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THE ROLE OF EMPOWERING LEADERSHIP IN ENHANCING THE ADAPTIVE PERFORMANCE OF EMPLOYEES

Jinan Ismail Saleh
Faculty of Administration and Economics – Al-Iraqia University, 9985+GX6, Baghdad, Irak,
dr.j.i.s.m.2018@gmail.com

Keywords: empowering leadership, adaptive performance of employees, Al-Iraqia University - Baghdad Governorate.
Abstract: The main objective of this research is to explore the effect relationship of two main variables: (empowering leadership and adaptive performance of employees), by surveying the opinions of a number of employees at Al-Iraqia University – Baghdad Governorate. The researcher used the simple random sample method and distributed the questionnaire to a sample of employees amounting to their number is (148) in the various departments and sections of the faculties. After sorting and checking the questionnaires, the number of valid questionnaires for statistical analysis reached (141) out of the number of (143) retrieved questionnaires. Statistical analysis of the collected data was carried out using the program (SPSS v.22). The research reached to accept the main hypothesis, and concluded that the principals at Al-Iraqia University in the study sample are interested and have a great orientation towards empowering leadership, which in turn enhances the adaptive performance of employees. The results of the current research are, to the best of the researcher's knowledge, a first attempt in the context of reducing or bridging the knowledge gap between the variables of empowering leadership and adaptive performance.

1 Introduction

The adaptive performance of employees in the work environment is one of the most important topics that have been addressed in management science because it leads to the employee's adaptation to and understanding of change in the workplace. An employee who adapts to all changes and situations is appreciated and taken care of by the management in any organization and is important to the success of any organization. As a result, employers are looking for highly adaptable employees, due to the positive results that can be obtained through it, such as excellent work performance, positive work behaviour, and ability to deal with stress and pressure. Employees who show high adaptive performance in the organization tend to have more advantages in career opportunities as opposed to employees who are unable to adapt to change.

In order for some employees, like other colleagues, to enjoy the adaptive performance and the ability to work in all changing circumstances, they need a kind of empowerment provided by leaders or managers who supervise them, which is known as (empowering leadership). As a key entry point to leadership, empowering leadership refers to the process of sharing power, allocating more autonomy and responsibilities to employees through a specific set of leader behaviors that entail enhancing business feasibility, enhancing participation in decision-making, expressing confidence in performance, and providing independence from bureaucratic constraints.

As a result of the foregoing, the researcher will try, through the current research, to test the effect of empowering leadership in enhancing the adaptive performance of a sample of employees at Al-Iraqia University - Baghdad Governorate.

2 Literature review

2.1 Empowering leadership

2.1.1 The concept of empowering leadership

Empowering Leadership emphasizes employee independence, participation, and development by encouraging self-direction by the leader, so empowered leaders are willing to share power with and support their followers. Accordingly, empowering leadership will lead to positive psychological reactions and attitudes from subordinates. As leaders behave in ways that enhance motivation and effectiveness among working individuals, as well as enhance their participation in business processes, these employees may feel more confident and have positive experiences and emotions about their work (Kim & Beehr, 2018: 2022).

In addition to the above, the increased interest in empowering leadership in recent years has been driven by the goal of harnessing the potential of better-educated and more skilled employees. Empowering leadership develops working people, the expression of confidence by leaders in their followers, and providing them with needed advice and resources. As work today becomes more complex and challenging, leaders are likely to benefit from delegating authority to their employees, seeking input from them, and allowing them to plan their work and make decisions for themselves. Therefore, and for these and other reasons, it is not surprising that empowering leadership is positively associated with high and superior performance outcomes at

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the individual, group, and organizational levels (Kearney et al., 2019: 23).

Empowering leadership is defined as "the process of implementing the conditions that allow sharing power with the employee by determining the importance of his job, providing greater independence in decision-making, expressing trust in his abilities, and removing obstacles to his performance" (Kim, 2019: 231).

As for (van Assen, 2020: 442), empowering leadership is defined as a set of leadership behaviors and traits that include expressing trust in subordinates, providing participation in decision-making, providing independence by removing bureaucratic constraints and other obstacles to performance, setting inspirational and purposeful goals, and highlighting the importance of working.

While (Taboli & Askari, 2021: 92) refers to empowering leadership as a leadership style through which leaders can organize and coordinate the distribution and practice of power with subordinates to develop their independence and self-control.

2.1.2 Dimensions of empowering leadership

In order to measure empowering leadership, the scale (Bonavia & Marin-Garcia, 2019) was relied upon because it is the most recent measure, and for its relevance to the Iraqi business environment in general and the organization under consideration in particular. This scale consists of six dimensions, which are as follows:

1. Delegation of authority: The process in which duties are transferred to other individuals to carry out activities aimed at achieving specific goals (Sukini et al., 2021: 1756).

2. Accountability: It is defined as the individual's perception that the leader and that will evaluate his decisions or actions, later; he will be awarded penalties or rewards because of those evaluations (Josephine & Riantoputra, 2021: 68).

3. Self-directed decision-making: Is the process in which subordinates are allowed to involve themselves in the problem-solving and decision-making processes related to their work, making them feel more empowered (Sonal et al., 2019: 55).

4. Information sharing: It is a process of sharing information between the leader and the employees under his supervision regarding joint work strategies (Kusmantini et al., 2020: 59).

