Proceedings in MANUFACTURING SYSTEMS

Proceedings in Manufacturing Systems, Volume 10, Issue 1, 2015, 45−50 ISSN 2067-9238

TRANSITION FROM THE CLASSIC SERVICE OPERATIONS TO THE DECISION SUPPORT IN MAINTENANCE ACTIVITY

Ştefan VELICU[1,*], **Ionel PĂUNESCU**[2], **Marius Daniel PARASCHIV**[3]

[1)] Prof. PhD, Machines and Manufacturing Systems Department, University Politehnica of Bucharest, Romania
[2)] PhD student, Machines and Manufacturing Systems Department, University Politehnica of Bucharest, Romania
[3)] Lecturer, PhD, Machines and Manufacturing Systems Department, University Politehnica of Bucharest, Romania

Abstract: *This paper introduces the researches performed for highlighting the development from classic service operations to decision support in maintenance activity. The use of the monitoring software of Schindler Company – manufacturer of a different types of elevators – for viewing the operation of the studied technical system elements and the employing of the information collected for decision support in maintenance activity. The studied components are checked at the time indicated by the manufacturer and the monitored rates are measured when the new belt is assembled. If at the time limit the rates do not exceed the values required by the documentation, the system is allowed to run along a period a time increased by about 10% compared to the average time reported by the manufacturer. The research paper demonstrates that the use of a monitoring software helps to support the decision in maintenance activity and to achieve strong economic performances for the end-user.*

Key words: *service, solutions /monitoring/expertise software, capital repair, overhaul, maintenance.*

1. INTRODUCTION

To maintain in operation equipment and to continuously improve the quality and productivity of the manufacture is necessary to make a full integration of processes, starting from design up to logistics, in order to control the variation of the parameters that influence the product performance, cost and reliability. As the complexity of the products and embedded technologies increases, the maintenance intervention decision making is increasingly challenging. The development of the methods and tools meant to improve the availability, reliability and maintainability of the products involves researches on the behavior of the sub-assemblies and their components in different operating conditions.

Maintaining equipment in operation conditions by applying a classic method of service/maintenance is that equipment is submitted to repairs at predetermined time intervals, depending on the type of machine. The kind, volume and content of the repairs to be made have a standard character, according to the technical documentation, regardless the running condition of the system at the time of entry into repair.

The categories of repairs provided are: maintenance and supervision; technical revision (Rt), current repair (Rc) of first degree (RcI), of second degree (RcII) and capital repair (Rk). This classic method of service/maintenance has some advantages such as allowing repairs based on a well prepared documentation; it is easy to apply; it has a high efficiency for the economic companies which operate a large number of technical systems [4].

But the disadvantages of the method are significant: it requires a larger volume of work for the preparation of the technical documentation necessary for applying this method; it raises the cost of repairs in a unjustified way in the case of these machines submitted to repairs activity even if their technical condition does not require so; in this system it does not matter the wear level but the number of accumulated operation hours; therefore it is possible that certain components and subassemblies are discarded yet functional.

Besides the technical interventions included in the classic system of service/maintenance, there are also other types of technical interventions performed in the economic companies such as: accidental repairs; refurbishment repairs; emergency repairs.

By using the classic system of service/maintenance, the repairs and maintenance of the machines/equipment require significant expenditures and the repair works involve the participation of a large number of highly skilled workers.

Figures 1 and 2 show the monthly and annual planning registration sheets for the repairs/expenses in the classic service system version [4].

In this context, an alternative method proposes to use the decision support in maintenance activity which helps to identify in due time and to eliminate the causes leading to the premature exit out of use of the components/elements of a technical system, with significant economic results such as: diminution of the unproductive

[*] Corresponding author: Splaiul Independenţei 313, Bucharest 060042, Romania
Tel.: +40214029457
E-mail addresses: *velstefan@hotmail.com* (S. Velicu), *paunescu.ionel@gmail.com* (I.Paunescu), *marius.d.paraschiv@gmail.com* (M.D. Paraschiv)

Economic Unit			Inspections and repairs Program					Total cost
No.	Equip-ment	Repair type	Duration (days)					
			1	2	3	4	5	
0	1	2	3					4

Fig. 1. Registration sheet of repairs/costs in classic service system version – monthly.

