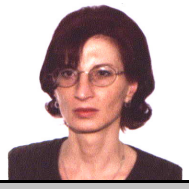
Human Reliability in Maintenance Tasks



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ABSTRACT

Maintenance Management requirements have in the present days another dimension as it was in the past. Looking for optimal tools of decision processes is not so easy. Present conception represents integration of theoretical, technical and management tools, which implementation in the praxis asks also their actual modification. The one result doesn't exist, either "the best" for all.

Technical measurements are connected with high level of the capital costs, the organizational with long time /term/ or hard estimated of the economical return.

What is the Maintenance Management task and how it can prevent Major Accidents? Is it necessary by management to consider- the Reliability of Maintenance tasks? How it can be done, it is the subject of this article.

Keywords

Maintenance, Risk Assessment, Failure, Reliability, Prevention.

INTRODUCTION

European legislation - keeps going by leaps and bounds – to protect human area against of work accidents or harms of occupations, which are result of dangerous production of technical equipments (89/391/EEN, SEVESO II). The environmental requirements are increasing. The machines and equipments failures are not only problem of breakdown, but main aspects are their consequences, which can lead to harm of life or environment. The question is, how and which types of the instruments have to decrease (reduce) possibility (or) the probability of these failures. Is (Is there any possibility of technical…) it possible technical, organizational or another type of resolution?

The Maintenance definition according to the European standard EN 13306 "Maintenance terminology" is possible to modify like that (in this way):

"Maintenance is the process of management of all technical, administrative actions during the life cycle of the object intended to retain it in, or restore it to, a state, in which it can perform the required function by acceptance of optimal costs and requirements of quality, safety and environment".

From that it is clear, that maintenance management has to take into account the different "customer" requirements, i.e. to offer services like a good addressed maintenance strategy and from that effective maintenance tasks plans.

The Fig.1 shows the Pyramid of Maintenance Management with an impact of requirements, which have to be transferred into the politics and maintenance aims.

It's clear, that for maintenance improving, it is necessary to apply one of present, well known, maintenance concept as RCM (Reliability- Centred Maintenance) or TPM (Total Productive Maintenance).

Safety of employees and publicity	Environmental aspects	Process quality, products/services	Optimal costs	Minimum breakdowns /delays

Fig. 1 The base Maintenance Management Pyramid with defined main company goals.

HISTORY AND CONCEPTS OF MAINTENANCE

The history of RCM starts up in 60-ies years of 20th century in USA, by (during) the aircraft maintenance of type Boeing B-747, as a result of activities to achieve effective strategy by their maintenance, when the development of efficient aircrafts showed on costs problems by (due to) preventive maintenance activities. Based on failure rates study and their possible consequences were created in this company maintenance program, defined in 70-ies years as **RCM** conception- **Reliability Centred Maintenance.** This conception helps to choose an adequate maintenance strategy for equipments or their parts, based on 7 main questions. In 1999 was this conception described by standard SAE JA 1011 and in Europe by standard IEC 60300-3-11.

After that raised in 1971 in Japanese (Japanese Institute of Plant Engineers) the concept named as **TPM – Total Productivity Maintenance.** According to the name it is clear, that this philosophy of the Maintenance Management is oriented on the productivity improvement or on the implementation of all activities to achieve this aim. Firstly it changes the position and form of Maintenance Management as a strategic partner of product process, with all company processes support. With the requirements and standardization procedures in the Quality Management, mainly in automotive industry, it's a base component of TQM (Total Quality Management).

Both of these conceptions have own advantages and justifications and their methods exist parallel in the enterprises with high standards of Total Management, covering requirements of safety and health, quality and environment ("excellent enterprises").

After 2000 it is possible to see so-called integrated ambitions and approaches of company management in the management of quality, safety and environmental requirements (ISM – Integrated Management System). Also is changing the ingress (approach) to the Maintenance Management as **Asset Management**, where Maintenance Management is accepted as a part of

Integrated Maintenance Management of company asset (Legát, 2006).

Integrated Maintenance Management follows up these goals:

- Keep asset in productivity and availability state based on requirement level of reliability and effectiveness.
- Prevent of rise of failure and after-failure state.
- Operatively eliminate the existing failures.
- Improve quality of maintenance tasks.
- Decrease environmental consequences of production and consequences of maintenance activities of production equipments.
- Assure of production safety and safety by maintenance tasks activities or improve the safety level by adequate maintenance strategy.
- Spend optimal maintenance costs in relation to achieve the availability and effectiveness of production equipments.
- Lead the Maintenance Management to achieve the world level of excellence (process of maintenance improvement).

