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Integration of a new smart sensor in a steel plant to improve the warning time of anomalies in the drive train

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The drive train is a central part of the production process in any production. Its contribution is so important that its malfunction or failure can cause many problems, such as insufficient or poor production quality or, in the worst case, production downtime. All these problems lead to high additional costs and in some cases contribute to the deterioration of the company's image. To avoid these issues, an innovative drive train condition monitoring sensor was integrated into the maintenance process in a steel mill plant of Arcelor Mittal Hochfeld (AMHO), to improve the warning time for possible anomalies or failures in the drive trains and to reduce the associated additional costs.

The aim of this paper is to describe some possible maintenance procedures depending on the sensors used with their failure prediction times for the condition monitoring of the drive train in a steel mill, to show their advantages and disadvantages and to present the limitations of these maintenance procedures, especially about the prediction time of possible anomalies. Subsequently, the current maintenance procedure in the steel plant is presented with its potential for improvement. For this purpose, a performance index (KPI) is introduced to evaluate the effectiveness of the maintenance procedure in the steel plant and to validate the effectiveness of the procedure improvement by integrating the new sensor. Finally, the main relevant points are highlighted in the conclusion of this paper.

KEYWORDS: DRIVE TRAIN, BEARING DAMAGE, EARLY DETECTION, ANOMALIES, MONITORING, PARASITIC PROPERTIES, OPTIMIZATION, INTELLIGENT MANUFACTURING

INTRODUCTION

One of the most important elements of powertrain maintenance is the fault prediction time. The prediction time of faults in the powertrain has a considerable influence on the efficiency of the maintenance plan. The use of appropriate and up-to-date sensors to detect possible machine faults in an optimal time frame facilitates maintenance planning and significantly reduces maintenance costs.

The paper will describe some possible maintenance procedures depending on the type of sensor and their failure prediction times, as well as a rough presentation of the application of FMEA (Failure Modes and Effects Analysis) in relation to the intelligent bearing sensor at AMHO for the improvement of maintenance procedures to have a positive impact on the production and resource planning of their drive trains. Due to the large number of failures and their causes in the powertrain. After that, we will have a description of the maintenance procedure as it

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is at AMHO and the improved maintenance procedure to show the improvement and its advantages. Finally, we will present the benefits of this improvement in production and resource planning using the key performance index (KPI).

MAINTENANCE PROCEDURES ACCORDING TO THE PREDICTION TIME OF THE SENSOR

Table 1 gives an overview of the efficiency, flexibility, and popularity of some of the methods of fault detection on engines currently in use or under development. Properties such as prediction time, efficiency, and the ability to be equipped with intelligence are of particular importance as they have a direct impact on maintenance planning and consequently on maintenance costs. As can be seen from the table, the most used sensors are not necessarily the most appropriate and efficient ones, such as temperature, noise, or vibration sensors [1] [3] [5]. In the case of lubricant analysis, although effective, the waiting time for laboratory results means that the prediction time is practically ineffective. The method using stator currents [4] and electrical signals [1] [2], on the other hand, has great potential due to its intelligence and the detection method, which considerably increases the prediction time for anomalies [5]. In this article we will present the integration of a smart bearing sensor (SBS) [1] [7] at AMHO steel plant based on the use of electrical signals injected into the machine and whose return signal gives an idea of the health of the motor or drive train.

Tab.1 - Sensor's method properties used for drive trains maintenance procedures in steel plant.

	Sensor's method					
Properties	**Grease check**	**Vibration**	**Noise**	**Temperature**	**Stator current**	**Electrical signals**
Use	high	high	moderate	high	low	low
Warning time	no	moderate	low	low	high	high
reliability	high	moderate	low	low	high	high
Smart	no	Moderate	low	low	high	high

PRELIMINARY FAILURE MODE AND EFFECT ANALYSIS

The FMEA applied at AMHO is the functional or system FMEA particularly for the drive train and its components. Starting from the measurement with the smart bearing sensor through the structure of the FMEA at AMHO with the 3 FMEA-steps (Failure's analysis, Risk analysis, optimisation analysis) as shown in Figure 1. Theses 3 steps enable the optimisation of the risk management of the drive train components. Table 2 gives an overview with some examples about the illustration of the application of FMEA at AMHO. As shown in Table 2, the first important part of this illustration is the accuracy of the sensor and the efficiency of the anomaly's detection methods. First, drive train component functions and potential function failures must be evaluated and with the outcome of this evaluation the failures severity will be classified. Then, the potential effects and reliable causes will be illustrated. The measurement and analysis of potential functions allows the detection of failures and risks. The results of the measurement analysis can be used to optimise the system, propose solutions, and prevent failures.