5. Skill development: The process of identifying and bridging the gaps through the development, improvement and renewal of relevant skills required to excel and improve the quality of outcomes in a particular job (Anjaneya & Pujar, 2021: 121).

6. Coaching for innovative performance: The behavior of a leader that encourages calculated risk-taking and new ideas, provides performance feedback to employees, and treats their mistakes and setbacks as learning opportunities (Bonavia & Marin-Garcia, 2019: 3).

2.2 Adaptive performance of employees

2.2.1 The concept of adaptive performance of employees

Historically, employee performance focused on two or more factors: (a) task performance and (b) contextual performance. Task performance refers to employee behaviors that are contained within job descriptions (i.e. related to the duties of assigned tasks). On the other hand, contextual performance refers to employee behaviors that are outside job descriptions but contribute to the achievement of organizational goals (such as helping co-workers to voluntarily complete a particular job). Nevertheless, at present, the need for changes in organizations, particularly in the nature of work, has required the employee to demonstrate adaptive performance. These changes in business processes in organizations have led to the extension of the theoretical model of employee performance to include another dimension called adaptive performance. Since work settings now require employees to adapt to changing organizational requirements and opportunities in order to work effectively, scholars have identified adaptability as another critical component of performance that needs to be further understood (Tabiu et al., 2020: 714).

In continuation to the above, the previous literature has inconsistently described adaptive performance. Apart from also calling it adaptive performance and experience conditioning, some articles refer to adaptive performance as a behavior, while others define it as the willingness/ability to adapt. Many researchers prefer to define adaptive performance as the ability of individuals or groups to change cognitions and behaviors to adapt to changing environments. However, others define adaptive performance as employees "modifying their behavior to meet the demands of a new situation, event, or changing environment" (Park et al., 2020: 4).

According to (Kaya & Karatepe, 2020: 2076), adaptive performance refers to the ability of employees to adjust their behavior in different personal situations.

As for (Tabiu et al., 2020: 714), they explain that adaptive performance in an organizational context means the level or degree to which an individual employee adapts to various changes in his role or work environment in order to meet the requirements of his organization or environment, or new events or situations in the workplace.

2.2.2 Dimensions of adaptive performance of employees

The scale (Park et al., 2020) was used for measuring adaptive performance, which consists of the following dimensions:

1. Handling emergencies and crises: It is the employee's ability to find appropriate and rapid solutions to avoid threats and risks that affect the work (Marques et al., 2020: 103).

2. Managing work-stress: It is the employee's ability to remain calm and cool when faced with difficult

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circumstances, workload, or a highly demanding schedule (Thukral, 2017: 455).

3. Solving problems creatively: It is the development of creative solutions to new or difficult problems (Davis, 2020: 4).

4. Training and learning effort: It is the efforts made in the process of analyzing the employee's needs and goals and developing a training system to meet those needs (Calopăreanu, 2012: 441).

5. Interpersonal Adaptability: The ability for individuals to be flexible and open when working with a variety of other people, and also to be open to receiving feedback from others and developing good working relationships (Johnstone & Wilson-Prangley, 2020: 6).

3 Research methodology

The current research seeks to answer the following questions:

a. Is there a tendency on the part of the principals towards empowering leadership in the university, the sample of the research?

b. Does the university in question seek to support the adaptive performance of its employees?

c. Is there an effect of empowering leadership in enhancing the adaptive performance of employees at Al-Iraqia University, the research sample?

In light of the aforementioned research questions, the hypothetical model of the research was reached. Which shows the nature of the effect relationship between the research variables, as shown in Figure (1).

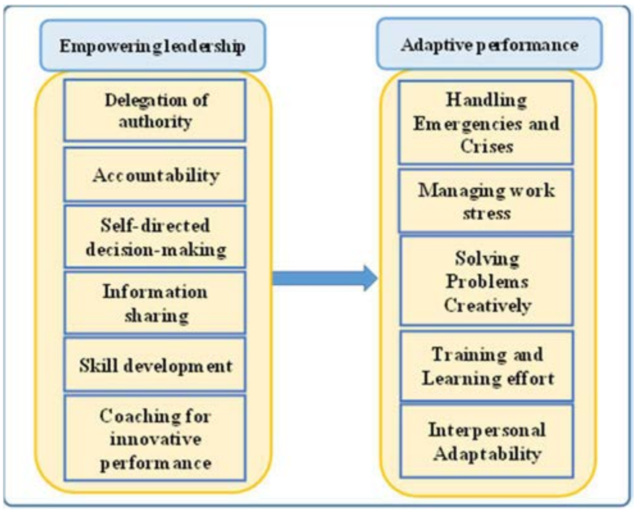

Figure 1 The hypothetical model of the research
Source: prepared by the researcher

In order to develop an accurate answer to the existing research questions, and according to the hypothetical model of the research, the research hypothesis was formulated as follows:

"There is a statistically significant effect of empowering leadership in enhancing the adaptive performance of employees".

As for the research sample, it included a sample of employees at Al-Iraqia University - Baghdad Governorate, and their number was (141) employees from various departments and sections.

4 Results

This section of the research deals with the procedures adopted by the researcher in order to test the answer to the questions raised in the current research and to achieve its objectives. As these procedures include a description of the research sample, and appropriate statistical methods for data analysis, and the following is a review of those procedures used.

4.1 Descriptive analysis of research data

The descriptive analysis of the data focuses on providing a summary of the response of the researched sample to the research variables and its diagnosis by adopting a number of statistical indicators that give sufficient significance for this description. Which helps researchers to understand the detailed meaning of the data to be analyzed by adopting tables or graphs and discussing them in detail.

