Methodology for optimizing the use of NDT in predictive maintenance

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Abstract

In order to avoid the problems that could be slow down and even stop the production, the company must adopt a strategy of maintenance of all equipment throughout their life cycle, which aims are: better management, organization, equipment control and anomaly detection as well as accurate diagnosis of malfunctions. Besides, a bad the nasty maintenance program could be prevented in increased production rates and poor business development, where the maintenance program must move towards predictive maintenance, which contains many NDT (non-destructive testing) techniques such as vibratory analysis, thermography, ultrasonic, radiography, penetrant testing and magnetoscopy. Therefore, the choice of an NDT technique among others on the nature of the physical parameter has to be monitored and according to the criteria of speed, cost, reliability, ease, and safety of each technique. Moreover, some components, have seen that several NDTs can be used, in order to optimize the use and the costs related to these NDTs. Thus; the present work consists of proposing a new methodology for ranking NDT techniques based on priorities. Nevertheless, the proposed methodology has proven its robustness in the study case part of one of the workshops of a phosphoric office.

Keywords
Preventive maintenance, predictive maintenance, NDT, methodology, optimization

1. Introduction

In the current context of opening a competitive market to competition, companies must improve their competitiveness and even their productivity, to produce more with lower cost, in order to have a better availability of the means of production while spending less. Therefore, the use of increasingly complex systems to face the challenges of sustainability, competitiveness, safety and security bring up maintenance problems which is one of the keys to the optimization of technological and industrial systems [1] [2]. Thus, the Maintenance costs are often the major part of the operating costs in many production units where these costs can be significantly reduced by predictive maintenance. This is not the case for traditional maintenance methods [3]. Therefore, the recent studies on the effectiveness of maintenance management have shown that more than a third of maintenance costs come from unnecessary or poorly performed operations [4] [5].Nevertheless; a bad maintenance policy has disastrous consequences on the quality of the products, to remedy it, the maintenance program must move towards a predictive maintenance, which contains many NDT techniques such as vibratory analysis, thermography, radiography, penetrant testing, magnetoscopy and ultrasonic [3] [6].

These NDT techniques have become essential to increase the reliability, safety and service life of installations [3]. They make it possible to characterize the state of integrity of the equipment, without destroying and without disturbing the production lines [7] [8]. Nevertheless, the choice of one technique among others lies in the nature of the physical parameter to be monitored [9] and according to the criteria of speed, cost, reliability, ease, and safety of each technique [10] [11]. In this context, it seemed appropriate to propose an approach that allows to choose the most suitable NDT technique to use where our approach is divided into four complementary phases as shown in (Figure 1): identify all the NDTs to be classified, establish a list of priority criteria, evaluate the performance of each NDT technique according to the different criteria selected and evaluate the performance of each NDT technique according to their overall scores. Therefore, the present work consists in providing a global description of each phase of our methodology as well as their deployment within one of the workshops of a phosphoric office.

2. Optimization approach the use of NDT

In some components, we see that we can use several NDT, in this perspective, our contribution will be to optimize the use of NDT and subsequently to optimize the costs related to these NDT, to address this problematic, a proposed multicriteria approach to prioritize NDT techniques. A family of criteria is proposed for ranking. The approach we have taken for this problem (Figure 1) is based on these four complementary phases are:

