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PROCESS SECURITY AS THE ASPECT OF TOTAL PRODUCTIVE MAINTENANCE

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Abstract: The paper presents the importance of process security as one of the parts of Total Production Maintenance. Knowledge about the standards and factors used in monitoring production processes has been systematized. The good manufacturing practices in production continuity management are presented in the article.
Keywords: process security, total productive management, TPM

1. INTRODUTION

The analysis of the functioning of business entities focused on manufacturing processes indicates a multiplicity of organizational issues and supervising the individual stages of production and delivery of products to customers. A well-organized production company provides security in three basic areas:

- work safety, understood as ensuring safe working conditions for participants of production processes,
- process security as monitoring and minimizing the risk of failure in production processes,
- product safety as a quality assurance of the effects of implemented processes (Cierniak-Emerych et al., 2017).

Process security is also understood as ensuring the safety of consumer products in various industries based on industry standards and the so-called GMP (Good Manufacturing Practice). In all activities related to the quality and safety of consumer products – QA (Quality Assurance), the basic element is a set of GMP good practices, consisting of, among others, QC (Quality Control), which is illustrated in Fig. 1.
Process security can also be understood as the safety of the technical environment, which consists of: technical resources on which work continuity, personal safety, and environmental safety depends. This should be done using tools for total productive maintenance - TPM (Total Productive Maintenance) (Anttila and Jussila, 2018; Brzeziński and Klimecka-Tatar, 2016; Maszke, 2019; Mielczarek and Krynke, 2018).

2. METHODS

TPM is a system for maintaining the production capacity (productivity) of machines and other devices. It is a modern way of managing technical systems in the aspect of maintaining the condition of technical condition, technical readiness and safety of operated machines. To achieve this, it requires:

- change machines with old construction to modern ones to make them: more reliable, durable, susceptible to operation, easier to use and operate,
- change the policy of maintaining the continuity of work by introducing the principle: "prevention is better than cure",
- change the outdated organization of the industrial maintenance and operation system to modern strategies of maintenance - in the future, this means new tasks and roles for maintenance staff and also their greater privileges.

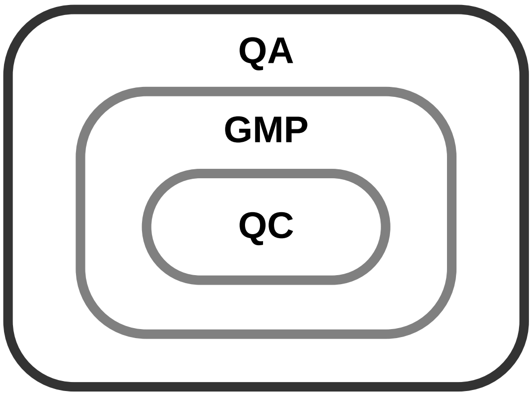

Fig. 1. Elements of good practice and quality control in pursuing the safety of consumer products

In the Lean Manufacturing era, the issue of maintenance management/TPM is extremely complex and is based on the use of methods and techniques such as: 5S, Kaizen, SixSigma, Kanban, SMED, OPL, VSM (Łazicki et al., 2013; Liker and Meier, 2005) and others. In accordance with the philosophy of continuous improvement, under the second pillar of TPM (improvement), attempt to search for sources of potential problems tools such as Ishikawa charts, Pareto diagrams, PDCA cycle, FMEA method and the 5Why method are used (Gawlik and Kiełbus, 2008).

3. RESULTS

The measure of effectiveness for TPM systems in manufacturing enterprises are the coefficients indicated in the standards i.e. EN ISO 13849-1 (ISO 13849-1, 2006) and PN-EN 61511-1 (IEC 61511, 2016), which relate to ensuring process security. However, it should be remembered that the overriding goal of TPM is to improve the efficiency of using the company's machinery by reducing the "Six Big Losses" (Wilmitt and McCarthy, 2000), which means:

- crashes,
- too long changeovers,
- micro-stoppages in the operation of the machine,
- reduced working speed,
- quality deficiencies,
- reduced performance during machine start-up.