Economic Unit			Annual program repairs				Authorized
No.	Equip-ment	Repair type	Months of year				
			January	February	March	April	Total cost
0	1	2	3				4

Fig. 2. Registration sheet of repairs/costs in classic service system version – annual.

stops; increase of the period between repairs and reduction of the expenses for their performance.

The end-user of some complex technical systems is able to implement analysis programs that enable faults detection in an incipient stage and thus easier to remove with low expenses. The data recorded during the monitoring of the machine/equipment operation are stored in a database representing the operating history. This information allows a proactive approach that leads to significant cost reductions in the short and medium term. Thus, the failure of a component of the equipment can be detected and diagnosed using specific devices and a small number of skilled personnel. The maintenance method proposed in this research paper makes possible the determination of the optimal timing of initiation of the maintenance activities and avoids the accidental failures that entail unplanned works and supplementary costs. The proposed solution increases the life time of the technical systems, diminishes the maintenance costs and ensures the operation of the system under predetermined quality conditions.

2. CASE STUDY

The driving systems of the doors of some elevator models contain many plastic components highly stressed in terms of wear. Their operation must be analyzed to help the increase of the overall reliability. For example, the movement transmission belt for elevator doors opening is made of textile reinforced polyester, providing up to 25% of the availability of the system. Given this, the researchers have been oriented to highlight the advantages of switching from service, equipment expertise and capital repair to decision support in maintenance activity.

2.1. Description of an elevator classic supervision

The Instruction Books given by the manufacturers specify the interval at which the technical revisions are performed depending on the hours of operation.

Also, the law imposes the obligation to carry out such revisions at specific intervals (for example, in case of elevators it is mandatory to make two current technical revisions each month); the activities to be carried out on this occasion are stated very clearly in the legislation that refers to each group of equipment separately. Taking as an example the elevators, the technical instruction PTR2/2010 specifies both the works to be executed during the current technical revision and the works included in the overhaul (annual) [2]. If there are disagreements between the equipment owners and those who perform the maintenance, overhaul and repairs, these ones can be settled by studying both manufacturer’s recommendations and obligations imposed by legislation (through ISCIR technical requirements) or, by using a software for system operation management when the system is provided with a module for acquiring the necessary information. The overhauls, which are more expensive, are made depending on the operating mode, on the age of the equipment, on the relevant legislation and on other factors that may influence the wear and the operation safety.

2.2. Description of service operations for elevator doors mechanisms

One explains how the system (including the toothed belt and the associated belt pulleys) works, highlighting the sensitive areas and the service operations required.

The door-drive mechanism of Schindler elevators, shown in Fig. 3, is formed of the following components: cams meant to actuate some safety elements for opening the door and facilitating the access into the elevator [1], system of belt, driving gears, rollers [2], latch [3], device for metering and taking over the information from the system elements [4]. The mobile equipment for recording the service operations and some of the operations performed by means of this equipment are shown in Fig. 4, with indication of software installed on IOS operating systems.

By means of the software installed on this equipment, we have the possibility to find out if the part to be replaced is available and its location (in the intervention car, in Supplier’s warehouse stock or ordered from the manufacturer).

Figure 5 presents the monitored sub-assembly and Fig. 6 shows the diagram obtained after the interpretation of the results.

In this case, the operation of the elevator brings benefits (the elevator is not stopped – about 3 hours, with the associated costs - for replacing the belt); it is possible to order the belt at the service company in due time, there are other advantages if the end-user holds a battery (of elevators bigger six pieces (minimum down time, possibility of assembling out of end-user’s working hours).

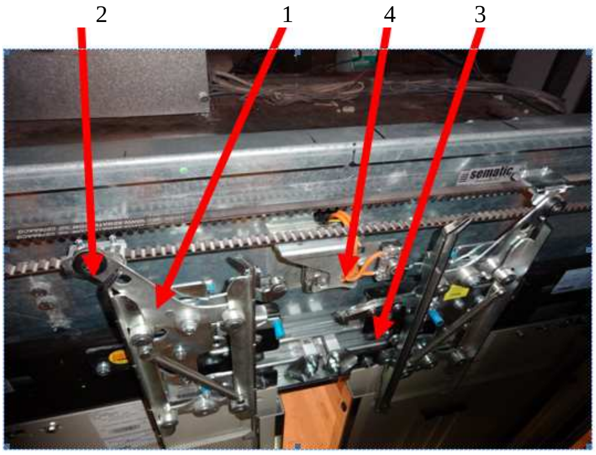

Fig. 3. Door-drive mechanism of Schindler elevator.

