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"5S" METODOLOGY IN E-MANUFACTURING

Abstract: *In manufacturing, the health degradation of equipment is crucial and diagnostics should be carried out frequently. It is done with the help of statistics methodology or machine learning models. Obtained data is converted into prognostics information, so as to reduce "down time" to zero.*
"5S" is a step-by-step methodology used for prognostics with the aid of various computing tools for different applications in an e-manufacturing environment. It sorts out useful data from raw datasets, and converst data into information vital to equipment performance.
Keywords*: health degradation, prognostics, 5S methodology*

1. INTRODUCTION

If we would like to introduce prognostics technologies for e-manufacturing into manufacturing applications, from a management related field, we could adopt concepts such as "technology-push" and "need-pull".

The planning of a prognostics system in these two concepts is used in different ways. In "technology-push" concept, a series of planning steps are taken so as to adopt a plan, and to, eventually, obtain a final aplication and spread the technology. Unlike this, in "need-pull" concept the planning is based on the customers' demands meeting. Every system that cannot meet the standards is replaced, and the technology is adjusted according to the market needs, with an aim to fill any gap in the system.

In order to determine critical components, data streamlining is performed. The best option is to convert all processed data into information that can be later used. With this procedure, many other technologies are explored in order to consider the possibility and the benefit of introducing the prognostics, which would provide the decision makers with important information.

In some cases, companies know exactly what prognostic functions and machines are most important, and in those cases NP aproach can be applied. Depending on the need of prognostics functions and on the monitoring objects, different prognostics technologies are selected to be appropriate for applications and to give appropriate information, which helps decision makers.

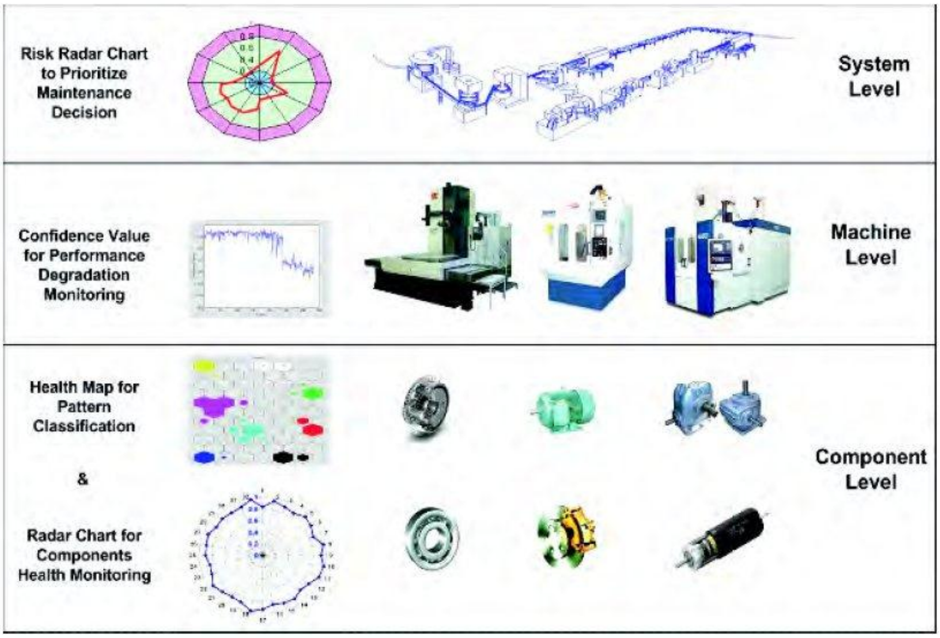

Figure 1 - Decision making at different levels

Radar chart for components health monitoring – the advantage of this tool is its property to provide maintainance practitioners with an overview of the health of different components. Each axis in the chart indicates the confidence value of a specific component.

Health map for pattern classification - with this map, a practicioner has got an overview of different failures and main causes of degradation and failure. Failures are shown in failure modes and each mode is indicated with different colour.

Confidence value for performance degradation monitoring – If the confidence value is low (0: unacceptable, 1: normal, 0~1: degradation), a mantainance practitioner can track a confidence value curve in order to determine the degradation trend. If the value goes below unacceptable threshold, an alarm will be triggered.

Risk radar chart to prioritise maintainance decision – This tool helps us to visualise the management of a plant-level maintenance management. If TP aproach is considered, all obtained data has to be converted into useful information that finally gives us an overview fot the feasibility of using a specific computing tool at different levels. After that, specific vsualisation tools are selected to display the information. NP aproach is a different. First, after the prognostics objectives are determined, the visualisation tools are selected. After that, visualisation tools are selected, with which decisions are made at different levels.