Integrated Maintenance Management represents management /control/ of all management activities which define aims, strategy and responsibilities of maintenance and which management implements by these tools as a maintenance plan, Management and Control, also as improvement of Maintenance Management Methods include economical, safety and environmental requirements.

It is clear, that in the Maintenance Management it is possible to apply the process approach (ISO 9001: 2000) by Deming's cycle P-D-C-A (Plan – Do-Check – Act), Fig.2.

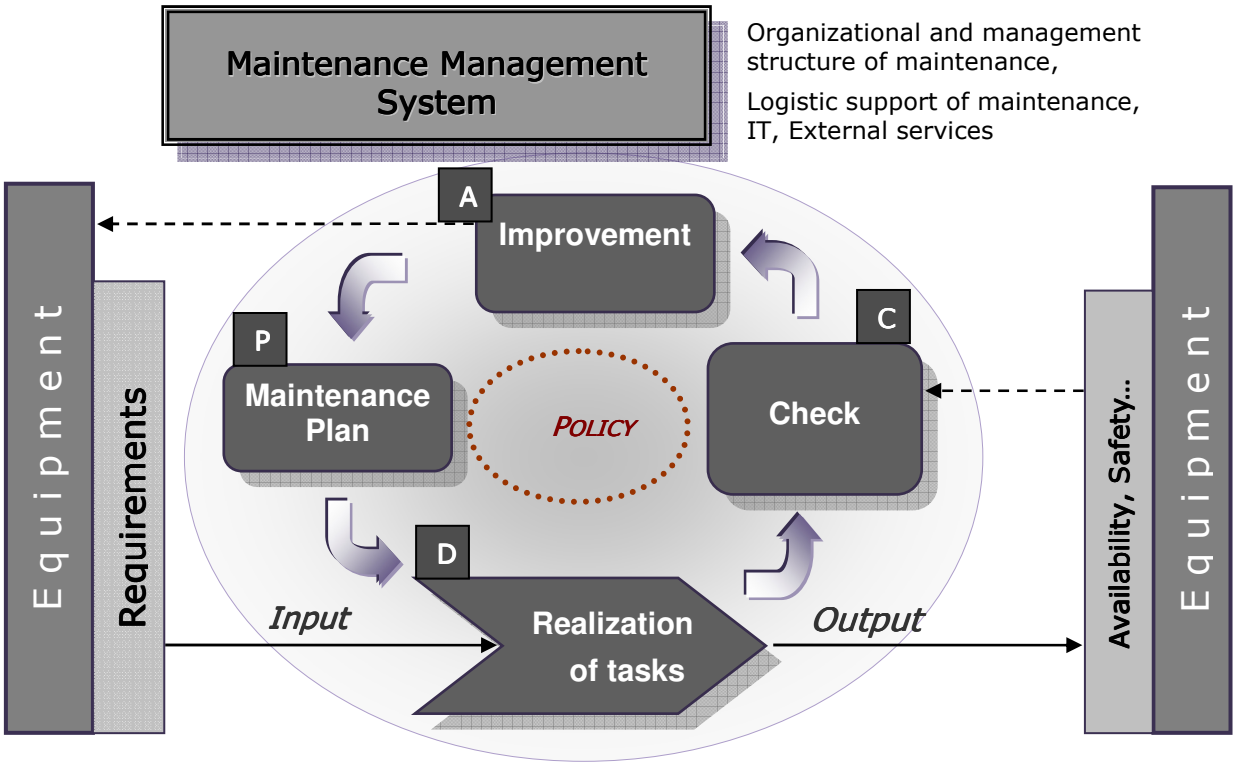

Fig.2 PDCA cycles in Maintenance Management.

FAILURE OF EQUIPMENT AND HUMAN ERRORS

Major Accidents (catastrophes) are possible to divide (can be divided into) to the main three groups (Bártlová, 2003):

- **Natural** – to rise (arising) from natural sources influences, which are result from energy accumulation changes inside or on the Earth surface.
- **Antropogenal** - are resulting from civilization activities, e.g. major accidents from technical sources (technogenal accidents), or from environmental influences.
- **Combinational**.

It is very important in term of precede these accidents to know how to identify their possible causes and implemented effective measures consequences. In case of anthropogenal accidents, mainly from technical source, it is very important nearer specification of their causes for close risk analysis asked by EU legislation. The probability of their rise is extensive higher, but on the other side the prevention possibility are the rules of company management, who can decreased this by effective tools implementation.