Fig. 4. Mobile equipment for service operations recording.

Fig. 5. Sub-assembly used for the research.

A lot of information can be highlighted, acquired and stored by means of the online monitoring program of Schindler elevators operation. The research paper monitored the number of openings and their frequency in a period of time *T*. This information enables us to mark the normal operation period of some components/safety elements of the system (the research paper studied the behavior of the following elements: belt, gear, bearing, doors locking hook). In Fig.6, in the diagram of system operation one can set/mark a series of data, respectively: start/end of the analyzed elements monitoring period, alarm when the normal operation period (notified by the manufacturer) is reached. When this period is reached, the items subject of research can be visually inspected and one may decide to continue the system operation or to stop it for replacing the component.

Figure 7 highlights online monitoring of a number of lifts to a monitor located in the maintenance department dispatcher [6]. Monitoring program allows identifying the equipment operating parameters selected by specialist maintenance for a period of time (set by operator), helping to identification of dysfunction in the system [7].

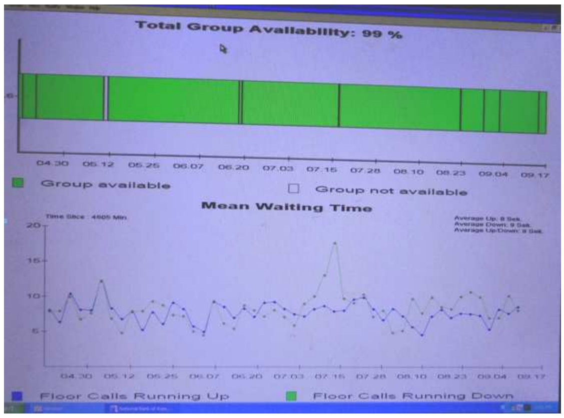

Fig. 6. Elevator operation diagram during the time *T*.

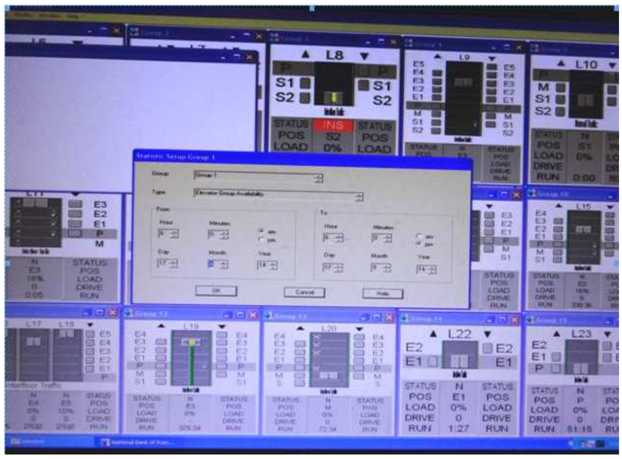

Fig. 7. Online monitoring an equipment group on end-user site. of elevator doors operation.

In Fig. 8, are highlighted within the range of proper operation for a system element. Using our monitoring an operating period made available by the program when the installation can locate the item studied. We also studied the book element technique we can find lasting smooth running, which locate at time T_n.

During this time check is done at low cost rates, being an operation of the service, which is in accordance with ISCIR, two times per month. From this starting point, measurements wishing to highlight non adjustment dimension *B* (20 mm). In the first stage a total of about 40 000 openings tolerant finds that this rate tends to vary, increasing it (to make a new adjustment). We can by this time T_n, adjust elevation by using a gauge. After adjustment rate is kept controlled

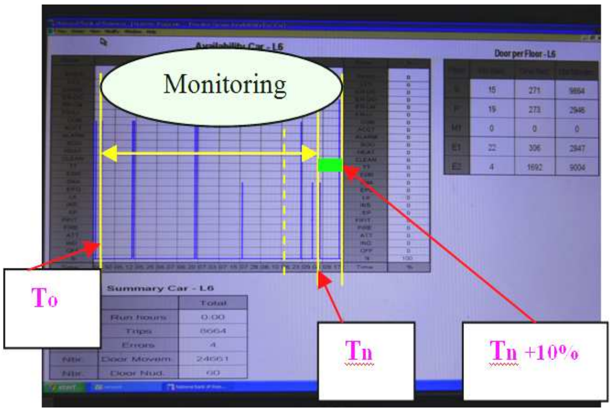

Fig. 8. Information file with the statistics.