In this case, it is necessary to rely on a set of descriptive statistical indicators represented by the arithmetic mean, which shows the extent of the sample's response to the variables investigated, and the standard deviation, which shows the extent to which the values deviate from their arithmetic mean. As well as diagnosing the relative importance of each of the paragraphs and one of the dimensions through which the variables were measured, so the hypothetical mean value was adopted at a rate of (3) meaning that the achieved value of the arithmetic mean indicator that is less than the hypothetical mean is considered an unacceptable value, otherwise it is considered an acceptable value. On this basis, a five-point Likert scale (completely agree, agree, neutral, do not agree, do not completely agree) was used. As indicated in the paragraphs below:

4.1.1 Analyzing the sample answers about the empowering leadership variable

Table (1) below shows the descriptive analysis of the empowering leadership variable, which includes arithmetic means, standard deviations, and the relative importance of the dimensions of empowering leadership.

By analyzing the data on the answers of the research sample, on the questionnaire that included the paragraphs of the empowering leadership variable in the research and shown in Table (1), the following appeared:

1. The arithmetic mean of the total empowering leadership variable was (3.94), which is higher than the hypothetical mean of (3), which is used to test the response

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levels of the respondents, and the standard deviation reached (.835) with a relative importance of (79%).

2. The dimension of delegation of authority ranked first in terms of relative importance, which amounted to (87%), with a mean of (4.34) and a standard deviation of (629.).

3. The dimension of accountability ranked second with a relative importance of (81%) and an arithmetic mean of (4.05) and a standard deviation of (.743).

4. The dimension of skill development ranked third in terms of relative importance, which amounted to (80%), with a mean of (3.98) and a standard deviation of (.803).

5. The dimension of information sharing ranked fourth with a relative importance of (77%) and a mean of (3.83) and a standard deviation of (.845).

6. The dimension of self-directed decision making ranked fifth in terms of relative importance, which amounted to (76%), with a mean of (3.79) and a standard deviation of (901.).

7. As for the dimension of coaching for innovative performance, it ranked sixth and last with a relative importance of (73%) and an arithmetic mean of (3.64) and a standard deviation of (.948).

Table 1 Descriptive analysis of the empowering leadership variable

Dimensions	Sample	Mean	Std.	R. Imp.	Sequence
Delegation of authority	141	4.34	.629	87%	**1**
Accountability	141	4.05	.743	81%	**2**
Self-directed decision making	141	3.79	.901	%76	**5**
Information sharing	141	3.83	.845	%77	**4**
Skill development	141	3.98	.803	%80	**3**
Coaching for innovative performance	141	3.64	.948	%73	**6**
Total empowering leadership	**141**	**3.94**	**835.**	**79%**	

Source: Prepared by the researcher based on the results of Spss v.22

The above results indicate that the employees at Al-Iraqia University, are aware of the nature of the empowering leadership variable in its dimensions, and the effect of the availability or lack of this type of empowerment on how they work, through the extent of their response and agreement on the paragraphs contained in the contents of the questionnaire related to the measurement of the empowering leadership variable. As a result, of what was mentioned, there is a tendency by managers in all departments and sections towards empowering leadership in the university sample of the research.

4.1.2 Analysis of sample answers about the adaptive performance variable of employees

Table (2) below shows the descriptive analysis of the adaptive performance variable, which includes arithmetic means, standard deviations, and the relative importance of the adaptive performance dimensions.

Table 2 Descriptive analysis of the adaptive performance variable

Dimensions	Sample	Mean	Std.	R. Imp.	Sequence
Handling Emergencies and Crises	141	3.73	.967	75%	**4**
Managing work stress	141	4.16	.874	83%	**2**
Solving Problems Creatively	141	3.81	.935	76%	**3**
Training and Learning effort	141	3.65	.984	%73	**5**
Interpersonal Adaptability	141	4.38	.823	88%	**1**
Total adaptive performance	**141**	**3.95**	**818.**	**79%**	

Source: Prepared by the researcher based on the results of Spss v.22

By analyzing the data on the answers of the research sample, on the questionnaire that included the paragraphs of the adaptive performance variable in the research and shown in Table (2), the following appeared:

1. The arithmetic mean of the total adaptive performance variable was (3.95), which is higher than the hypothetical mean of (3), which is used to test the response levels of the respondents, with a standard deviation of (.818) and a relative importance of (79%).

2. The dimension of interpersonal adaptability ranked first in terms of relative importance, which amounted to (88%), with a mean of (4.38) and a standard deviation of (.823).

4. The dimension of solving problems creatively ranked third in terms of relative importance, which amounted to (76%) and with a mean of (3.81) and a standard deviation of (.935).

5. The dimension of handling emergencies and crises ranked fourth with relative importance (75%) and an arithmetic mean of (3.73) and a standard deviation of (.967).

6. As for the dimension of training and learning effort, it ranked fifth and last with a relative importance of (73%) and an arithmetic mean of (3.65) and a standard deviation of (.984).

The above results indicate that employees at Al-Iraqia University, are aware of the nature of the adaptive performance variable in its dimensions, and the extent to

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which this performance affects the university's reputation and development and the incentives and rewards that they may obtain as a result of it, through the extent of their response and agreement on the paragraphs contained in the contents of the questionnaire related to measuring the performance variable Adaptive. As a result of the above, the university under consideration seeks to support the adaptive performance of its employees.