Fig.1 - Functional FMEA structure at AMHO.

Tab.2 - Illustrative example of the application of a functional FMEA at AMHO.

Smart Bearing Sensor Measurements	Detection Methods	Component/ Drive Train Function Evaluation	Potential Function Failures	Failures Severity	Potential Effects	Potential Causes	Prevention/ Reparation Suggestions
e.g. √ Bearing status √ Motor status √ Drive train status	e.g. √ voltage signal analysis √ Vibration signal analysis	e.g. √ Motor enables balanced rotational movement √ Drive train enables suitable velocity in the production	e.g. √ Unwanted vibrations √ Unbalance in motion	e.g. √ Tolerable √ Serious √ Critical	e.g. √ insufficient product quality √ Unwanted vibrations √ Unbalance in motion	e.g. √ Lubricant lack √ Unsuitable lubricant √ Bearing ball damage	e.g. √ Lubricant monitoring √ Suitable lubricant √ Vibration monitoring √ Suitable components

IMPROVED MAINTENANCE PROCEDURES AT AMHO

Figure 2 and Figure 3 show the maintenance procedures at AMHO before and after the planned improvement with the smart bearing sensor and its additional expandable sensors for many purposes such as system monitoring in correlation with product quality.

Figure 2 shows the maintenance procedure with the vibration sensor as main sensor for anomalies detection. The procedure starts with a new or refurbished motor or other drive train component, which be installed in a drive train. Only after all drive train components have been completely installed can monitoring of the drive train begin. In the procedure, this is monitoring level 2, because monitoring begins first after the drive train has been assembled. After the vibration analysis with the vibration sensor, there are only three possible results. In case of a good or tolerable result, the drive unit is allowed to remain in operation. In case of a bad or non-tolerable result, the powertrain will be sent for reconditioning.

Figure 3 shows the maintenance procedure with the smart bearing sensor concept. Differently from the maintenance procedure with the vibration sensor only, the procedure with the smart sensor has 2 monitoring levels. Monitoring level 1 for the new or reconditioned engine or other drive train components. Monitoring level 2 for the assembled drive train, also with 3 possible results (good, tolerable, not tolerable, bad), with the major difference that the function of the new component as a stand-alone element can already be proven before it is assembled in the drive train. In addition, the intelligent bearing sensor allows the extension of other detection methods, even with high accuracy requirements.

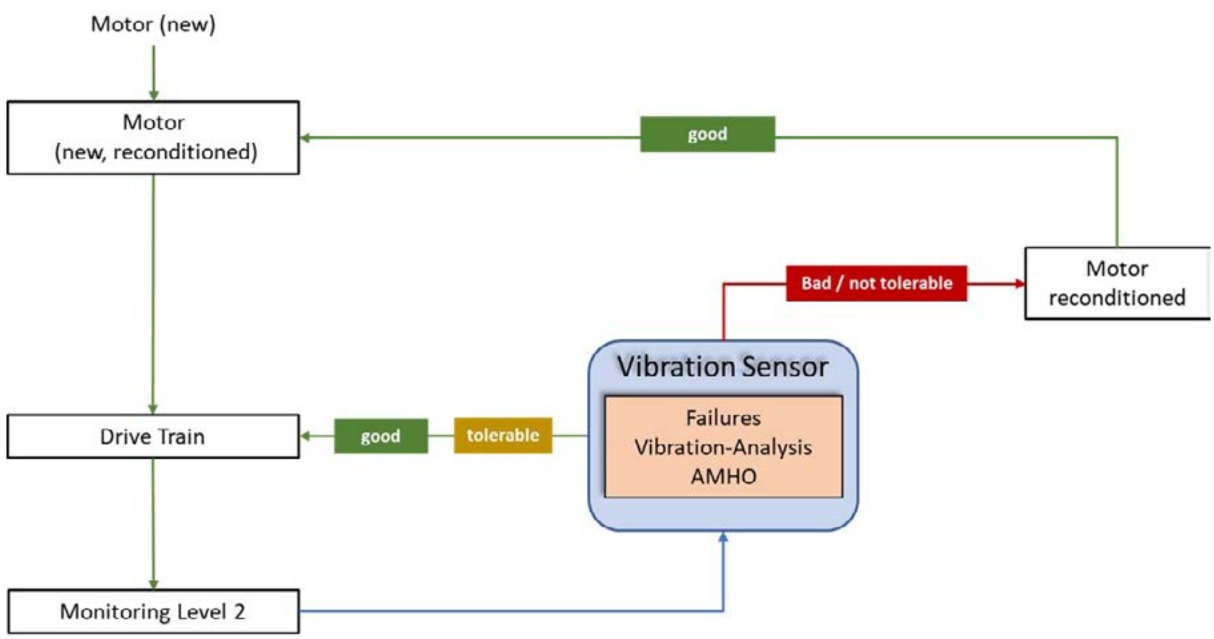

Fig.2 - Maintenance procedures before the improvement at AMHO.