Some of the technogenal causes of major accidents are summarized in Table 1.

Tab.1

The arise causes of technogenal major accidents		
Category	**Description**	**Maintenance effect/ requirements**
Technical Failure	Design Faults	Frequently Failure, redesign necessary
	Material Faults	Increase of condition control
	Hidden Failure	Hard to identify and cause detection
	Material fatigue	Hard to identify and cause detection
	Wear	Condition monitoring or replacement
	Corrosion	Preventive activities
Technological	Breach of physiochemical and technical-safety demands (rules)	Failures from operation mistakes
	Improper safety items	Hard to identify cause of failure
	Improper layout of equipments	Maintenance mistakes
Human errors	Improper directions	Incorrect strategy, work under the stress
	Inefficient qualification	Fault awards by causes and failure identification
	Break technological rules	Bad repair sequences and replacement of items
	Physical disproportion	Hard manipulation by repair, impossible prevent control
	Stress	Decision faults, faults by incorrect maintenance, decrease efficiency
	Own negative aims	Knowingly equipment damages or to ignore item deteriorate condition

Failure of equipments are possible to structure (can be structured) from external, internal causes aspects, from time aspect (abrupt and degradation), from level of destruction (half-way or total) or their combination.

The statistic of Major Accidents (directive 96/82/EC or SEVESO II) to declares that 90% of them are caused by human failures. From that the maintenance staff mistakes, more than 60%.

The consequences from these accidents are life hazards or health harms, different levels of environmental contamination, damage own or outside property or damage of technical infrastructure.

In the present time is System Reliability R_{SC} specified as combination of two main factors that are machine and man (Man-Machine):

$$R_{SC} = R_C \times R_S \quad (1)$$

Where: R_C - Human reliability,

R_S – Machine reliability.

The level of Human Reliability in work place depends on three main factors:

- Physical ability,
- Psychical attitudes,
- Knowledge level.

Generally, we can define dependence between Human Reliability and factors, which it influenced, after this manner (John P. Bentley, 1999):

- Intrinsic factors,
- Environmental factors,
- Stress factors.

Intrinsic factors (I) – cover the base characteristics of an individual, there are i.e.:

- Motivation – does the person want to perform the task correctly?
- Physical ability – to perform proper the activity (power, long, high).
- Mental ability – the base intelligence assumes to perform the task.
- Temperament – how long can man remain sufficiently calm under stress to perform the proper task?
- Concentration – ability to exclude all other influences while performing require activity.
- Speed of response – how person quickly can response in emergency situation?
- Knowledge – is the level of knowledge adequate to perform these activities?

External factors (E) – represent collection of environmental aspects, where person performs his/her activities. Cover the physical, organizational and personal factors. Physical factors are interference mainly of work place quality, like temperature, humidity, noise level, time of day, dirt and chemical exposition.

Organizational factors include mutual relationships between colleagues on the workplace, level of management, feeling of job satisfaction, salary, and security and so on.

Personal factors include perception of hunger, thirst, tiredness, physical and mental health, and home life.

Stress (S) in present time belongs to major loading elaboration. It is perceived as positive and negative aspect in relation with require human performance. There are: physiological and psychological stressors – fear, monotonous work, overload and so on.

Maintenance conception RCMII (Moubry, 1997) divides from human perspective as a man and machine to factors, which affect rise of human error in these categories:

- Anthropometric factors – depending on layout of equipments.
- Human sensory factors – in relation with problems to break the base dimension for perception (to see, hear, feel…), i.e. warning symbols.
- Physiological factors – cover loading of workplace – physical, chemical factors, noise, vibration, dust (external factors).
- Psychological factors – are defined as intrinsic factors, which can be results of unintended actions or intended action to lead to the error.

HOW IS IT POSSIBLE TO ASSESS HUMAN RELIABILITY IN MAINTENANCE PROCESS

From the previous it is clear, that as it is possible to classify the failure of equipment, it is also possible to classify the human errors in the requirement reliability relation of performed activities.

Maintenance introduces one of main preventive tools for failure prevention, which consequences can be major accident occurrence. A lot of analytical tools for risk assessment cover influence of human misses, as a one base factor, Tab.2 which affects overall system reliability (FTA, ETA).

Mean time between failures is applicable for assessment of mean time between human errors. Therefore, for human reliability assessment of human activities is possible to apply a lot of the same methods and advance like for reliability Machine Assessment.