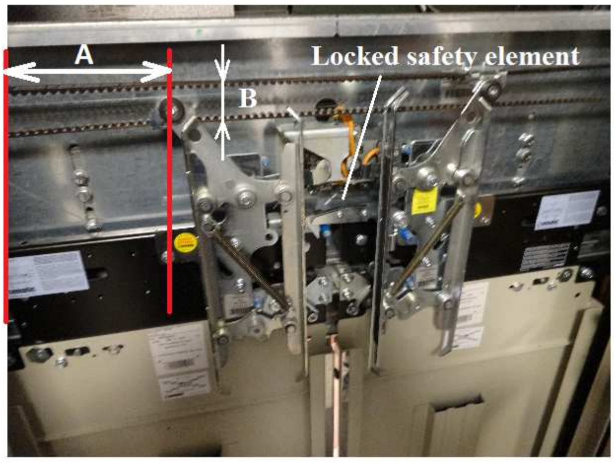

Fig. 9. Initial sizes after belt adjustment.

The dimensions significance is as follows:

1. *B* = 20 mm ± 1– deflection measured after assembling the new belt;
2. *A* = 240 mm ± 1 – distance at which the belt deflection is measured, from the roller axis (the system has the safety element locked).

Figure 9 shows the limits (average time) highlighted by the manufacturer and communicated by the service company to the end-user [6].

The end-user's representative who manages the operation of the system requests to participate in the verification of the dimensions 1 and 2 achieved at the assembling of the new belt at the deadline set by the manufacturer. If the dimensions do not exceed the initial values, after a visual inspection of the belt teeth and gear teeth, and after consultation of Service Company's specialist, it shall be recorded by mutual agreement that the operation is still allowed for a period of about 10% of the time proposed by the manufacturer for belt use.

The number of hours recommended by the manufacturer for normal operation is of 9000 operating hours or 2 years in condition of 50 openings per day.

Belt tension measurement sheet will include:

1) general information (name controlled dimension value, allowable limits, interval between two measurements);
2) completion of the measurements;
3) diagram of measured values;
4) book values of technical indicators (minimum, rated, maximum);
5) conclusion: after measurement the decision should be for adjustment or replacement.

The mode of variation of the measured values presented in Fig. 10 can provide information such as wear. Supervision limit (dotted line) is a limit of "warning" when system operation should be pursued when this value is reached (at points 6 and 7) and very carefully observed when it is exceeded. The upper limit of normal value limit is a "warning" that require intervention only when it is exceeded.

Figure 11,*a* and *b* highlights the decision for adjustment/replacement of the belt. If measurements show attained data, there is the possibility of adjustment by its manufacturer. If after a number of checks (over 1000, Fig. 11,*a*) it is ascertained an exceeding of the range over 1 mm and also wear, the decision is for replacement. If after 1000 measurements the measured value is in the range smaller than 1 mm, the decision is for adjustment and the measurements are repeated until the range is exceeded. In this way the operating time becomes with 10% greater than that given by the producer.

In Table 1 the measurements made to dimension *B* are shown. Density measurements are inconclusive after a number of door openings of 70 000 when *B* dimension changes. If we made a number of adjustments, after a number of 74 000 openings the measurements are more

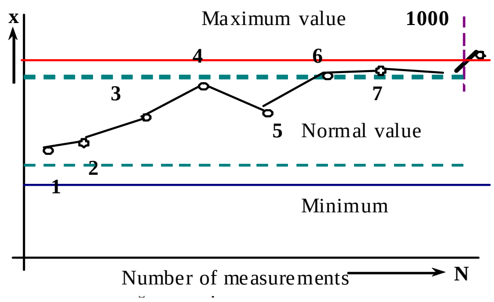

Fig. 10. Representation of measured values measurement chart sheet.