4.2 Test of effect hypothesis

The amount and nature of the effect between the main research variables will be identified by testing one main hypothesis. A simple regression analysis will be performed between the main variables, and the slope coefficient, regression coefficient and other data will be extracted using the statistical program (SPSS v.22). Acceptance or rejection of the hypothesis will depend on the level of significance, as the researcher assumes a level of significance (0.05), and these results are as follows:

The main hypothesis of the research states: (there is a statistically significant effect of empowering leadership in enhancing the adaptive performance of employees). After measuring the effect, the following results were shown in Table (3), as follows:

Table 3 Test of the effect of empowering leadership in enhancing adaptive performance

Dependent variable	**Adaptive performance**					
Independent variable	**β**	**T. Value**	**R^2**	**F. Value**	**Sig.**	**Result**
Empowering leadership	.820	7.594	.706	9.842	.000	**Acceptance**

Source: Prepared by the researcher based on the results of Spss v.22

Table (3) above shows that there is an effect of empowering leadership in enhancing the adaptive performance of employees, as the regression slope coefficient reached (.820), which is significant because the level of achieved significance reached (.000), which is less than the level of significance that the researcher assumed, which is (0.05). In addition, the coefficient of determination (R2) has reached (.706), which means that empowering leadership explains (.706) the variation in the dependent variable adaptive performance of employees, which is acceptable based on the calculated (F) value of (9.842) which is greater than its tabular value (4.00). Moreover, according to these results, this hypothesis is accepted at the level of this research.

5 Conclusions

To survive in the ever-changing global business world, adaptive employee performance and sustainable work cultures become key features of organizational success. The adaptive performance of employees in the work environment is seen as referring to the employee's adaptation to changes, problems or crises that occur in the workplace. As today's business organizations are undergoing a rapid pace of change, they need these highly adaptive employees. In order for organizations to enhance this performance, its need a type of empowerment provided by leaders or managers, which is known as empowering leadership, which refers to the extent to which supervisors express their trust in the capabilities of their employees, emphasize the importance of their work, involve them in decision-making, and reduce or remove bureaucratic constraints. The ability of empowering leadership in its dimensions to enhance the adaptive performance of employees has been proven through the results of the research. It was found that these dimensions, if followed and applied by the leader, will lead to enhancing the adaptive performance of employees and increasing their ability to deal with problems and crises in an appropriate manner. As a result, the objectives that the current research sought to test have been achieved.

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ANALYSIS, PRACTICAL APPLICATION AND POSSIBLE INTERCONNECTION OF INDUSTRIAL ENGINEERING METHODS AND KEY PERFORMANCE INDICATORS

Martin Marecek-Kolibisky
Institute of Industrial Engineering and Management, Faculty of Materials science and Technology the Slovak University of Technology in Bratislava, Ján Botto street 2781/25, 917 24 Trnava, Slovakia, EU, martin.marecek-kolibisky@stuba.sk (corresponding author)
Tomas Brlej
Institute of Industrial Engineering and Management, Faculty of Materials science and Technology the Slovak University of Technology in Bratislava, Ján Botto street 2781/25, 917 24 Trnava, Slovakia, EU, tomas.brlej@stuba.sk
Marta Kucerova
Institute of Industrial Engineering and Management, Faculty of Materials science and Technology the Slovak University of Technology in Bratislava, Ján Botto street 2781/25, 917 24 Trnava, Slovakia, EU, marta.kucerova@stuba.sk

Keywords: improvement methodology, industrial engineering, industrial engineering methods, Key Performance Indicators (KPIs), Industry 4.0.

Abstract: In connection with applying the principles of Industry 4.0, the industrial practice also requires the consistent application of industrial engineering methods to improve process performance. The transformation of society into digital affects almost all areas of industry, public administration, healthcare and all walks of life. The implementation of Industry 4.0 is very important in the automotive, engineering and electrical engineering industries. It is the move towards Industry 4.0, the collection of large amounts of data and the decision-making based on the data obtained that provide the ideal basis for using more complex industrial engineering methods and better process evaluation.

The paper's main goal is to analyse and identify the use of industrial engineering methods and key performance indicators of companies in industrial practice in Slovakia, where practice shows a lower acquaintance with these methods, especially among medium-sized companies. The paper deals with the issue of industrial engineering methods aimed at improving process performance in the context of key performance indicators. The paper contains some results of a questionnaire survey aimed at gathering information on improvement methods and identifying the use of key performance indicators in industrial practice. Which results will bring us closer to which types of methods are most used in Slovak practice and why?

1 Introduction

Today's modern technologies contribute to performance and productivity and have also taken over some of the activities in the production process. In modern companies that have implemented Industry 4.0 technologies and use highly automated machines and equipment in production, these machines have replaced people in selected parts of production. Production workers only operate the machine, which is a characteristic element of the fourth industrial revolution. Thus, Industry 4.0 is characterised by interactions and communication between machines and cyber-physical systems for real-time operations management [1].

The main idea of industrial transformation is to increase competitiveness by increasing enterprises' efficiency and productivity. Companies can achieve this goal under the conditions of monitoring and subsequent improvement of the performance of the processes taking place in the system, improvement of the quality of processes and elimination of discrepancies in the production system [2].