However Maintenance Management has own cycle (PDCA). In this cycle is possible to define the causes of human misses and their effects on overall system maintenance management reliability. This model to allow solves not only reliability of individual system (man-machine) but also reliability of maintenance management system.

The all (whole) model comes out from defined cycle PDCA (see the Fig.2), where to the individual models items are disposed possible causes of failure and also to them the type of factors like external (**E**), intrinsic (**I**) and stress (**S**). To each of the item (factors) is disposed weight factor from 1 to 10 interval (i.e. v_E for (E) external factor). By their multiplication it is possible to define overall value of impact cause on the given level of Maintenance Management. If model is added with probability value to release to given activities and its cause, it is possible to specify probability of failure for this situation (activity) in dependence on level of weight factor.

This design model to assess of reliability maintenance activities for all maintenance management process is described in table 2.

Plan – Planning		**Cause**	**E**	v_E	**I**	v_I	**S**	v_S	**R**
1.	**Analyses FMECA, FTA (RCM,RBI,...), Criticality analysis**	- improper selected method of analysis			**x**	**8**			**8**
		- lack of input dates			**x**	**5**	**x**	**9**	**45**
2.	**Create the maintenance plans**	- support of other interests			**x**	**3**	**x**	**5**	**15**
3.	**Ensure maintenance sources/support**	- lack of sources	**x**	**7**	**x**	**7**	**x**	**8**	**392**
4.	**Risk Assessment of maintenance activities**	- inadequate method			**x**	**5**			**5**

Do – Realization of maintenance activities /strategy									
5.	**Perform maintenance activities**	- inadequate practice	x	8	x	7			56
		- incorrect failure assessment			x	9	x	3	27
		- assembly failure	x	9	x	2	x	2	36
		- unacceptable environment/dust, noise ...	x	5			x	2	10
6.	**Perform of predictive maintenance – technical diagnostics**	- incorrect control of measurement parameter			x	5			5
		- improper interpretation of measurements results			x	9	x	2	18
		- ignorance of measurement methods /not enough experience ...			x	10			10
		- unacceptable environment/dust, noise ...	x	10			x	5	50
7.	**Realization of repair (maintenance technology)**	- assembly failure /disassembly	x	8	x	8	x	2	128
		- delay/ no delivery of spare parts...	x	9	x	9			64
Check – Checking in maintenance									
8.	**Maintenance Quality**	- none of indicators			x	6			6
9.	**OHS in maintenance**	- no assessment			x	8			8
10.	**Audit in maintenance**	- only formally			x	9			9
Act – Improvement									
11.	**Measurement of performance and effects of maintenance: technical and economical KPI**	- non-existing / process is not enough described			x	10	x	2	20
12.	**Assessment by top-management**	- desinterest			x	10			10

CONCLUSION

The human error is defined as the failure in specific task (or to process denied activities), which can be cause of machine failure or interruption of normal action of planed operations.

For probability of error rise occurrence are implemented frequently of mistakes to refer on performance operation not on time item. Performance of easy task (to read from digital value from display) has error probability from 10^{-4} to 10^{-3}. While it is complicated task (under stress) is this value from 10^{-1} to 1.

In present time there are a lot of methods to assess probability of human errors or human reliability. Their goal is to quantify human errors, i.e. identify possibilities of rise of these errors (or causes) in "man – machine" systems, and to find more effective measurements for their rise minimization.

Well known methods in present time, for human reliability assessment (HRA-Human reliability assessment) are:

- THERP (Technique for Human Error Rate Prediction),

- SLIM (Success Likelihood Index Method),
- HRC (Human Cognitive Reliability),
- CREAM (Cognitive Reliability and Error Analysis Method).

It is necessary by application of these methods to consider structure of the system and its functions, so it means the human activities, severity and required frequency. Not all methods are fully implemented. It is necessary to consider on process of information changes between man and machine and way of realization or level of demands by this goal achievement.

From Maintenance Management can design proposal in table look like systematic and global way for human reliability assessment in Maintenance Management. It is very important to describe in detail the causes, which have consequences on management items of system. The value of reliability R- can is moving between 1 to 1000, where value to 300 is probability of failure in relation of checked cause as very small, from 300 to 600 is the middle, over 600 is high. These values have only formal character. As it will be possible to change the effects in the columns with the probability value (i.e. E = P(E)) from official statistical databases, than a multiply with weigh factors assign by level of own system assessment, is possible to achieve the adequate model for human failure probability assessment in Maintenance Management process.

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