Base Principles and Practices for Implementation of Total Productive Maintenance in Automotive Industry

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ABSTRACT

Purpose: IATF 16949:2016 standard requirements do not represent a totally new approach of quality improvement within the automotive industry. The change of the last, from 2009 year ISO/TS), the quality management standard is only an expected consequence of changes, which, in managerial systems, was brought by ISO Organization in 2012 (Annex SL). Implementation of the Total Productive Maintenance (TPM) requires several important steps. The article describes framework of TPM implementation on a basis of PDCA (P-plan; D-do; C-check; A-Act) cycle and evaluates influence of Occupational health and safety pillar (OHS) on the “stability” of TPM house.

Methodology/Approach: Individual steps of TPM implementation are analysed and added with suitable tools for making the effective integration of TPM and IATF (which is expansion of ISO 9001:2015).

Findings: Implementation of autonomous maintenance and other TPM pillars requires support from management. Although the 5S tool is understood as a basic TPM tool, knowledge from its implementation suggest the fact that 5S is also a significant tool of management integration within organisation.

Research Limitation/Implication: Research presented in this article is influenced of the maturity of organisation as well as its size and types of its activities.

Originality/Value of paper: Method of TPM implementation analysis in the conditions of integrated approach with an emphasis on 5S and its relation to OHS management is original approach.

Category: Conceptual paper

Keywords: maintenance management; risk; safety; TPM; 5S

1 INTRODUCTION

Maintenance management is constantly encountered with an effort to be identified as a less important aspect of a complex organisation management (Antosz, 2018; Willmott and McCarthy, 2001; Pacaiova, et al. 2012; Park, Kim and Won, 2017). It is possible to express the definition of maintenance management (if the definition of quality management is applied, STN ISO 9001, 2016) as follows: it represents a part of company management, the aim of which is optimisation of maintenance activities considering both material and human resources, support of manufacturing of the expected final product quality and safety of operation (if possible, defined by means of figure parameters) as well as support of prospective further growth and development of organisation – its goals.

Or: maintenance management is a discipline for ensuring of outputs, contributions and processes of maintenance, that are supplied with a purpose to fulfil the customers' requirements and parties in question.

In maintenance management (STN EN 13306, 2017), maintenance is defined as a combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function.

Quality management mainly in automotive industry relies on two basic concepts:

- based on the standards ISO 9001, IATF 16949 etc. (Fonseca and Domingues, 2018; Zgodavova, Hudec and Palfy, 2017);
- based on other frames such as e.g. total quality or world quality management - TQM (Total Quality Management), WCM (World Class Manufacturing), (Storey and Harrison, 1999).

In automotive industry, quality is one of the most significant arguments for management. In order to maintain a long-term achievement of quality, it is necessary to retain the capability of machines (processes), their reliability and performance (Fonseca and Domingues, 2017, Pinto, H et al., 2016). By TQM implementation, involvement of all the employees into full-company effort to eliminate all defects (non-conformities) is emphasised. Similarly, TPM results from a principle of a zero loss achievement, whether a machine, human, outputs, energy or material is considered (Galar et al., 2012; Chlebus et al., 2015; Jain, Bhatti and Sign, 2014). The difference between TQM and TPM is often declared mistakenly. TQM is oriented on quality and TPM is oriented on machines and equipment (Sahoo, 2018). However, it is not true. Their objective is mutual – to eliminate all the losses that may have an impact on objectives of the organisation, or possibly, at least, to reduce them to the lowest possible level (Singh et al., 2013; Pacaiova, Sinay and Nagyova, 2017). Chronic problems in organisations are often understated; however, sporadic (assumed) problems are solved by means of preventive measures as well as by checking their efficiency.

TPM is integrated part of TQM, thus, of quality management, and it observes identical objectives. It must be based on thorough process analyses of their significance for the fulfilment of the requirements of customers and parties in question, analysis of effects on non-quality, searching of the most suitable tools of how to eliminate them by means of appropriate improvement. The difference is only in the fact that TQM creates frame, TPM strengthens it and provides further components or tools how to maintain or develop this frame.

WCM – world class manufacturing is a concept, which, at present, is trying to integrate all the processes of TPM, TQM, Lean Manufacturing, Six Sigma etc. into one integrated system, that is able to provide increase of profits through constant process improvement (Sukurma, 2014). This holistic approach is one of the possibilities of integration of requirements of managerial systems based on RBT.

2 METHODOLOGY

Applied research methodology was based on the analysis of theoretical approaches of TPM implementation and was compared with real conditions of its implementation and improvement in accordance with IATF requirements.