The indicated losses are additionally divided into:
- loss of availability: adjustments and settings, failures, micro-stoppages, retooling, commissioning, speed losses, deficiencies and corrections, shutdowns,
- efficiency losses: in the area of management, traffic, organization of lines, logistics, losses in measurements and regulations,
- production losses: energy losses, instrumentation and performance losses.

In the scope of securing continuity of machinery operation by specialized Maintenance Departments there is also prevention of failures and continuous monitoring of technological machines. In this field, the following indicators are particularly important:
- MTTF (Mean Time To Failure) - average time to failure,
- MTBF (Mean Time Between Failures) - average time between failures, and directly related to them:
- MTTR (Mean Time To Repair) - average time needed to repair the failure.

The indicators presented above are interrelated (as shown in Fig. 2) according to the calculations presented on Eq.1, 2 and 3.

MTTR = time of inability to work / number of corrective events [min], (1)

MTBF = (available working time - failure time) / number of events [min], (2)

MTBF = MTTR + MTTF [min]. (3)

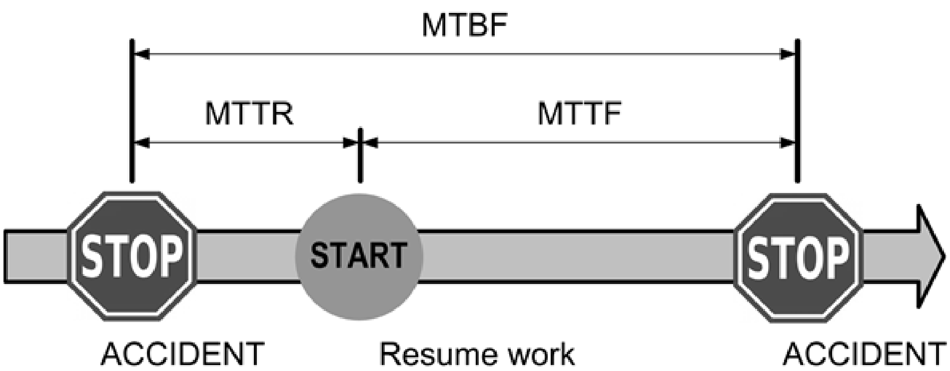

Fig. 2. Relationship between MTTR, MTTF and MTBF coefficients

The scope of the machine park that will be subject to the coefficient test (according to Eqs.1, 2, 3) is determined using Lean Maintenance by analysis (Misiurek, 2017):
- the impact of the machine on the production system,
- device position in the value stream,
- impact on (satisfaction) customers.

After the selection of priority machines from the point of view of production continuity, its failure rate and failure of its component parts (including tools and equipment) are analyzed (Misiurek, 2017). The following aspects should then be considered:
- impact of machine part failure on machine operation,
- predictability of failure on a given part,
- frequency of failures on the given part.

Monitoring of MTTF, MTBF and MTTR coefficients therefore concerns individual machine parts and tools, and not only the entire complex system as a whole.

According to TPM, the OEE (Overall Equipment Effectiveness) factor for assessing the condition of production machinery and equipment is composed of three parameters: a) **Availability** - specifying the time value (or percentage) in which the device is available for production (Eq. 5). This parameter is defined as the ratio of the time available to the total time available, where: the total time available is (e.g. 8-hour shift - GOT (Global Open Time)) minus standard breaks, e.g. breakfast breaks, daily training meetings - Eq. 4, and where the loss of availability is downtime (such as e.g. repairs and adjustments, cleaning, failures).

total time available = available time - standard breaks (4)

Availability = (total time available - downtime) / total time available (5)

b) **Efficiency** or effectiveness of results - determining the ability to maintain a given pace of work. This parameter is defined as the ratio of the product production cycle time multiplied by the number of pieces, to the time available minus the loss of efficiency or downtime (micro-stops, start-ups, retooling, failures, etc.) as shown in Eq. 6.