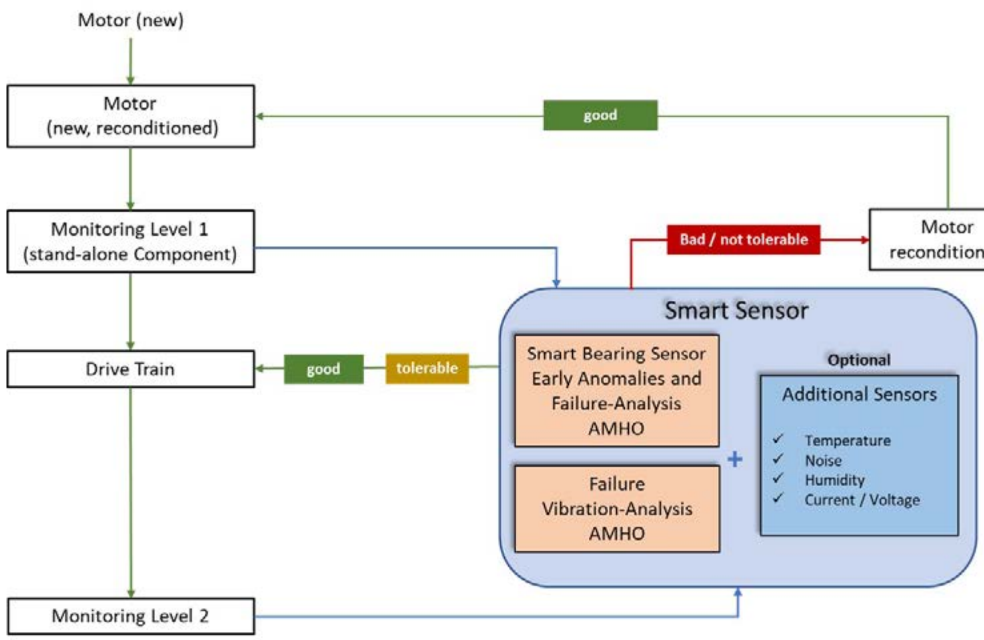

Fig.3 - Maintenance procedures after the improvement at AMHO.

IMPROVEMENTS IN ICT LANDSCAPE

Figure 4 shows the IT landscape at Arcelor Mittal Hochfeld. The part marked in green shows the upgrade of the IT landscape at AMHO to integrate the new SBS sensor to improve the warning time by detecting faults or anomalies by installing the 2 most important components (Central Processing Unit, sensor contact) of the new sensor and their connection to the current IT landscape.

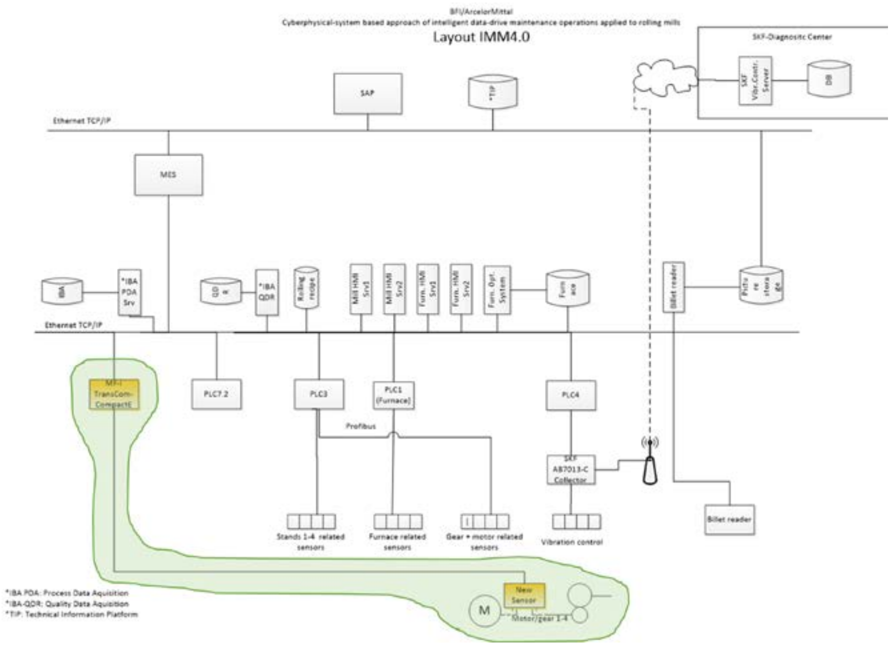

Fig.4 - Improved ICT landscape at AMHO.