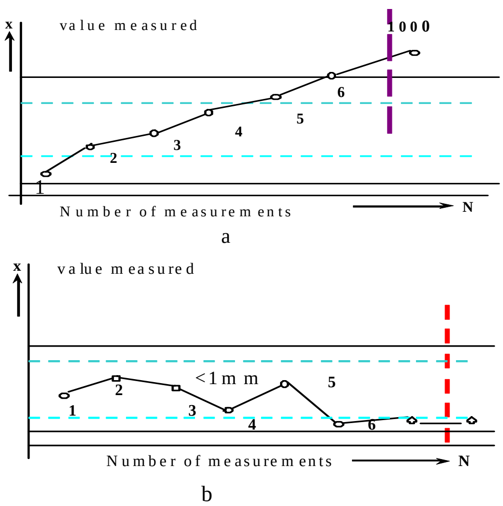

Fig.11. Variation indicator setting decision (depending on system monitoring): *a* – specific variation wear (need replacement); *b* – disorder (recovery rate operation).

Table 1

Variation of the quota depending on the number of closing/opening of the door

	Nr. closing/operating, hours								
Dimension [mm] / Measurement	**5016 hours- To**	**2000**	**3700**	**1400**	**8000/1230 hours**	**19000/1800 hours**	**40000/1990 hours-Tn**	**50000/2000 hours-10%**	**70000/2800 hours**
1	20								
2		20.05							
3			20.05						
4				20.05					
5					20.05				
6						20.07			
7							**20.01**		
8								20.08	
9									20.1
.									
1000									

frequent (at least 2 times per month), but the time of the belt life is increased by 10%, reducing the maintenance costs, the most importantly thing [7].

If measurements are based on the number of closing/opening of the door to the elevators and there is no output from the quota imposed by the manufacturer (average), it can be stated in Table 1 that the setting is appropriate and the system is operational. After the carried out measurements, it is found the upper value (warning dimension). The number of measurements after this value increases. Operating time can be increased by adjustments to the warning quota and time of the belt operation increases by 5–10% compared to the average time recommended by the manufacturer [4].

2.3. Improving data acquisition and processing system based on the reliability

To counteract the effects of technological system aging is in need of replacement or correction of degraded/damaged components. These interventions are designed to increase system reliability and hence the frequency of data acquisition should be adjusted accordingly [9]. When reliability is close to the maximum, data acquisition is normal to have a constant high frequency, to more accurately predict the time availabele for operation. After acquisitions frequency, the values of the system wear should lower for the technological evolution of the system ito not need attention [7]. The reliability decreases, however, the frequency of acquisition must be increased for predictive maintenance system to be able to correctly estimate the remaining time of use (Fig. 12).

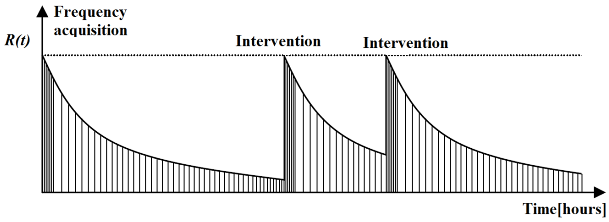

Fig. 12. Frequency of purchase depending on equipment reliability.

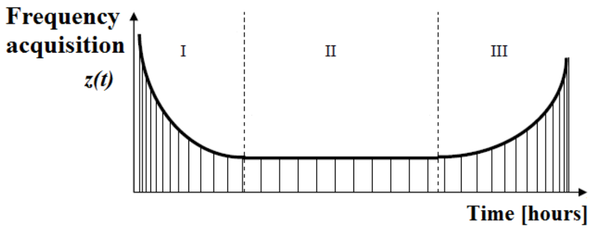

Fig. 13. Frequency of acquisition according to the system life cycle.

2.4. Improving data acquisition and processing depending on the rate of failure

Failure rate is limited relationship between the probability of a technological system to malfunction in the interval ($t - \Delta t$, t] and is denoted by $z(t)$. Statistic failure rate is the ratio of the number of failures per unit time and the product of a subinterval of time and the number of technological systems in good working order at the beginning of sub-interval of observation

$$z(t) = \frac{n(\Delta t)}{N(t - \Delta t) \cdot \Delta t} . \tag{1}$$

As technological system failure rate is important in the context of predictive maintenance and frequency of data acquisition from sensors should be adjusted according to it. The failure rate is higher than the frequency of data acquisition should increase to qualify data illustrating the technological system guarded condition. Thus the above chart would look like Fig. 13. The vertical segments represent data acquisition times and the distance between them − during the break [7].

2.5. Data acquisition and processing based on the criticality index of failure

The maintenance critical criteria are used to determine the importance of controlling certain components, subassemblies or equipment of a technological system. Index of criticality, in the context of FMECA and FMEA method is a function of three terms: the frequency of occurrence of a fault (F), gravity (G) and its detectability (D):

$$C = F \cdot G \cdot D \quad . \tag{2}$$

For each of these terms assessment criteria are determined, thus criticality index is encoded. It is very important for describing the criteria for each assessment.