2.1 TPM Structure

Concept of TPM was first defined in Japan in the 70s of the last century (Japan Institute of Plant Maintenance JIPM), and it initially brought requirements on the quality process aimed at reliability, high profit, minimum costs and later on, requirements on minimisation of impact on environment and safety. The entire TPM philosophy is illustrated by means of the so-called "TPM house" (Chlebus et al., 2015; Kigsirisin, Pussawiro and Noohawn, 2016), where individual pillars of the house represent basic elements which enable achievement of the determined objectives in a form of elimination of all the non-conformities, i.e. zero number of human failure (defects), equipment failure, accident and waste, Fig. 1 (Nakajima, 1988; Kigsirisin, Pussawiro and Noohawn, 2016).

A lot of organizations, having experience with TPM, prefer naming total productive manufacturing (eng. Total Productive Manufacturing), due to emphasizing the relations among production and maintenance employees, as the notion total productive manufacturing tempts to limitation of the activity connected thereto and their transfer to maintenance department only. Especially in this effort, it is possible to see non-understanding of the relation between TPM and TQM (Pramod et al., 2006).

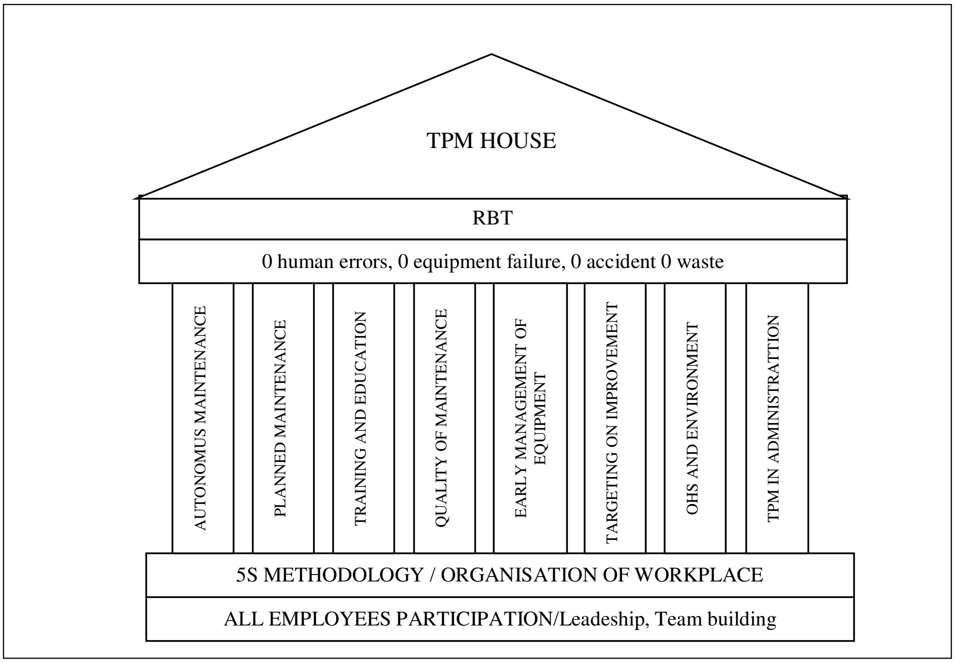

Figure 1 – TPM Structure – 8 Pillars

TPM is based on involvement of all the employees and activities on all organisation levels, targeting at reduction of losses, the so-called 6 main losses and increase of machine and equipment efficiency and the activites related to it (plus 10 losses in the field of human activities and materials). Losses such as unplanned (random failures) and planned stops; small stops and slow cycles; production rejects and startup rejects; in tree areas availability loss, performance loss and quality loss are considered.

The meaning of individual words of TPM notion (Jain, Bhatti and Sign, 2014) is explained in easy way by holistic approach in TPM management related to the expectations of the parties in question, see Tab. 1.

Effectiveness of TPM implementation depends on the level of mastering five basic principles:

- achievement of maximum equipment effectiveness (OEE – Overall Equipment Effectiveness);
- creation of complex system of preventive maintenance based on constant improvement;
- participation of all: constructors, technologists, operators and maintenance workers, safety technicians;
- involvement of each employee from the top (top-management) up to the lowest management level – complex activity support (management support);

- implementation of preventive maintenance for small groups – autonomous maintenance.

TPM combines all activities related to machines and equipment and the products manufactured by them, and which are important for the "core business" of organisation. Actual 8 pillars, illustrated on Fig. 1 and defining the TPM concept, was extended from 5 initial ones (Jain, Bhatti and Sign, 2014): Focused Improvement, Autonomous Maintenance, Quality Maintenance, Training & Education, Prevention Maintenance; similarly, as the identification Six Big (equipment) Losses was extended to 16 Global Losses. However, the Six Big Losses (6BL) became a basis for assessment of organisation performance by means of OEE indicator.

