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Complex Predictive Solution for Computerized Processes in Tire Industry

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Abstract. Following increasing market needs of productivity, cost reduction and safety requirements, computerized industry are faced to finding optimum between economic aspects of business and safety-related risk management. Modern factories equipped with computerized processes and extended diagnostic tools to support operator do not often use of all information's which comes from the equipment. Some of the relations between the events are also omitted or neglected. Authors after analyzing the defects of modern production lines with batch production, noticed a correlation between the defects and the historical information registered by the supervisory system controlling the production process. The problem is that with the multitude of appearing information, they are not analyzed on an ongoing basis. This article presents a new approach to increase machinery reliability, safety and quality increase through predictive data analysis.

Keywords: Reliability · Failure prediction · Data mining · Functional safety

1 Introduction

Until the 40's of the twentieth century, the approach to the failure was based on the reactive approach or principle "broke down, so fix it", this approach began to change during World War II when the reliability of more and more complex technical devices often decided about life or death. This was the beginning of planned repairs and inspections and parts replacement. However, this solution also had some drawbacks, among other things, it brought a high cost of maintenance, as the part which was in very good condition was often exchanged. In particular, the aviation industry, similarly to today, in the 1960s, analyzed the costs of maintaining the fleet of aircraft. With the arrival of Boeing 747 with advanced technology, the Reliability Centered Maintenance (RCM) method was developed [1].

Based largely on a predictive approach analyzing the condition of machines (called Condition Based Maintenance). Due to the rapid development of electronics, it became possible to more and more accurately analyze the parameters of machines and devices. On the other hand, the increasing share of electronics in machines caused that apart from the traditional "bathtub" distribution of damage, several new ones started to appear. Vibroacoustic measurements, oil analyzes and thermographic measurements of machines and electrical cabinets and substations are currently standard in the industry. Various types of real-time measurements are also becoming more and more widely disseminated. Also, thanks to the advances in technology, the sensor market has expanded its offer by testing many physical quantities and at the same time the cost of a single sensor has dropped several dozen times. All this has meant that modern production lines are equipped with hundreds and sometimes thousands of sensors that collect data on an ongoing basis and monitor the state and course of the production process [2].

The problem faced by engineers today is the opposite of that of factories at the beginning of the last century - today it can be seen an excess of information, controllers and through them, Supervisory Control and Data Acquisition (SCADA) systems present hundreds of information to the operator [3]. The most important are filtered and presented in such a way that can be effectively manage the process, but nevertheless a significant part of the data is skipped.

The authors of this article proposed a comprehensive approach to the method of detection of machine defects. The method can be applied and be effective in detecting functional safety anomalies, cyber security threats and can be effective in detecting deviations of quality and energy efficiency analysis, binding together the influence of the parameters of the prescription to increase energy consumption. The last possible profit is the analysis of operator behavior recorded in the machine control systems and then proposing corrective actions.

2 Proposed Prediction Methodology

Every technical device requires human operation and maintenance, the more technically advanced it is, the more trained the operators and maintenance must be, but human behavior remains the same regardless of changes in technology, resulting in the need to implement organisational techniques such as Total Productive Maintenance (TPM) [4] and cost optimization such as RCM. This is the foundation for further work with the advanced solutions proposed in the article.

Authors after analyzing the defects of modern production lines with batch production, noticed a correlation between the defects and the historical information registered by the supervisory system controlling the production process. The problem is that with the multitude of appearing information, they are not analyzed on an ongoing basis. The idea was to create a tool that would generate reports of impending defects with a certain frequency. These reports read by personnel would be verified by inspection. If the predictions of the system were confirmed, actions would be taken to eliminate the anomaly before the occurrence of the defect, or to minimize its impact and the size of the losses [5].

On the market exists the solutions of predictive analytics but their scope is limited to one aspect –maintenance predictive [6, 7]. The proposed solution concerns not only improving the reliability of machines and devices. It also significantly influences the improvement of the safety and quality of manufactured products by reducing anomalies, process disturbances such as defects, a much faster diagnosis of deviations, which reduces the amount of production rework or scrap. The last, however, the most important element improving is the level of cyber security (Fig. 1).