Because of the importance of preventing failure modes with an criticality index greater, the frequency of data acquisition that provides information on the evolution in the direction it should be also higher [8, 9].

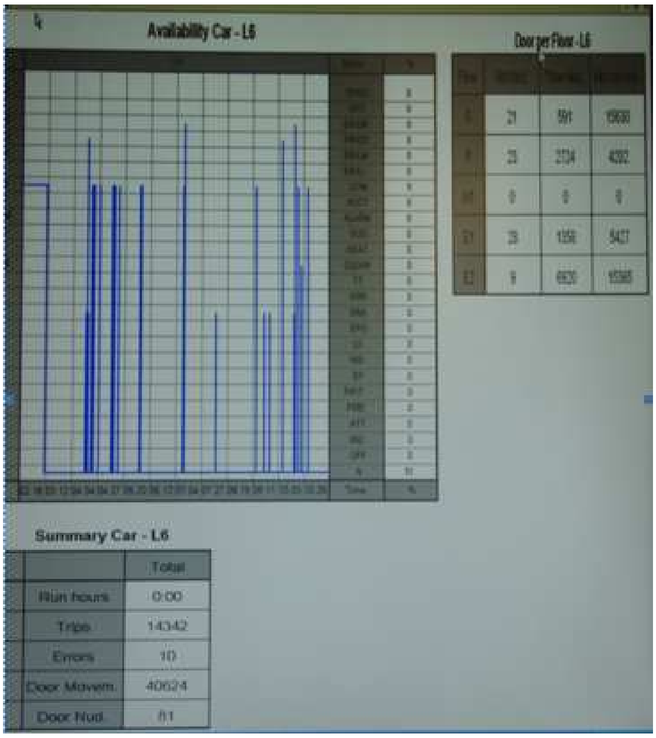

Fig. 14. File with information on the statistics of elevator doors operation.

Data acquisition frequency is a function of four parameters: failure rate (z), equipment reliability (R), the index of failure mode criticality (C) and equipment criticality (c):

$$F_{ac}(t) = (z, R, C, c)(t). \quad (3)$$

3. CONCLUSIONS

The use of the online monitoring system of Schindler Company (Fig. 14) as a working method of analysis of the operating behavior of technical system safety elements and of the maintenance history has the following results:

- identification of the moment when the analyzed parts determine the maintenance decisions;
- establishment of adjustments correctness and their optimum setting;
- implementation of the best maintenance strategy adapted to the operating conditions of the system;
- optimum management and knowledge of the defining elements of maintenance intervention (technological operations, human resources and materials used, execution time, costs);
- diminution of the operating costs;
- possibility to increase the availability of the technical system safety conditions (assembling of elevator door-drive mechanism) by about 10%);
- use of the history occurred during the operation period of the assembly increased by + 10% and increase of this one by another close percentage, resulting some operational benefits.

1. REFERENCES

[1] GD 2139/2004 *on the useful life of fixed assets*; representing Romanian Government decision 2139/2004 - *Catalogul privind clasificarea si duratele normale de functionare a mijloacelor fixe* (Catalogue on classification and useful life of fixed assets).

[2] PTR2/2010 – *ISCIR Technical Prescription*.

[3] SR EN 15341/2007 *Maintenance performance key-indicators.*

[4] I. Ceauşu, *Management of maintenance activity in industry*, University "Politehnica" of Bucharest, Romania, 2001.

[5] SR EN 60706/2007 *Equipment maintainability*.

[6] *http://www.schindler.com/content/ro/internet/ro/ solutii de-mobilitate/produse/ascensoare/Schindle-5400*.

[7] *http://www.schindler.com/ro/internet/ro/service-intretinere.html* (10.10.2014).

[8] A. Velicu, *Cercetări privind mentenanţa integrată a sistemelor tehnologice* (Research on integrated maintenance of technological systems), PhD. Thesis, University "Politehnica" of Bucharest, Romania, 2010.

[9] T.C. Ionescu, A. Velicu, *Developing an integrated maintenance method*, U.P.B. Sci. Bull., Series C, Vol. 74, Iss. 3, 2012, pp. 15−24.