Table 1 – TPM Meaning and Its Expression

Meaning description	Meaning explanation	Comment
Total	Involvement of all the employees.	i.e. not only maintenance workers and operators
	Elimination of all non-conformities.	4 zeros strategy
Productive	Activities performed prior to problem origination.	Proactive approach using root cause analysis
	Manufacturing problems are minimised continuously.	Active attitude of all in improvement, e.g. Ishikawa diagram
Maintenance	Maintenance of equipment in good conditions	Preventive care of equipment and work environment
	Consistent performance of regular maintenance activities such as: repair, cleaning, greasing, checking etc.	Preventive, predictive and autonomous maintenance strategy

On one hand, the calculation of this figure helps to measure all the processes contributing to the achievement of maximum productivity of significant processes of the entire organisation, and to eliminate or minimise loss causes, but on the other hand, it requires observance of the most possible objective method of its measurement and assessment. (Hedman, Subramaniyan and Almstrom, 2016; Fonseca and Domingues, 2017). Fundamental relation for its calculation with regard to loss characteristics contributing to individual OEE parameters is as follows:

$$\begin{aligned} &OEE \\ &= Availability\ (function\ of\ Time\ Losses) \\ &*\ Performance\ efficiency\ (function\ of\ Speed\ Losses) \\ &*\ Quality\ rate\ (function\ of\ Srap\ Losses) \end{aligned} \tag{1}$$

Effort to overtake responsibility of operators for the condition of the equipment – autonomous maintenance (the one who knows it best), supported by maintenance department as a professional advisor and a “doctor” in case of need performing specialized preventive checkups is a prerequisite for finding the best solutions motivating all employees to improvement. These activities clearly cannot work without support of the others, e.g. technologists and constructors, safety technicians and of course, the management of organisation.

Fundamental tool for maintaining the “attention” in TPM is formed from Japanese words (Nakajima, 1988; Storey and Harrison, 1999; Singh et al., 2013; Devaraj, Patidar and Soni, 2015):

1. SEIRI – Organization, removal of unnecessary things away from workplace – “Throw everything unnecessary away!”.
2. SEITON – Systematization, ordering of things in the workplace for easy availability.
3. SEISO – Cleaning, keeping the workplace neat.
4. SEIKETSU – Standardization, establishment of high level of cleanliness and order in the workplace and creation of graphical and written standards.
5. SHITSUKE – Self-discipline, to ensure that people cared for cleanliness and order by themselves and so that they observed the documented procedures.

By organization of the workplace (1S), losses of searching and running around shall be eliminated, obstacles shall be removed as well; systematization (2S) shall ease the selection of tools and availability of the workplace; cleanliness (3S) is a basis for both prevention as well as identification of pollution sources. Creation of the standard (4S) – what, where and how it should be solved, enables enhancement of reliability and safety of operation. Thus, the last 5S is only logical consequence such as 4 previous “S” targeted on controlled checking of the workplace to maintain systematically and in the long term (e.g. 5S audit).

2.2 Relation between IATF and TPM

By IATF standard, maintenance was clearly assigned the obligation to introduce a concept of maintenance management within organization, or a system, as it is defined in the section 8.1.5.8. It requires the organization to create and keep a documented TPM system, which must include:

- Identification of the equipment used in the manufacturing process inevitable for manufacturing of identical product in required volume, , *i.e. identification of the so-called critical equipment that may be important source of 6BL*;

- Availability of spare parts for critical equipment, the so-called *provision – (logistics) of critical spare parts*;
- Provision of sources for machine maintenance, equipment and their facilities – *maintenance support ability*;
- Packing and preservation of equipment, tools and measuring instruments - *maintenance support ability and logistics of spare parts*;
- Documented method of realization of customers' specific requirements – i.e. *documented information of the requirement identification, objective setting and maintenance planning*;
- Documented maintenance objectives (e.g. OEE, MTBF – Mean Time Between Failure, MTTR – Mean Time to Repair etc.), measurement and assessment of preventive maintenance, whereas, maintenance performance, considering its objectives, must be entry for the management system(s) investigation – thus *measurement and assessment of maintenance performance as integral component part of organisation performance evaluation*;
- Regular reviewing of plans and maintenance objectives and documented action plan for solution of corrective measures, where the objectives determined have not been reached – *reviewing by management and adoption of corrective measures*;
- Using of preventive maintenance methods (*maintenance realisation*);
- Using of predictive maintenance, if suitable (*maintenance realisation*);
- Periodic overhaul (*maintenance realisation*).