The radar chart and health map (Figure 1) can be used for displaying component degradation information. In order to create a radar chart, all data needs to be converted into confidence values (CV), which goes from 0 to 1. The health of each monitored component can be examined from the CV on each axis on the radar chart.

In order to provide all necessary information for diagnostics, a health map can be created with the help of a selforganizing chart. Risk radar chart is used to set maintainance priorities, based on each machine's risk value. The risk value of each machine is calculated by multiplying the degradation rate of the machine with the cost/loss of the machine, which doesn't indicate the performance degradation only, but also shows the costs during the downtime. Therefore, the examining of risk values on risk radar chart can set maintainance priorities.

A 5S Methodology is a tool that can be used during the reducing machine degradation and in the reducing downtime as well. 5S Methodology consists of:

- **S**treamline;
- **S**mart processing;
- **S**ynchonise;
- **S**tandardise;
- **S**ustain.

2. THE 1ST S – STREAMLINE

This tool has got an aim to identify critical components and determin data with which next S – Smart processing will be precise. The identifying of critical components is the first step in identifying prognostics methods that should be applied. Next step is the identification of critical components, and its goal is to, among many components, identify those ones whose degradation affects either system performances most or increases costs during downtime. In practice, there are cases when obtained data are useless and don't help at all, because they are too many and occur due to noise and sensor degradation. Therefore, a decision is not immediately made and prognosis is not carried out, but it is necessary to streamline raw data first, before processing.

Sort, filter is the identifying of critical components that are in the maintainance records. The best method to identify critical components is to create a four quadrant chart that is shown in Figure 2, which shows frequency of failure vs average downtime of failure.

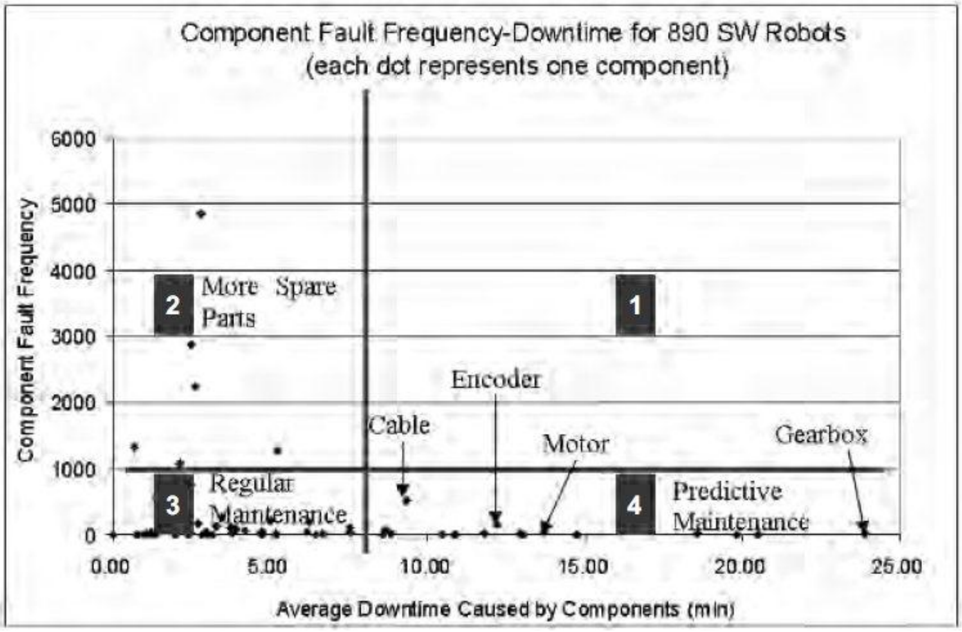

Figure 2 - Four qvadrant chart for identifying critical components

The graphic display of data gives better overview of the current maintainance scheduling. In the graph, there is a horizontal and a vertical line that form four quadrants. They are numbered from 1 to 4, starting from top right quadrant anti-clockwise. In quadrant 1, there are most frequent component failures that cause longest downtimes.

In quadrant 1, there should be no failures, because they should be eliminated in the design stage. In quadrant 2, there are components with high frequency of failure. The failures that occur cause short downtime. It is recommended that for these failures, a lot of spare parts should be available. In quadrant 3, there are components that don't fail often and which don't require special maintaining. In this case, standard maintaining is adequate. In quadrant 4, there are components that are very critical and that cause longest downtime per failure, even if they don't occur often. This is the most important quadrant, and prognostics should pay special attention to it. The critical components that cause failures are: cable, encoder, motor and gearbox (Figure 2).