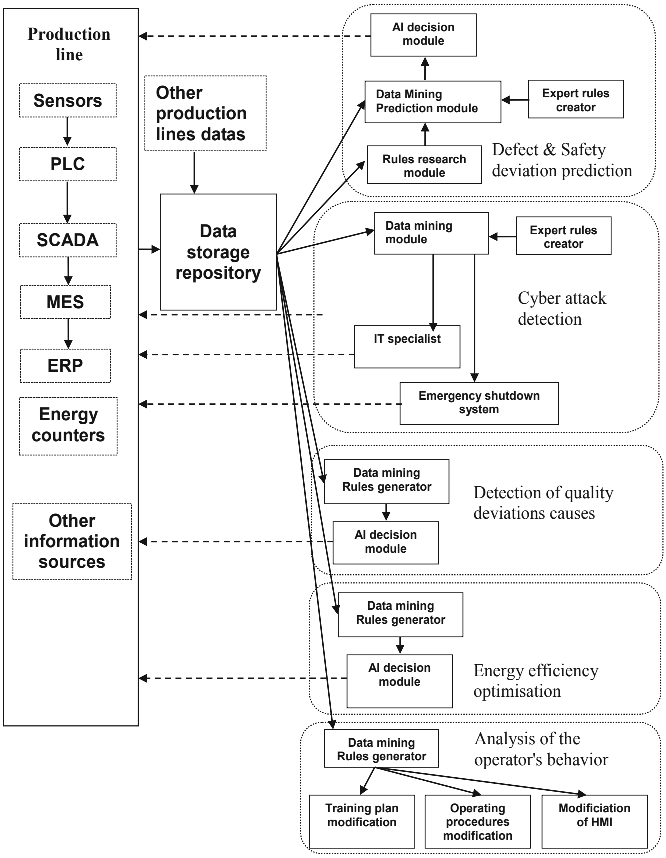


Fig. 1. Integrated concept of factory data mining and prediction supported by artificial intelligence

The main assumptions of each of the above-mentioned functionalities are based on the same tools and mechanism. Therefore, the proposed comprehensive tool will be explained briefly on the example of the section on machine defect & safety deviation prediction module.

The authors propose a prediction tool based on statistical instruments. This tool consists of four modules considered as a comprehensive approach to prediction (Fig. 2). The first element of the system – Data collection - consists of output data from the production line. In modern production lines all data from sensors, inverters, drives, intelligent sensors, networks, programmable logic controllers (PLC), human-machine interfaces (HMI), Supervisory Control and Data Acquisition (SCADA), Manufacturing

Execution System (MES) and Enterprise Resource Planning (ERP) are collected in a data storage repository (Fig. 1). These data are, by nature, in different forms.

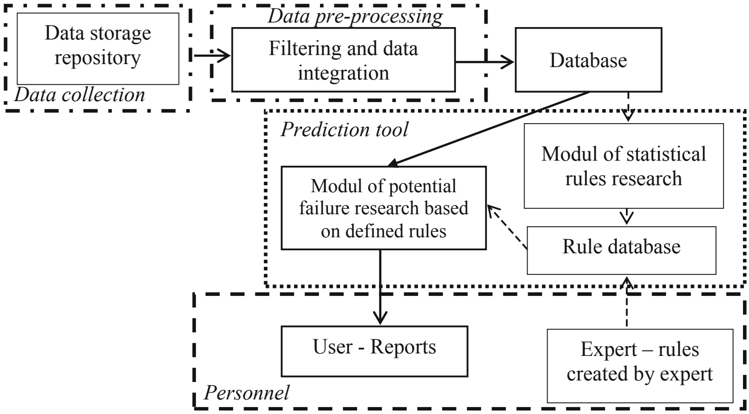


Fig. 2. Functional diagram of proposed solution for defect and safety prediction

The second module - Data pre-processing - is used for data processing by pre-filtering and integrating data into one-dimensional data. The data are then collected in a common database. Next step is that information's has to be classified into two categories – cause or effect. Without this category's algorithm treat every event as a potential cause and effect what leads to a considerable prolongation of time for calculation. The third module - Prediction tool - is the work with the collected and pre-prepared data in order to obtain useful information and conclusions from them. In the first stage, a statistical rule search module is used to analyze historical data. In this case we have to deal with the need to use statistical tools of machine learning and methods of artificial intelligence to discover the relationship between events gathered in the database.

A statistical tool created for this purpose is association analysis [8]. Results of machine learning tool feeds the rules database with ready-made rules. The second stage is to analyze the data gathered on an ongoing basis at specific time intervals. The module filters data through predefined rules using time-frame set for some period defined by the system administrator and searches for potential events.