There are many methodologies and industrial engineering methods aimed at improving process performance. The paper's content is the analysis and use of industrial engineering methods in conjunction with Key Performance Indicators (KPIs) in industrial practice. We investigated the actual state of use of methodologies and methods of industrial engineering in industrial practice in order to improve process performance, increase quality and eliminate deficiencies. Using a questionnaire survey, we found out the state of use of industrial engineering methods in practice and at the same time, we want to draw attention to the real state of use of methods and methods of industrial engineering in practice, and also using KPIs to measure and analyse data in companies.

Businesses must maintain or improve competitiveness to analyse activities and processes using data within the production system. They can also obtain this data using KPIs and then evaluate it and suggest improvements using the given industrial engineering methods.

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1.1 Theoretical connection of industrial engineering methods and KPI

Process improvement is an activity that specifically focuses on analysing process behaviour, identifying the causes of problems related to process continuity and also focuses on process quality, efficiency, and productivity. Process improvement is based on the current process, depending on how the process is documented in the documentation or according to the knowledge of the process participants [3].

The starting point for improving the efficiency of production processes and the overall production system of the company is the optimal setting and use of production factors. Factors arising from the need to meet all customer requirements and adapt to the changing conditions of the company's environment (e.g. increasing competitiveness, reducing costs, or increasing the overall flexibility of the company) are important. The aim of these business activities is to achieve measurable economic and production results, such as the efficiency of the production process and timely performance of tasks, identification of factors affecting not only product quality but also shortening inter-operational times, minimising inventory. Advanced methods of industrial engineering and management of production processes in the company play an important role in improving existing production systems and eliminating errors [4].

Process management in an industrial enterprise is applied not only at the level of production but also in logistics, customer service, etc. All these processes and activities must be coherent and coordinated at a high level in order for the company to be efficient in production, respectively in services. Some processes and their management are taken care of by artificial intelligence thanks to the advent of Industry 4.0. All processes in business practice are measurable and analysed with technologies and elements of Industry 4.0 in real-time. Processes can be measured using indicators such as productivity indicators (OEE), economic (profit, cost, profitability), qualitative (FPY, complaints, scrap), time (clock time, cycle time). These indicators are analysed in companies using various methodologies, methods, tools, techniques of industrial engineering. At present, a number of different methods and tools are described in the scientific literature, which is used in improving processes in business practice, e.g. simple quality management tools, various statistical methods, value flow mapping, SMED, TPM, bottleneck theory, and methodologies such as Lean management, Six Sigma and more. In fact, it is worth noting which of these methods of improvement will be effective even in conjunction with technologies and elements of Industry 4.0 [5,6].

By introducing Industry 4.0 technology into business practice, new processes are expected to be created. These processes will involve more technology and be smarter, but they will remain processes. These future processes will still create space for the use of Six Sigma and other methods, respectively, improvement methodologies. Processes will continue to require analysis, the definition of capabilities, control to be effective and efficient, but they will also require information and the definition of new parameters that will affect them. With increasing automation and the potential to mass produce unique products, automation processes should collect more data and be faster in real-time. There will be a lot of overflow of data and information about the processes, which will need to be sorted according to the importance of the parameters at a given time [7].

New technologies bring a new era of business, new approaches to business operations, as well as new jobs that require new competencies and skills of employees. While new jobs will require new knowledge and skills, the right combination of skills needed to perform in modern industrial enterprises is becoming more complex and will continue to evolve with the development of a technologically advanced work environment. This will require future generations of workers to develop their digital skills and build access to lifelong learning [8].

Process performance can be defined as the extent to which a process result is able to meet the requirements of internal or external customers of the process. Within a company as a system of different departments, interconnected material and information flow, and complex process chains, the performance of a particular process cannot be measured independently. In this context, the interdependencies with the delivery procedures at the beginning of the delivery, failures, and the setting of control variables or parameters are important impact factors that need to be taken into account when evaluating process performance [9].

The new parameters will be measured by built-in sensors on machines equipment. Examples of parameters are temperature, speed, pressure, rotation, etc. This is precisely the space for the development of the Six Sigma methodology, which can develop a lot of data and information and analyse this data in the repository, but also the space for the development of other methods and the implementation of advanced industrial engineering methods in practice. Thanks to Industry 4.0, such as Big Data, methods and methodologies will be developed based on the measurement, analysis, and application of statistical tools and techniques. Current statistical tools and techniques will increasingly find their use, and it is likely that new techniques and tools will emerge to focus on statistical management and quality control of new processes. New tools and methods will emerge, but current methods such as DMAIC, PDCA cycle, Pareto analysis, or Ishikawa diagram will still be used. Most of the methods and tools used in the Six Sigma methodology will continue to be used, and it will still be necessary to understand the causes of problems and address problems. Future machines and equipment will take control of the processes individually or in cooperation with statistical control, real-time analysis, and autocorrection [10].

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ANALYSIS, PRACTICAL APPLICATION AND POSSIBLE INTERCONNECTION OF INDUSTRIAL ENGINEERING METHODS AND KEY PERFORMANCE INDICATORS
Martin Marecek-Kolibisky; Tomas Brlej; Marta Kucerova

The development and implementation of key performance indicators (KPIs) methods support manufacturers by quantifying processes, identifying potential vulnerabilities, and evaluating and comparing them. KPIs focus on key aspects of the performance of the assessed fact/process. They are part of a family of key indicators divided into two main groups, namely performance indicators and result indicators. These quantifiable and strategic measures are essential for understanding and improving production performance, both in terms of eliminating waste and achieving the strategic goals that are most important for current and future success. Based on industry principles for evaluating technology, KPIs support the comparison of different processes and their results within the manufacturing industry. KPIs are those indicators that focus on aspects of an organisation's performance for which the organisation's current and future success is paramount [11].