If we analysed the assumption what results from these requirements, it is obvious that the standard confirmed, that TPM is a system supporting quality management in automotive industry in a strict manner, i.e. as a part of ISO 9001:2015 requirements. Problem arises in the moment when there is a real obligation of suppliers for automotive industry to respect the IATF, if any range of their activities is related to this field. For automotive chain, many of these organisations represent by their activity only 10% or less, but they need to fulfill the requirements for 100% if they want to remain on the supplier position. The tools characterising TPM must be applied in full range (5S, audit 5S, team cooperation, visualisation, data collection and their analysis – FMEA, motivation system, OEE assessment etc.). Some of them work in advanced organisations as a part of management targeting on constant improvement, however, it often happens that their involvement is only a formal way applied for the purposes of obtaining the respective certificate, most frequently within the field of quality management.

For easier understanding of TPM structure and its integration into quality management system, the TPM concept based on PDCA cycle – see Tab. 2 was designed for supplier in automotive industry.

Table 2 – TPM Meaning and Its Expression

PDCA element	**Characteristics**	**TPM 8 pillars**	**Function of pillar**
Plan	Identify problem and develop plan for implementation	Safety Health and Environment	Hazards and sources of losses identification Risk assessment Stated KPI (OEE) structure
		Early Equipment Management	
Do	Implementation, realisation	Autonomous Maintenance	Maintenance Plan and Autonomous standards KPI (OEE) measurement
		Planned Maintenance	
Check	Assess plan and evaluate results	Quality Maintenance	KPI (OEE) evaluation
		Administration TPM	
Act	Improvement	Focused improvement	Systematic problem solving Decision making
		Training & Education	

2.3 Safety and TPM

By implementation of TPM, similarly as by TQM, it is necessary to apply the so-called hard – normative but also "soft" processes (Zgodavova, Hudec and Palfy, 2017). TPM cannot work without all the pillars being formally as well as functionally applied. Usually, the very first problem is to persuade operators about the importance of change of their approach to machines and equipment used for manufacturing. The other significant problem is implementation of 5S and securing its stability for 8 pillars. Why indeed is this tool a fundament of the TPM house? It is obvious that for creating of organisation culture mainly within the field of OHS management, quality and environment, it is important to identify hazards, source of defects (risk), and to select appropriate procedures how to check and maintain them on a long-term acceptable level. With regard to all the losses, it is possible to describe the influence of 5S as follows:

1. SEIRI – Organize the work area (layout) – prevents time losses when transporting the materials; identification of problems, malfunctions and errors; supports environment suitable for each employee – respects their ergonomics, thus has influence on health protection and safety.
2. SEITON – Systematization – saves time at solving problems, enhances performance and readiness, enables to identify near miss and prevent them effectively.

3. SEISO – Cleaning – prevents origination of malfunctions, enables quick identification of the possible sources, has an impact on hygiene and safety of workplace.
4. SEIKETSU – Standardization – is a result of previous three activities serving for the identification of unwanted events (potential losses), is a basis for analysis and risk assessment and creation of appropriate procedures, and implementation of efficient preventive measures for their reduction.
5. SHITSUKE – Self-discipline – helps to train and improve in the way so that each employee is provided with comfort in the workplace. Its result is active approach to increasing of reliability level, safety and health at work and its long-term maintaining.

Within the organisation, where OHS is managed on a high level and is integrated into all the managerial activities, 5S has already been implemented subconsciously. Elements of ergonomics, human behaviour (e.g. BBS – Behaviour Based Safety), both work and external environment are taken into consideration. However, it often happens that safety at work is a subject of external contractual relation, which brings difficult starting-point conditions, when trying TPM implementation, Fig. 2.

Figure 2 – Workplace with Implemented OHSMS Prior TPM Implementation according to IATF (Author's Elaboration)

Assessment of the readiness of organisation was performed by 3 suppliers for automotive end producer. Each of these suppliers has already had implemented OHS management system (OHSMS) in the past according to OHSAS 18001. Even two of them are (transmission producer; vehicle lighting system producer) currently working on implementation of ISO 45001 (STN ISO 45001, 2018) standard.