KEY OF PERFORMANCE INDICATOR AT AMHO

Key Performance Indicator (KPI) Equation (1) is used to evaluate the robustness and improvement of the prediction time and the efficiency of the method. Thus, for a significant increase in the prediction time of an anomaly, we will have the prediction period P_{pred} greater than the maintenance period P_{maint}, so the KPI_{sensor} will be greater than 1 (2) and there will be an improvement of the prediction time and a confirmation of the efficiency for the event observed. Otherwise, we will speak of a restriction or no effectiveness for the event examined (3).

$$KPI_{sensor} = \frac{P_{pred}}{P_{maint}} \quad [1]$$

Improvement of prediction time

$$KPI_{sensor} > 1 \quad [2]$$

No improvement or no effectiveness

$$KPI_{sensor} \leq 1 \quad [3]$$

CONCLUSIONS

The implementation of the smart bearing sensor offers new possibilities such as the monitoring of stand-alone drive train components, the monitoring of the complete system or the flexibility for more area monitoring with additional sensor also with high accuracy requirements. The 2 levels monitoring enable deeper analysis thanks the high precision data and earlier detection method, starting from the components up to the assembled drive train. All these features could contribute to a better planning of the maintenance and production at AMHO. Furthermore, the advantageous warning time enable to detect anomalies in the components already in the first use before the assembling in the drive train, all this enable a better preventive monitoring and reduce the maintenance costs. This efficient preventive monitoring contributes significantly to optimize the resource scheduling.

Concerning the KPI_{sensor} (1), the fact that the detection can be done as soon as it leaves the factory gives P_{pred} a maximum value which will always be higher than P_{maint} and consequently KPI_{sensor} is much higher than 1 for a P_{maint} of 2 weeks (maintenance period), which confirms a strong improvement in the prediction time of the anomalies by this new method.

ACKNOWLEDGMENTS

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Integrazione di un nuovo sensore intelligente in un impianto siderurgico per migliorare il tempo di preavviso delle anomalie nella catena cinematica

La catena cinematica è una parte centrale del processo produttivo in qualsiasi produzione. Il suo contributo è così importante che un suo malfunzionamento o guasto può causare molti problemi, come una qualità di produzione insufficiente o scarsa o, nel peggiore dei casi, un fermo di produzione. Tutti questi problemi comportano costi aggiuntivi elevati e, in alcuni casi, contribuiscono al deterioramento dell'immagine dell'azienda. Per evitare questi problemi, un innovativo sensore per il monitoraggio delle condizioni delle trasmissioni è stato integrato nel processo di manutenzione di un'acciaieria di Arcelor Mittal Hochfeld (AMHO), al fine di migliorare il tempo di preavviso di possibili anomalie o guasti nelle trasmissioni e ridurre i costi aggiuntivi associati.
L'obiettivo di questo articolo è fornire una descrizione di alcune procedure di manutenzione standard per il monitoraggio delle condizioni della catena cinematica in un impianto siderurgico, mostrarne i vantaggi e gli svantaggi e presentare i limiti di queste procedure di manutenzione, soprattutto per quanto riguarda il tempo di previsione di possibili anomalie. Successivamente, viene presentata l'attuale procedura di manutenzione nell'acciaieria con il suo potenziale di miglioramento. A tal fine, viene introdotto un indice di prestazione (KPI) per valutare l'efficacia della procedura di manutenzione così com'è nell'acciaieria e per convalidare l'efficacia del miglioramento della procedura con l'integrazione del nuovo sensore. Infine, nelle conclusioni del presente lavoro vengono evidenziati i principali punti rilevanti.

PAROLE CHIAVE: TRASMISSIONE, DANNI AI CUSCINETTI, RILEVAMENTO PRECOCE, ANOMALIE, MONITORAGGIO, PROPRIETÀ PARASSITE, OTTIMIZZAZIONE, PRODUZIONE INTELLIGENTE

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