Performance indicators, which can be defined as information collected at regular intervals to monitor system performance, are the basis for evaluating and comparing the performance of processes across enterprises. Through ratios and metrics, and measurements, they help control processes by making it possible to compare planned and achieved results. Different approaches are used to classify process performance indicators. For example, there are classifications by service dimensions (process, potential, and outcome), performance dimensions (quality, cost, time, customer satisfaction, flexibility), or by supply types (e.g. maintenance, planning, repair). Such classifications help define performance indicators suitable as metrics for analysis and control with a special focus on specific aspects [9,12,13].

Indicators, in general, need to be distinguished by absolute numbers and relative numbers. Absolute numbers are independent of other indicators. They contain an individual number, sum, difference, and average. They gain importance only by comparison with other indicators. In contrast, relative numbers combine information, e.g. indicators through ratios [14].

The relative number can be divided into quotas, reference numbers, and index numbers. Quotas are a ratio of one indicator to the whole, and important indicators can therefore be compared. Reference numbers are the ratio of the same indicators with different contents. Last but not least, index numbers compare time series. Thus, the literature focuses more on financial KPIs and less on non-financial ones. Important non-financial KPIs are productivity, quality, time, and intangible assets. Nevertheless, it is possible that a company will comprehensively obtain information about business problems only by considering financial and non-financial KPIs.

Appropriately selected and set KPIs meet the conditions of SMART, so they are measurable, unambiguous, understandable, set according to real facts, and limited in time. The time limit in the case of KPI represents the frequency of measurement and evaluation of a given indicator [15].

2 Methodology

Using methods of improvement, companies improve, among other things, competitiveness, innovative production processes, and product quality. In order to be able to use the methods of improvement, they need to obtain data within the production system and the actual performance of the company. They can also use KPIs to obtain this data from the production system. The use of these KPIs is important as well as the use of industrial engineering methods. The actual state has ascertained the use of methods and methodologies of industrial engineering and the use of KPIs through a questionnaire survey.

The questionnaire survey was focused on medium and large companies, while in 2020, when the survey was conducted, there were 1344 companies in Slovakia. Most of the companies involved belong directly to the automotive industry or are suppliers to the automotive industry. Two hundred and thirty-six companies were contacted with a request to fill in an online questionnaire. Sixty-four enterprises participated in the questionnaire survey, of which 68.7% were medium-sized, and 31.3% were large enterprises. Due to the small variability in the area of their operation, it was decided not to distinguish between the individual sectors in which companies operate for further work with the results of the questionnaire. Table 1 shows the percentage of enterprises by nature of production and size of the enterprise. Medium-sized companies with serial production had the largest share. The future research will be primarily focused on this type of company.

Table 1 Nature of production due to the size of the company (own processing)

Company size and nature of production		%
Medium enterprise	Pride production	23.44%
	Batch production	40.60%
	Mass production	4.69%
Large-scale enterprise	Pride production	4.69%
	Batch production	17.19%
	Mass production	9.38%

3 Results and discussion

Respondents to the question *"What methods or do you use industrial engineering tools to improve the company's*

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processes?". This question was opened without a choice, and therefore, the participating respondents mentioned the Six Sigma option. As part of our research, the issue of Six Sigma is classified as a comprehensive improvement methodology, which is why the DMAIC was assigned to Six Sigma.

Table 2 shows what industrial engineering methods and tools to improve processes and their performance are used in a sample of companies operating in Slovakia. The chosen criterion for identifying the parameters of use was the size of the company. Based on this criterion, Table 2 shows the structure of the use of these methods in medium-sized enterprises (blue) and large enterprises (red). The most common answer for medium-sized companies was that "they do not use any methods, or tools "as part of improving business processes (up to 15% of companies gave this answer). This fact is a negative finding in business practice in Slovakia. The answer was that they could not name the method, and the results say that if they use the methods, they do not know about them, as they do not even know how to name and define them. This was followed by methods and tools that he considers simple and has only partial positive results in improving processes when used individually without a defined methodology. In the case of medium-sized companies, it was found that companies do not use the Six Sigma methodology, or DMAIC procedure, which was the most common answer in a group of large companies.

Table 2 Use of methods and tools of industrial engineering within a sample of companies (own processing)

Methods and tools of industry engineering	Medium enterprise	Large-scale Enterprise
We do not use any methods	15.3%	1.2%
5 S	7.1%	2.4%
We can not name it	11.8%	0.0%
Ishikawa diagram	4.7%	4.7%
PDCA	3.5%	3.5%
DMAIC / SIX SIGMA	0.0%	9.4%
Kaizen	3.5%	2.4%
8D	3.5%	2.4%
TPM	2.4%	3.5%
TQM	1.2%	1.2%
5x why?	1.2%	2.4%
SMED	0.0%	1.2%
Brainstorming	3.5%	1.2%
VSM	1.2%	4.7%
Analysis of customers requirements	0.0%	1.2%

The Six Sigma method was included in the DMAIC procedure in the answers, i.e. as a comprehensive improvement method. Individual methods and industrial engineering tools are used for process improvement. None of the addressed medium-sized companies does use the Six Sigma method or the entire DMAIC process, as well as the SMED method and the Customer Requirements Analysis.