Efficiency = (standard cycle time * number of pieces produced) / (time available - downtime) (6)

c) **Quality** or level of defects - defined as the ratio of the number of good items (not having defective features such as deficiencies, defects, or out of standards) (Eq. 7) to all items produced, as shown Eq. 8.

number of good pieces = number of pieces produced - number of defective pieces (7)

Quality = number of good pieces / number of pieces produced (8)

Based on the above clarifications, the OEE coefficient is defined as shown Eq. 9.

OEE = Availability * Efficiency * Quality (9)

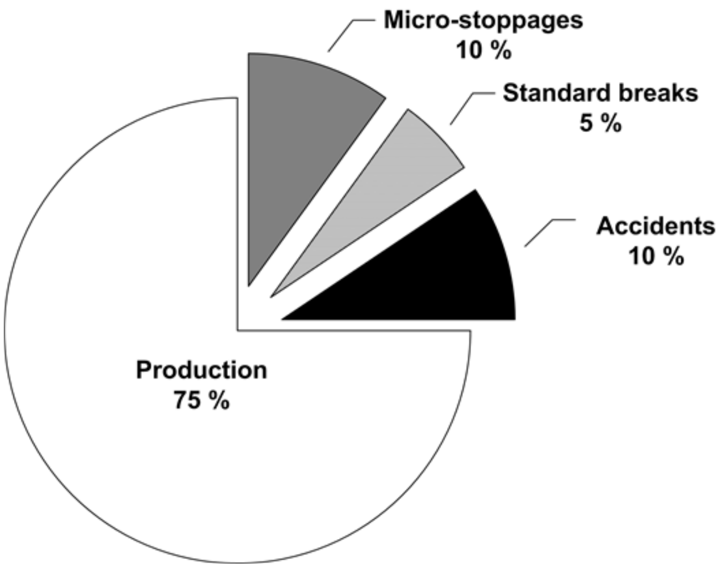

Fig. 3. Example of the pie chart of losses

The OEE factor can be used to evaluate a single machine, production line as well as a whole department or industry plant. In addition to the quantitative indicators as shown earlier, it is possible to simultaneously use the MTTF, MTBF and MTTR time indicators. It is also well visualized in the form of a loss pie chart as shown in Fig. 3.

4. DISCUSSION

Adaptation of modern organizations to the high complexity and dynamics of the environment and related unpredictability of phenomena occurring in it, requires fast adaptation of management systems and business models used by enterprises. This is a prerequisite for implementing strategic goals and gaining competitive advantage. The dynamics and volatility of the market that regulates economic processes requires enterprises to ensure process security.

Currently, most machines and production lines are designed in such a way that the only option in the event of a hazard is to immediately break and finally stop the machine. Most often this is achieved by using additional actuators and advanced devices such as safety relays. This approach is highly hardware-based and thus static, which means that it is not particularly suitable for intelligent production processes where there is a need to change the configuration of the installation, and the associated changes in functional security.

Mentioned built-in intelligence appears to be very important in those hardware-based industries as fuel cells production (Włodarczyk et al., 2011), power plants infrastructure (Osocha, 2018), steelworks (Ulewicz et al., 2013; Ulewicz et al., 2014), woodworking (Ulewicz, 2016) or heavy-duty machines design (Domagala, 2013; Domagala et al., 2018a; Domagala et al., 2018b), control (Filo, 2013; Filo, 2015) and maintenance (Fabis-Domagala, 2013; Fabis-Domagala and Domagala, 2017). It may be also of interest in biotechnology (Skrzypczak, 2016; Skrzypczak et al., 2017; Skrzypczak et al., 2018) and designing of surface layer's special properties (Korzekwa et al., 2016; Pietraszek et al., 2017).

In the implementation of Industry 4.0 era, it is required to create control systems capable of managing distributed intelligence with centralized and user-friendly methods. Industrial installations should be divided into independently functioning units that can be managed. In the process data control system, there are designated boundaries dividing functional modules that can be adapted to the tasks of control systems as well as to safety tasks.

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