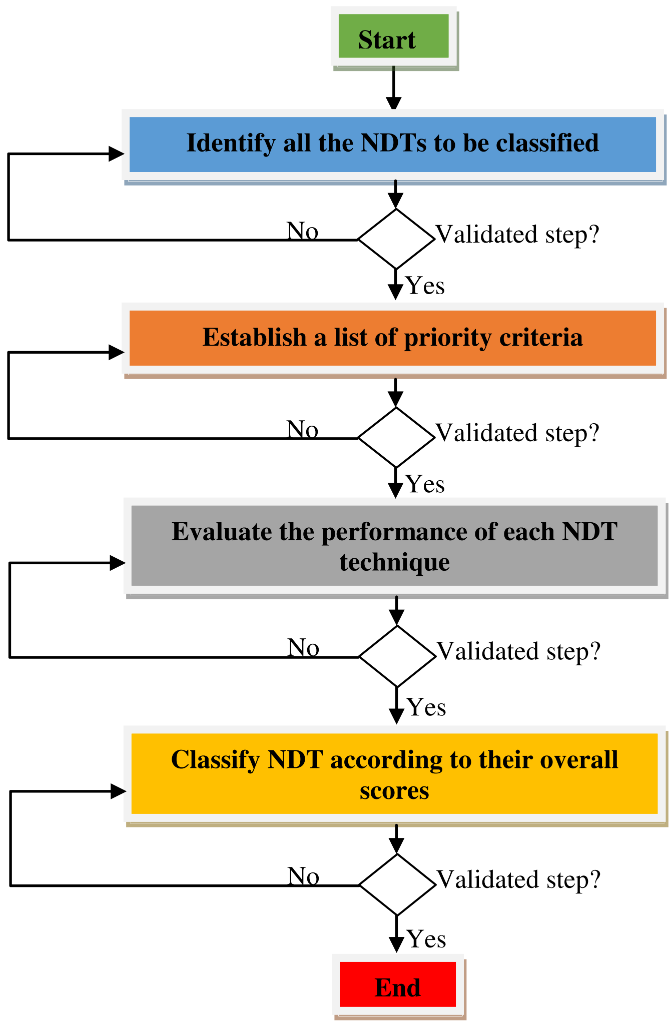

Figure 1. Implementation process of the optimization methodology use NDT in predictive maintenance

2.1. Identify all the NDTs to be classified

This phase consists in defining the physical quantities (Vibration, acoustic emission, temperature ...) that must be sensitive to the appearance and/or the evolution of the defect and that will allow us to choose the control means (equipment) to integrate, these the latter depend on both: the complexity of the equipment and the available equipment provided by the technology service providers. And subsequently to better select non-destructive testing techniques.

2.2. Establish a list of priority criteria

Concerning the family of criteria, a list of priority criteria must be drawn up in order to operate the most suitable NDT technique to use objectively. These criteria also make it possible to justify later choices of the operated NDT. The establishment of priority criteria can help increase the availability of components, and also reduce the maintenance costs. In order to optimize the use of NDT techniques, it will be necessary to consider only criteria directly related to the speed, cost, reliability, ease, and safety of each technique. Moreover, the establishment of priority criteria allows easy comparisons between several NDT techniques.

2.3. Evaluate the performance of each NDT technique

In order to be able to evaluate and classify the various NDT techniques on the basis of the priority criteria, each criterion must be associated with a rating scale in order to make of it a measurable dimension.
As a first step, priority criteria must be ranked in order of importance. The second step consisted of distributing a set of 100 points between the different criteria while respecting the established classification.

2.4. Classify NDTs according to their overall scores

And finally, for the classification of the NDTs, we sort in a descending order according to their scores.

3. Case study

For the deployment of our proposed approach, the workshop chosen is the sulfuric workshop whose main function is the production of sulfuric acid (H_2SO_4), according to the MONSANTO with double absorption, based on liquid sulfur. It also generates the superheated vapor for the internal phosphoric office useful, which builds an important part in the phosphate industry and their derivatives. To ensure its annual production, this office disposes of a set of workshops to assemble their goods and services that schematizes as follow:

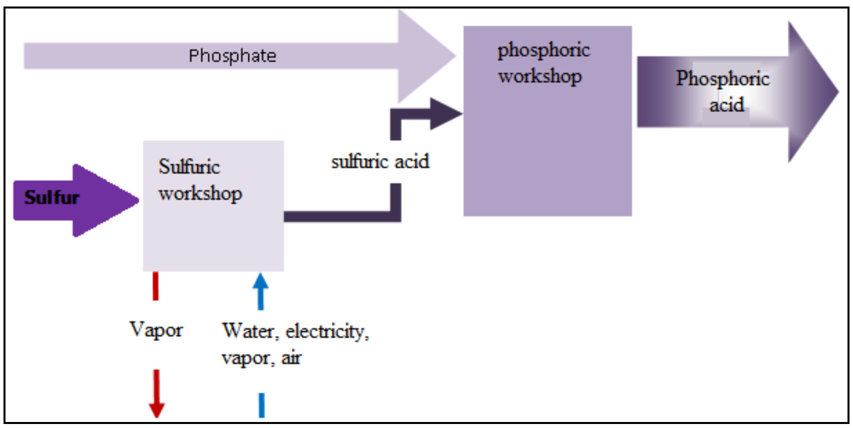

Figure 2. Block schematic of the phosphoric office workshops

The Sulfuric workshop object of the study is divided into 5 processes namely: Storage of liquid sulfur; Combustion of sulfur; Conversion; Sulfuric acid production; Storage of sulfuric acid.