The questionnaire was focused on the use of KPIs, and these results are shown in Table 3. The survey shows that the concept of key performance indicators is widely used in large companies and companies defined as a medium. Only 4.3% of the participating medium-sized enterprises do not use any key indicators. However, it should be noted that the automotive industry, together with its suppliers, in Slovakia is most closely connected with foreign companies, in which key indicators have been used for a long time. Therefore, for industrial enterprises in Slovakia focused on other industries, the use of KPIs may differ depending on the industry.

Table 3 Use of KPIs in business practice due to the size of the company (own processing)

Used KPI	Medium enterprise	Large-scale Enterprise
Productivity, efficiency	21,5%	15,2%
Economic	12,7%	10,1%
Quality, confusion, KPI	11,4%	8,9%
Time	10,1%	7,6%
Do not use	2,5%	0,0%

Another interesting finding when using key indicators is the percentage distribution of these groups of indicators, which are shown in Table 3. The area of productivity and process efficiency was found that the area where key indicators are most used, with 37% of medium-sized enterprises using these indicators and 36.4% of large enterprises. The most frequently reported productivity and process efficiency indicators were overall equipment effectiveness (OEE), productivity index, and internally determined productivity indicators in the company. The quality of processes is also closely related to productivity and process efficiency. For example, the addressed company states the common measurement of customer satisfaction, confusion, and the ratio of nonconforming products to the total number of products produced. Given this fact, it is assumed that industrial engineering methods, which are closely related to the efficiency of the process, whether in their design or later elimination of the identified shortcomings, thereby also contributing to improving the

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quality of processes and their outputs, will be a suitable platform for the implementation of key indicators.

Research has shown that Six Sigma is used in large companies. However, the results by medium-sized companies are stated little interest in the use of Six Sigma as part of the initiative to improve processes and product quality continuously. In the near future, even small and small businesses are expected to be forced to use the Six Sigma methodology, primarily those that act as suppliers to large global companies. The Six Sigma methodology offers a large number of radical improvements in the quality of processes and products, which leads to increased competitiveness, the company's improved financial performance, customer satisfaction, and an overall improvement of the company's results.

The question is why medium-sized companies do not use the Six Sigma methodology. This is assumed to be due to ignorance of the methodology, low awareness of the methodology, insufficient knowledge of employees about the methodology or overall application documentation, and the use of statistical tools and methods, respectively, industrial engineering methods within the given methodology. These facts will be investigated further in our work and focus on the problems of implementing the Six Sigma methodology.

Based on the perceived greater interest in the Six Sigma methodology by medium-sized companies, which generally have less insight into not only the methodology itself but also other methods of industrial engineering, as well as the fact that modern technology gives business managers access to fast and precise information, which requires the need for appropriately selected methods of measuring and evaluating business processes. In the Six Sigma methodology as well as in the application of other methods of industrial engineering is anticipated a wide possibility of applying the philosophy of key indicators.

Through research, in the application of methods to improve performance, respectively improving the quality of processes and products themselves were founded that due to the company's size, there are obvious differences between medium and large companies in industrial practice in Slovakia.

4 Conclusion

Technological progress is constantly advancing, and nobody knows what to expect in the next decade, which will bring the Industry 4.0 paradigm. The Industry 4.0 concept is adopted by companies and implements individual technologies that ensure the company's competitiveness. The competitiveness of companies will be ensured by new technologies and the use of individual methodologies, methods, or tools to improve the quality of products, processes, and services. Because companies know how to measure and evaluate a given quality, key performance indicators - KPIs are used. The main goal of this paper was to identify and analyse the use of industrial engineering methods and key performance indicators in industrial practice in Slovakia. The paper dealt with the issue of industrial engineering methods aimed at improving process performance in the context of using key performance indicators. This paper is dealt with the analysis and evaluation of a questionnaire survey focused on the use of improvement methods and the identification of KPIs in industrial practice. The research concluded that only some methods are used in individual companies to improve processes. Still, very few Slovak companies use the methods of improvement as a whole within the given methodology. Based on the findings, it is emphasised that methods aimed at improving processes must be used as a set of methods in applying the methodology, such as Six Sigma. It is necessary that within the applied methodology, there is a connection between measurements and performance evaluation using KPIs.

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TOTAL PRODUCTIVE MAINTENANCE IN LAB SET UP OF EDUCATIONAL SYSTEM – CASE STUDY

Panneerselvam Sivasankaran
Department of Mechanical Engineering, Manakula Vinayagar Institute of Technology, Pondicherry – 605 107, India,
sivasankaranmech@mvit.edu.in

Keywords: equipment effectiveness, Total Productive Maintenance (TPM), lab set up, daily maintenance.
Abstract: Total productive maintenance (TPM) is used to evaluate the performance of equipment used within the manufacturing facility, lab set up etc. TPM Concept used to improve the efficiency of machinery by undergoing serious maintenance activities every day based on the usages. Productivity is defined as maintaining the workplace and surrounding facilities neat and clean. Equipment used for performing work is said to be monitored every time continuously. Due to the continuous observation about the performance of the equipment will help us to note down the conditions of equipment also suitable remedies to further increase its effective usages. In this paper, an attempt has been made to use TPM concepts (Total Productive Maintenance) in the lab to set up the environment within the technical education institution in south India. The case study is conducted to study the quality and effectiveness of lab instruments with the help of TPM concepts used in real-time applications.