The last module - Personnel - is the human-system interface module. There is a division into an expert and a user. The role of an expert who also based on knowledge, experience, familiarity with control systems and mechanisms operating in them can supply the database of rules. The second important role is to remove automatically found rules of minimal importance for the goals of the company. The user, on the other hand, is a client of the system who receives ready-made reports with predicted events. Its role is to analyze reports and take preventive steps at the facility.

3 Implementation of Proposed Methodology on the Plant

Two modern production lines equipped with a wide range of sensors monitoring both the process and machine status on-line were selected for pilot implementation. TPM and RCM methods are implemented on these production lines. After collecting and analysing historical data from the period of more than three months, it appeared that on average 11830 messages for operator were generated daily. The test implementation was limited to 6 months and was limited to the defect's prediction module only. The statistical tool created for this purpose was the association analysis. The solution widely used for statistical analyses in recent years, enriched with a package enabling application in industrial plants, was the Statistica software package. Sequential analysis to detect recurring patterns during events resulted in 684 rules with the following indicator levels: minimum support = 0.1, and minimum trust = 0.5. Only simple rules were searched by principle "if the predecessor then a successor". No rules were searched for with a sequence of several preceding events.

Analyzing the results obtained in relation to the predictions, the proportions in which symptoms appear before the occurrence of the defect were proportional. During 8 h before the defect 80% of symptoms appear (Fig. 3).

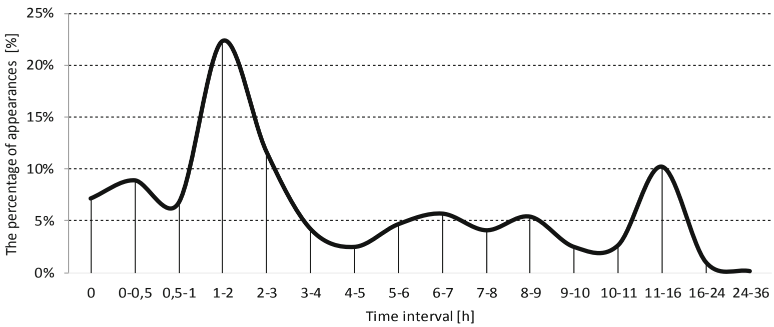
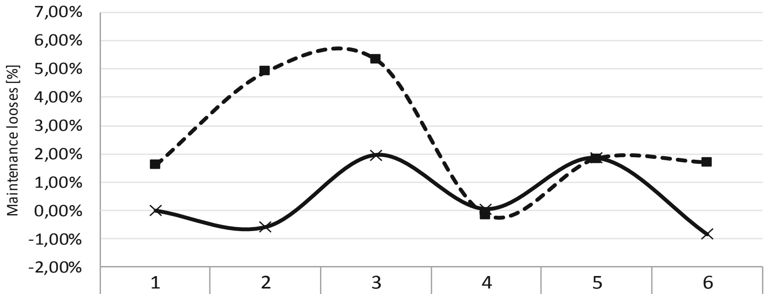


Fig. 3. Chart of time intervals between symptom and effects symptom-effect relationship

It was also puzzling that almost 7% of all relationships appeared in time almost simultaneously with the occurrence of the defect (Fig. 3). The verification of these events showed that some rules should be turned off due to their dull character. Analysing the graph of maintenance looses (Fig. 4), where the first month of year *n* (year of tool implementation) was taken as a percentage reference could be seen decrease of 2,13% year to year in maintenance loses indicator. What is also important from the point of view of the maintenance services customer's, compared to the previous year there has been a reduction in the fluctuations in the time load for which the maintenance operations are made. Greater stability results in fewer disturbances, more stable production, which translates into stability of quality results and improvement of production indicators.



	1	2	3	4	5	6
year n-1	1,60%	4,91%	5,34%	-0,17%	1,84%	1,70%
year n	0,00%	-0,57%	1,96%	0,06%	1,85%	-0,83%

Months

Fig. 4. Losses due to unplanned and planned maintenance activities on line A in the year of tool implementation and previous year.

4 Conclusion

The results of the test solution showed that it is possible to simultaneously increase machine availability and improve machine safety by predicting faults based on a statistical analysis of the symptoms recorded by the control system. The short test implementation time and limited resources did not allow for the expansion of the system and use of all presented modules, however the results obtained confirmed the effectiveness and usefulness of the tool.

After optimization of the solution, the system can be easily copied and installed on other similar installations in the enterprise. This results in a very fast, cheap and not requiring large human resources increase the reliability and safety and security of machines, which indirectly affects also the improvement of the quality of manufactured products.

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