Basic analysis in this tool has got a goal to select features, samples and statistical methods, which reduces the calculation time for the real-time application and the number of input sensors. Correlation and conversion of relevant data has got a goal to use graphs and data processing methods so as to find correlation between datasets and avoid useless data. In some applications, some data can be useless, and they can burden and impair the model performances. It is necessary, therefore, to give some efforts before further analysis, so as to provide precise mathematic models.

3. THE 2ND S – SMART PROCESSING

The second S is Smart processing and it is focused on mathematic tools. These computing tools convert data into information with an aim to get component health assesment, performance prediction and diagnostics in manufacturing application. Three basic elements of Smart processing are:

1. evaluate health degradation – it includes methods for assesing the overlapping between most recent feature space and those that will be obtained. This overlapping is expressed through CV that is in range from 0 to 1;
2. predict performance trends – it extrapolates the behaviour of process signatures over time and predicts their behaviour in future, in order to obtain information before a failure occurs;
3. diagnose potential failure – it analyzes the patterns in the data in order to find out what previously observed fault has occured so as to find a reference for taking maintainance steps.

There are two important issues that require attention in applying the second S to various aplications. They are the tool and the model selection. The tool selection enables us to determine specific required algorithms and select the most appropriate ones, and then to select proper tools. Next step is to define appropriate parameters for each model, so as to provide balance between the complexity of the model and the error during testing. The whole procedure of Smart processing is shown in Figure 3. The data from Smart processing are obtained from several sources, and they are later converted into multi-mode features, by selecting appropriate computing tools for signal processing and feature extraction. In feature space, health indices are calculated by statistically detecting the deviation of the feature space from the baseline. Next step is to select appropriate tools for health evaluation. The future machine/component degradation are predicted according to health indicators. Next step is to establish dynamic radar chart which displays the critical components health.

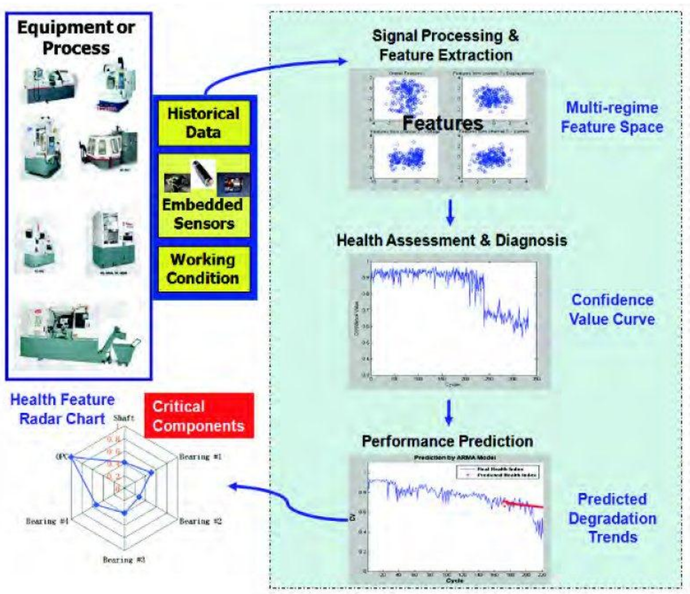

Figure 3 - Data-to-information conversion process

4. THE 3RD S – SYNCHRONISE

Synchronise is the third S in 5S methodology that aims to correlate the results of previous two S (streamline and smart processing) and it uses advanced technologies. Decision makers can use the tools as a basic help and a decision-making support. On the basis of obtained information, they can asses, consider the performances and make a decision necessary to prevent further failures. There are 4 basic elements of Synchronise:

1. embedded agents (hierarchical and distributive) include an architecture with hardware and software platform that is used for faster and easier "data to information" conversion and information transmission;
2. only handle information once, is an important principle in coversion of machine data into information only once. Among a lot of information, those that are usless are selected and filtered, therefore only valid and useful are left. The decision is made according valid information;
3. tether-free communication is an online communication that provides on-line and on-time access to prognostics information necessary for decision making;
4. decision support tools include a set of tools used for decision making. They should be user-friendly and enable fast decision making, in order to reduce downtimes, i.e. failure frequency.