Figure 3. The 5 processes of the phosphoric sulfuric workshop

3.1. Identify all the NDTs to be classified

Identify all the NDTs to classify is to find parameters that highlight the failures (Displacement, Temperature, Pressure, Vibration, Emission, Acoustics, Temperature, Current ... etc.) provided by its state (measurement situation). These physical quantities will allow us to select the sensors and subsequently the NDT techniques to use. Furthermore, we have developed a decisional algorithm of the technique or measurement techniques to be used presented in Figure 4 [12]:

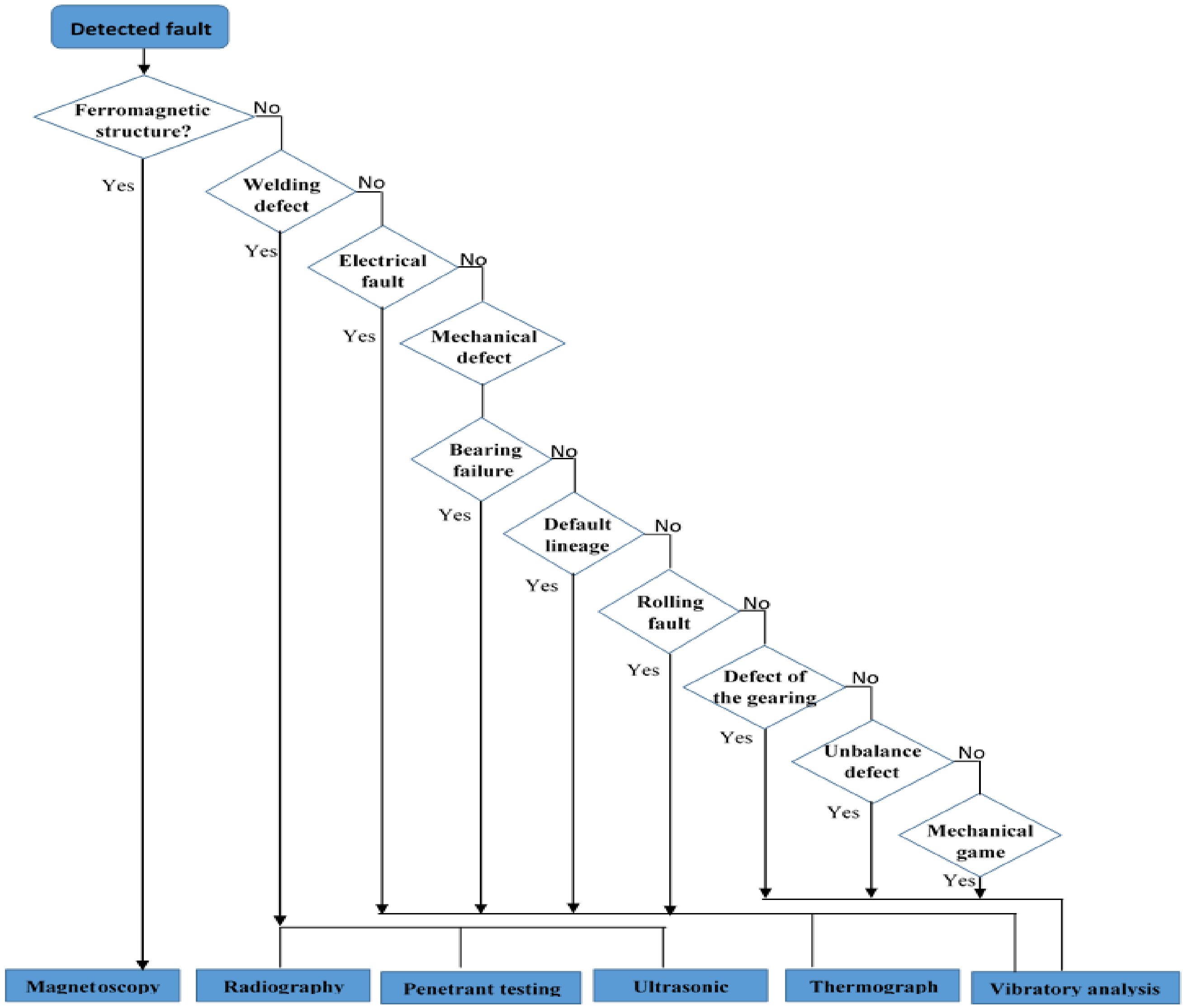

Figure 4. Decisional algorithm on the technique or measurement techniques to be used

The NDT will be noted as follows:

- T1: vibratory analysis;
- T2: Magnetoscopy;
- T3 Radiography;
- T4: Penetrant testing;
- T5: Thermography ;
- T6: Ultrasonic.

