied.

– *Image analysis* The current implemented image analysis method has several limitations. A more general implementation, where physical properties are taken into account, preferably validated by theoretical calculations and/or simulations, would be more reliable. Also, the method does not exploit the expected shape characteristics of the spot welds—the erroneous result could be avoided by exploiting the visibly circular structure of the weld.

– *Simulations* The problem with peel tests is that they are time-consuming and expensive to perform in large numbers. In order to evaluate variations and enable the work suggested in the previous two items, a simulation model should be built and used for large scale tests. Real peel tests could then be used in a small number in order to validate the model.

– *Excitation source* During the study several questions regarding the excitation were raised. The influence of the heat from two adjacent flashes should be examined, and shiny surfaces

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need to be handled. Moreover, for a system to be used in a production plant, the influence on the work environment is important.

D. Dinakaran et al. covered an ultrasound online monitoring of crater wear of the uncoated carbide insert during the turning operation [17]. The process depends upon inducing ultrasound waves in the tool, which are reflected by side flank surface. The quantity of reflected energy is correlated with crater wear depth. Various ultrasonic parameters are measured for defining the crater wear and individual role of each parameter is analyzed. The ultrasonic parameters, amplitude, pulse width and root mean square (RMS) of the signal are utilized to quantify the crater depth and width. The power spectrum analysis of received signals demonstrates the value of frequency components in defining the tool wear. In the presented work, the normalizing of signals is carried out by inserting hole, which is provided for clamping. This signal is not affected by the wear but affected by other factors like tool material variation, improper couplant, temperature, etc. The reaction of the wear signal is normalized to the response of hole signal by mathematical division. A new approach adaptive neuro-fuzzy inference system (ANFIS) for monitoring of crater in carbide insert is presented. This improves the system accuracy and eliminates the limitation in statistical modelling that was presented in previous studies. The boost in crater depth promotes the scattering of ultrasonic waves that causes the lessening in amplitude and RMS of signal. The frequency domain of signal shows the gradual loss of frequency components can be related to crater wear. The standard dB loss calculated from the signal diminishes as the crater wear increases. System modelling based on conventional mathematical tools is not well suited for dealing with ill-defined and uncertain systems. Here ANFIS is used as a modelling algorithm, which communicates the ultrasonic parameters with tool wear, which progress the system accuracy. The reaction of the wear signal is normalized to the response of whole signal by mathematical division. A novel advance adaptive neuro-fuzzy inference system (ANFIS) for monitoring of crater in carbide insert is presented. This improves the system accuracy and eliminates the limitation in statistical modelling that was presented in previous studies. In future the areal information of wear can lead to change in the present criteria. The cumulative pulse width is severely affected by the width of the wear. This is due to the fact that the fresh flank region loses its integrity and that irregularity causes the accumulation of grass- like signals with the peak signal. This can be used to predict the wear width. So the three-dimensional information about the wear can be predicted.

## RESULTS & DISCUSSIONS

The figure 3 shows graph between Year of Publication V/S No. of Research papers. It is clear that amount of work in the field of on-line condition monitoring using NDTs is very less.

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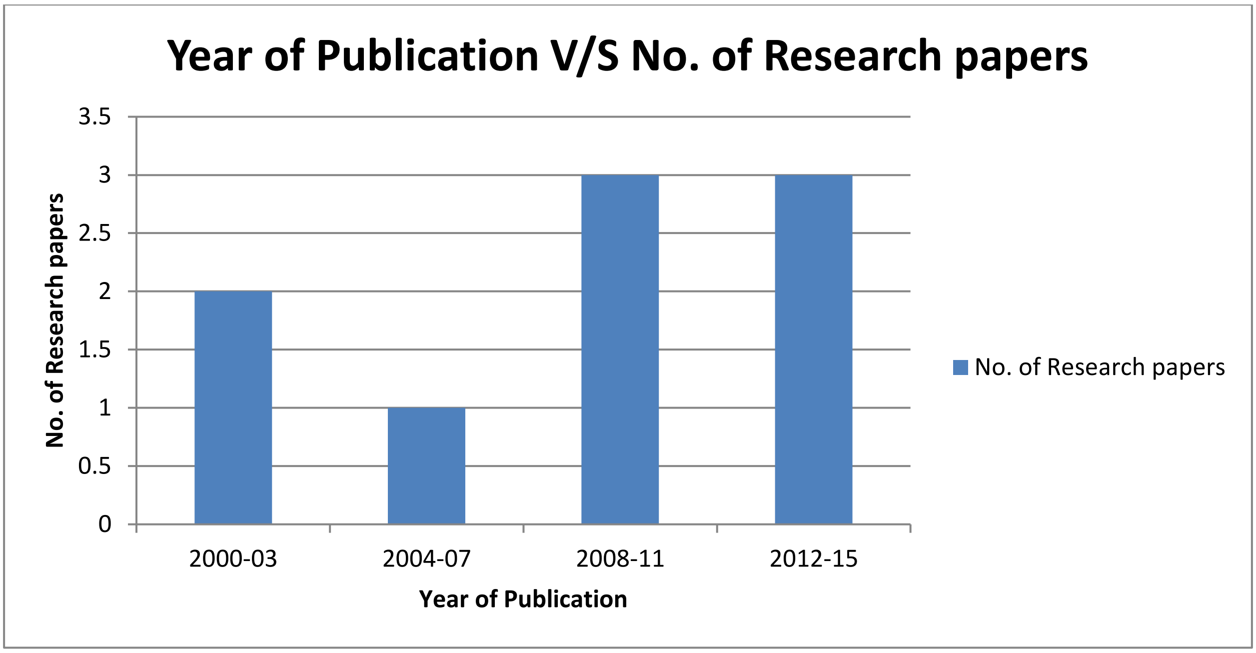