For the assessment of the 5S level, as of the TPM basis, criteria were formed as follows:

- Workplace organization must be obstacle-free, safety distances and ergonomic requirements according to regulation and standards must be observed.
- Systematization of workplace must take into consideration fluency of both production and need of operator for the achievement of maximum performance in a safe way (e.g. by using of BBS methodics). Tools, personnel equipment must be suitable for the respective purpose and certified (CE marking).
- Cleaning must be described in standards for all operators and maintenance personnel as a part of performed preventive activities. Requirements for cleanliness maintenance must be included in OHS (Occupational Health and Safety) as a risk prevention (dust, chemical substances, slippery floor etc.).
- Standardization is sufficiently visualised in a suitable way. It is a component part of regular checkings and consultations. Accidents, non-conformities, and mistakes are a part of OHS trainings and are regularly assessed. Information is verified in the workplace randomly by all employees.
- Discipline (or Self-Discipline) is managed with a target to secure constant improvement. Suitable motivation tools for observance of rules are adopted. Violation of regulations (also within the field of OHS) is primarily a subject of investigation of possible mistake in description of methodology or in procedures, and only then conclusions towards the violator of regulations are drawn.

The methodology assessed 5S requirements in integration with OHS requirements in the following way: they were assigned points from 0 (criteria are not fulfilled) up to 10 (all the criteria are fulfilled in terms of formal as well as realization aspect). Average values and standard deviations of the assigned number of points of 5S elements for individual producers are found in Tab. 3.

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Table 3 – Evaluation of 5S Methodology based on OHS Factors

5S Methodology with OHS aspects	**producer of plastic products**	**transmission producer**	**vehicle lighting systems producer**	**Statistical parameters**	
	I.	*II.*	*III.*		
	OHSAS 18001	ISO 45001	ISO 45001	$\bar{x}$	s
1S Organisation	7	9	10	8.67	1.53
2S Systematization	6	8	8	7.33	1.15
3S Cleaning	2	8	9	6.33	3.79
4S Standardization	5	4	8	5.67	2.08
5S Discipline	9	10	10	9.67	0.58
$\bar{x}$	5.8	7.8	9		
s	2.59	2.28	1		

Statistically significant difference in assessment of the readiness of organization among 3 suppliers was assessed by means of one – way analysis of variance (ANOVA), Tab. 4.

The one-way ANOVA (Guzanova et al., 2017) is used to determine whether there are any significant differences between the means of three or more independent (unrelated) groups. The one-way ANOVA compares the means between the groups and determines whether any of those means are significantly different from each other. Specifically, it tests the null hypothesis:

$$H_0\text{: } \mu_1 = \mu_2 = \mu_3 = \cdots \mu_k \quad \textit{and then} \quad H_1\text{: non } H_0 \tag{2}$$

Where μ - group mean and k - number of groups. If, however, the one-way ANOVA returns a significant result, we accept the alternative hypothesis (H_1), which is that there are at least 2 group means that are significantly different from each other.

Table 4 – One-Way ANOVA Application

Variable	**One-way ANOVA** Marked effects are significant at $p < 0.050$							
	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	P
Producer	26.133	2	13.067	51.6	12	4.3	3.0388	0.0855

Notes: SS – sums of squares; df - degrees of freedom; MS - mean of squares; F - testing characteristics; p – value.

The result of test is *p-value*, $p = 0.0855 > 0.05$, is then the null-hypothesis accepted on significance level 0.05. The 5S methodology implementation based on OHS factors in tree producers for automotive companies is not a statistically significant difference. Since null-hypothesis accepted (H_0: $\mu_1 = \mu_2 = \mu_3$), that as, which is that there are not at least 2 group means that are significantly different from each other. For this reason, it is possible to claim that OHS plays a role of the same importance by implementation of 5S methodology (TPM) by all the producers.

In case there were several compared producers, there is assumption, that statistically significant differences might arise and subsequently, by means of multiple comparison (by means of post hoc analysis), those couples would be determined whose OHS management level has a significant impact on 5S.

3 CONCLUSION

Correctly managed safety and health at work requires correctly managed risks. If hazards and assessed risks are not identified properly, it is possible to manage them adequately. It often happens that the risk assessment process is only a formal matter. External services within OHS are limited by price offer, however, the result of which are problems pointing at inappropriate managerial practices. According to literature (Mohammadfam et al., 2017), it is possible to state, that until 2018, more than 100,000 companies in the world have been implementing management system of OHS according to OHSAS 18001 (currently, gradual transition to ISO 45001:2018 is expected). However, certificate should declare “quality” of OHS management. TPM implementation according to IATF standard represents integrated approach of quality and safety management (Devaraj et al., 2015; Teeravaraprug Kitiwanwong and SaeTong, 2011; Andodnou, 2017) that can be achieved only if these objectives have adequate management support.

This article describes integration of IATF and OHSMS requirements by using 5S methodology (TPM). The next research in this field requires a greater number of compared producers and also extension of criteria, e.g. with figures of performance assessment within maintenance, safety and quality and their mutual interaction.

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