3.2. Establish a list of priority criteria

Regarding this phase, a list of six criteria has been developed in direct collaboration with the general management, based on the questionnaire that we have already treated in the context of our thesis [13]. These criteria are:

- C1 'Reliability': we have made questions concerning the reliability OF NDT techniques studied as follows: does it have a very important reliability? ? Important? Or, not important? ;
- C2 'Cost': the NDT technique studied is very expensive? Moderately expensive? Cheaper? ;
- C3 'Influence on the safety of people': the use of the NDT technique in question is Mortal risk? Risk of high damage? Or, no risk ? ;

- C4 'Speed of execution': it expresses the preparation time to implement the NDT technique studied, are the preparation times medium long ? Averages? Or, short ? ;
- C5 'Requirement of interpretation of people': the NDT technique studied requires an interpretation moderately very often? Often? Or, Rarely?
- C6 'Ease of implementation': we question whether the use of the NDT technique is easy or not.

3.3. Evaluate the performance of each NDT technique

The scales used are summarized in Table 1. It should be noted that in the case of this study, all criteria are to be maximized. The attribution of the weights (or coefficients) to the criteria was carried out according to the method «Ranking & Rating » [14]. As a first step, we asked the actors of our project to rank the six criteria in order of decreasing importance. The second step consisted of distributing a set of 100 points between the different criteria by respecting the previous ranking. The resulting weight values are given in the following table:

Tableau 1. Weight of criteria and scale of measures

Criterion	**Weight**	**Evaluation**
C1: Reliability	30%	Not important ....1 / 3 Important.............................2 / 3 Very important ....3 / 3
C2: Cost	15%	expensive............................. 1/3 Moderately expensive .... 2/3 Cheaper................................ 3/3
C3: Influence on the safety of people	8%	Mortal risk .... 1/3 Risk of high damage .... 2/3 No risk ....…3/3
C4: Speed of execution	15%	Long .... 1/3 Average .... 2/3 Short 3/3
C5: Requirement of interpretation of people	17%	Very often......................... ..1/3 Often .... ……..2/3 Rarely ....…........... 3/3
C6: Ease of implementation	15%	No……………..…………..1/2 Yes…………………..…….2/2

As for performance evaluation for NDT techniques, scores were assigned against each of the six criteria, based on the measurement scales as presented in Table 2. The results of these ratings are grouped together in the next board:

Tableau 2. NDT performance

Technique / **Criteria**	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**
C1	0.3	0.2	0.1	0.2	0.2	0.3
C2	0.15	0.15	0.1	0.15	0.15	0.05
C3	0.07	0.047	0.047	0.047	0.07	0.047
C4	0.15	0.1	0.05	0.1	0.15	0.15
C5	0.12	0.12	0.12	0.18	0.18	0.06
C6	0.15	0.075	0.075	0.15	0.15	0.075

3.4. Classify NDT according to their overall scores

And finally for the classification of NDT according to their scores are presented in the following table :

Tableau 3. Classification of NDT

Technique	Designation	Scores	Rang
T1	Vibratory analysis	0.94	1
T5	Thermography	0.92	2
T4	Penetrant testing	0.827	3
T2	Magnetoscopy	0.692	4
T6	Ultrasonic	0.682	5
T3	Radiography	0.492	6

According to the previous table we see that if, for example, we have to make a choice between several NDT techniques, we first choose T1 'Vibratory analysis', then T5 'Thermography', then T4 'Penetrant testing', then T2 'Magnetoscopy', then T6 'Ultrasonic', and finally T3 'Radiography'.

4. Conclusion

In this work we have developed a new methodology of optimization of the use NDT techniques in predictive maintenance where our recommended methodology is based on four complementary phases, namely as follow: Identify all the NDTs to be classified, establish a list of priority criteria, evaluate the performance of each NDT technique and classify NDTs according to their overall scores. Therefore; a precise description of each phase of our methodology has been provided in this paper. Moreover, we have recommended the use of this methodology in addition to the principles and tools of improvement and planning of a preventive maintenance policy. In order to exploit and validate our proposed approach, a case study was conducted in one of the workshops of a phosphoric office. Thereby, this case study has highlighted the importance of the use of techniques. Although, the vibration analysis is the most widely used since the majority of equipment consists of mechanical systems, but the use of other techniques NDT sometimes completes the latter, hence the need for an approach allowing the choice of the most appropriate technique based on the indicators and physical quantities by a thorough analysis and operating conditions of the process studied.

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