**Figure 3 Year of Publication V/S No. of Research papers**

The figure 4 shows plot between domain and number of research papers. It is clear that number of NDTs including eddy current testing, dye penetrant testing and many more are remain untouched.

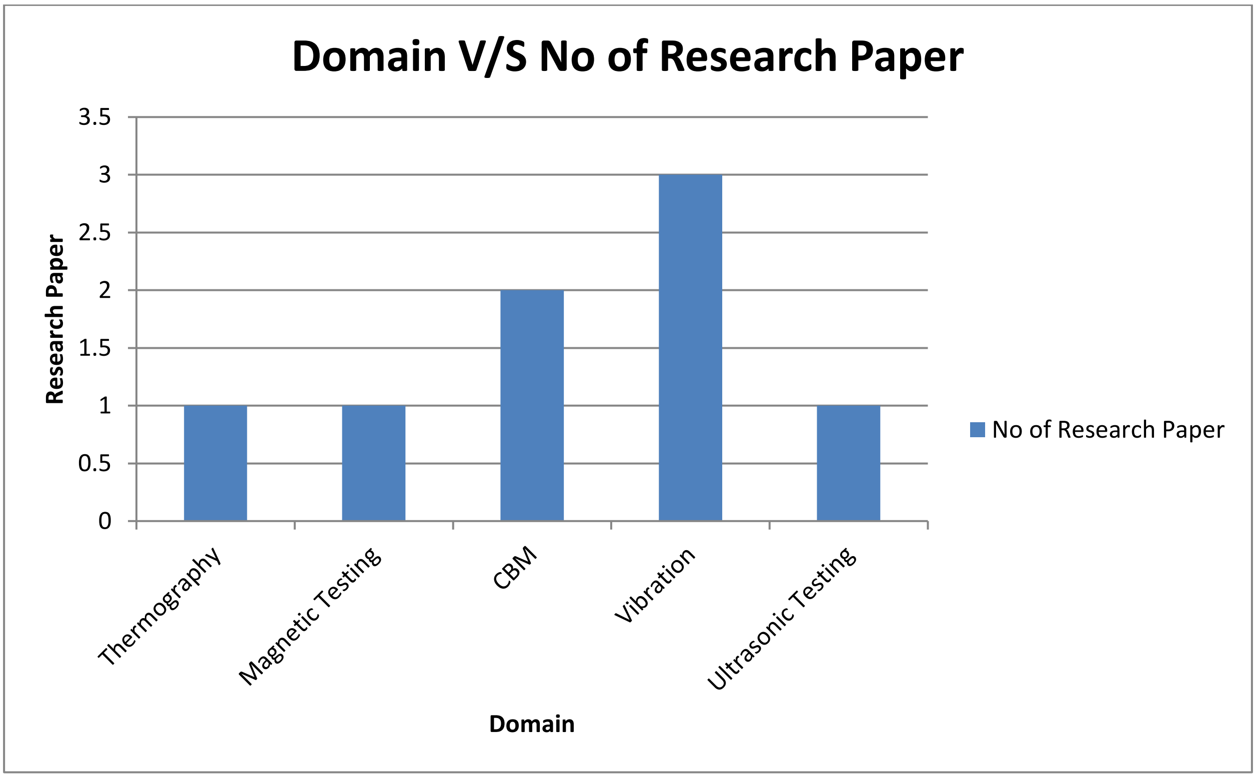


**Figure 4 Domain V/S No of Research Paper**

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## CONCLUSION

This research paper covered the research work related to online condition monitoring giving emphasis on those research papers which uses NDT as principal condition monitoring tool. It is clear from above discussion that the non-destructive techniques are the appropriate solution for testing and quality control but offline condition monitoring techniques is losing their importance due to highly competitive environment. Therefore, the most appropriate solution is on-line condition monitoring techniques in which machine or a component is continuously observed while it is in running condition by taking help of sensors. Furthermore, there is lot of scope remain in terms of area of research and development of condition monitoring methods

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