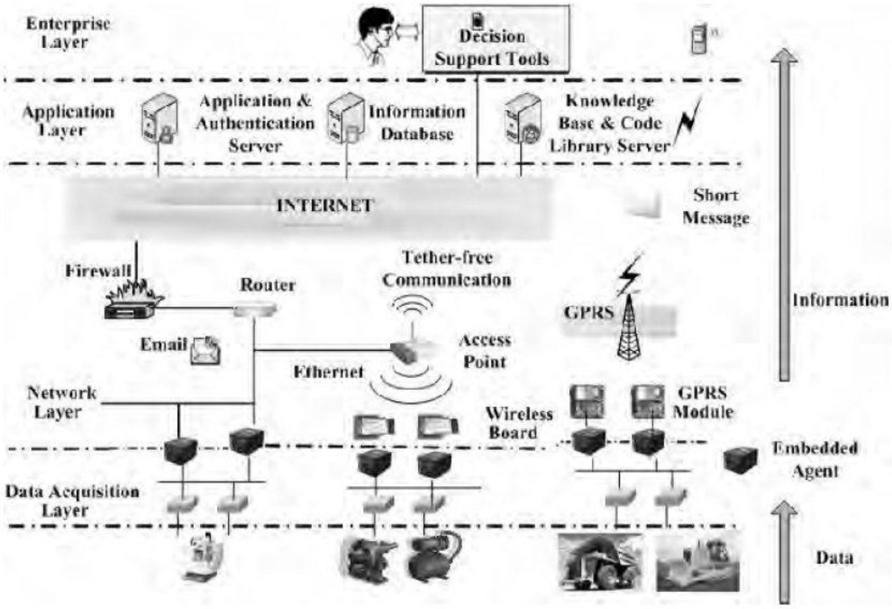

Figure 4 - Example fot theinfrastructure of Synchronise

For lage-scale industry application, a four-layer infrastructure can be used. It is shown in Figure 4. A data acquisition layer consists of multiple sensors. Sensors collect raw data from components and machines on various locations. Connection and data transission is via Ethernet and industrial bus. All embedded agents can communicate and collaborate through ethernet so as to accomplish a specific task. They are connected to a router wirelessly in order to have a secure connection to Internet.

For secure connection between Internet and the router, there is a firewall. The firewall prevents outter vicious attacks from harming the embedded agents. The basic elements of the application layer are:

1. application and authentication server;
2. information database;
3. knowlege and code library.

The application/authentication server provides services between the enterprise user's requests and the database. The information database server contains all the asset health information, including the performance degradation information, historical performance and basic information. The knowlege base and code library contain rules such as how to select algorithms for data processing, health assesment and prognostics. The enterprise layer offers a user – friendly interface for decision makers to access the asset information via the web-based human machine interface.

5. THE 4TH S – STANDARDISE

Standardise plays an important role in an enterprise, especially in deploying large scale information technology applications. The implementation of those applications can benefit from a standardised open architecture, information sharing interface and plant operation flow. There are three basic elements of Standardise and they are:

1. systematic prognostics selection standardisation, it defines the unified procedures and architecture in prognostics system. For example, the six-tier prognosis architecture defined by MIMOSA OSA-CBM (data acquisition, data manipulation, state detection, health assessment, prognostic assessment and advisory generation);
2. platform integration and computing toolbox standardisation, it integrates and modularizes different hardware platforms and computing tools within the information system of a company. This element incorporate standards for system integration, so the modules can be developed independently and easily adopted in a current information system.
3. maintainance information standardisation, it includes enforced work standards in a factory for recording and reporting machine/system failures. This information is important for developing a robust prognostics system. Besides, it improves the existing prognostics system through online learning;

6. THE 5TH S – SUSTAIN

During the manufacturing of a product, we get information necessery for further production. These information are used as an information agent, , i.e. contain data about product usage profiles, historical data, middle-of-life and end-of life service data. They help designers in designing products. Sustain consists of three basic elements:

1. closed-loop lifecycle design, it provides a feedback to designers, based on the integrated prognostics information, performance prediction information and remaining useful life;
2. embedded self-learning and knowlege management, it performs the prognostics in manufacturing plants at different levels (component level, machine level, system level) with least human intervention. As a result, the qality of the product or the system is improved (Kaizen principle);
3. user-friendly prognostics deployment. It focuses on the perspective of end users or customers. It involves dynamic procedures such as simulation, evaluation, validation, system reconfiguration and user-friendly web interface development.

E-manufacturing informatics platform is an integration of both software and hardware platforms for assessing and predicting equipment performances, with decision support functions based on the input from multiple sensors, historical data and operation conditions. The software platform is on the basis of an agent that is reconfigurable. The hardware platform is an industrial PC that combines the data acquisition, computation and Internet connectivity capabilities.

7. CONCLUSION

Modern manufacturing systems pay a lot of attention to machine degradation evaluation, i.e. maintainance of machines and equipment used in manufacturing. The key to success in a turbulent market is providing a high level of reliability of the manufacturing system, in order to decrease the number of failures (preventive and corrective maintainance) and to decrease the costs.

Maintainance management has got a goal to improve the manufacturing, reduce downtime and reduce losses, using new methods and new technologies. The main goal is to produce better quality of a product, with less downtime and costs.

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