1 Introduction

TPM (Total Productive Maintenance) finds a good place for industrial implementation during the initial period. Then later TPM Concept was implemented in many different application areas like schools, colleges and higher level Research institutions. TPM concepts result to improve the overall equipment effectiveness that is termed as measuring the percentage utilization of machinery within the given facility or set up. TPM strives hard for continuous improvement in the workplace environment. In TPM culture, all peoples are equally involved together for the upliftment of standards maintained within the facility. TPM concepts focus on the reliability of equipment and its functions. The main discrimination between TPM and other concepts is described here as follows:

a. In the TPM environment, workers are also involved in improving equipment effectiveness.
b. Compared to other types of maintenance policies, TPM stands for proactive maintenance.

The goal of TPM is used to improve the overall equipment effectiveness of machinery by providing high precision results. TPM is said to be the innovative approach used in the workplace facility to minimize the elimination of several losses by increasing the reliability of equipment with fewer failures.

1.1 Types of maintenance systems

Specific maintenance can be classified into various types as listed below:

1. **Breakdown Maintenance.**
2. **Preventive Maintenance.**
3. **Total Productive Maintenance.**
4. **Condition-based Maintenance.**

These are the above types of maintenance policies available as per the literature.

1. Breakdown Maintenance:

The goal of breakdown maintenance is to do the maintenance activities after experiencing the problem in the later stage of equipment. Here in this type of maintenance system, failure is addressed only at the end after noticing the situation.

2. Preventive Maintenance:

Preventive maintenance is regular in nature which is carried out daily before experiencing the failure in the equipment. Successful maintenance strategy requires careful planning and scheduling.

3. Total Productive Maintenance:

Total Productive Maintenance uses everyday performance activity within the work place. TPM can be otherwise termed as total employee involvement system. TPM involves all peoples from levels of management to take necessary steps to foresee the various maintenance issues.

4. Condition-based Maintenance:

This type of Maintenance strategy monitors the actual condition of asset based on that further decision can be taken what to be done in order to improve the performance. This type of maintenance strategy measures the real time performance of the asset and that tries to find out the suitable remedial measures for the equipment effectiveness.

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1.2 Pillars of Total Productive Maintenance (TPM)

TPM (Total Productive Maintenance) is a lean management strategy which aims for zero breakdowns of machinery, zero defects and zero accidents within the plant system.

The following are the 8 pillars (Figure 1) of TPM (Total Productive Maintenance):

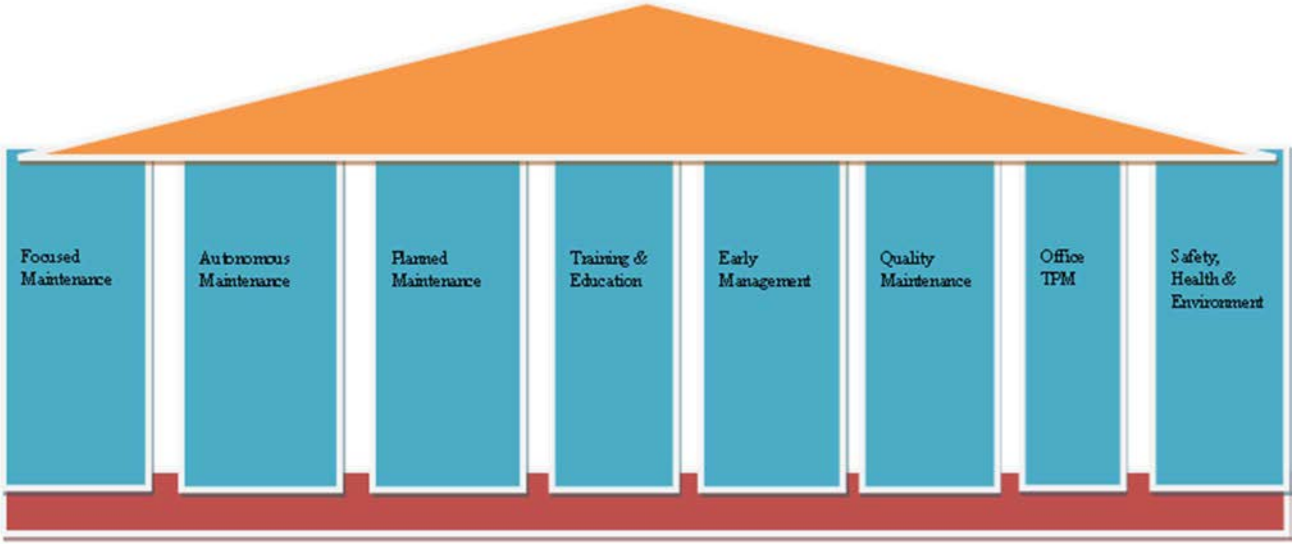

Figure 1 8 Pillars of TPM Framework

1. Focused Maintenance,
2. Autonomous Maintenance,
3. Planned Maintenance,
4. Training & Education,
5. Early Management,
6. Quality Maintenance,
7. Office TPM,
8. Safety, Health & Environment.

1. Focused Maintenance:

Focused maintenance is otherwise termed as continuous improvement the main goal is to improve the effectiveness of maintenance program.

TPM focuses on losses in equipment as listed below:

1. Unplanned or unexpected machine stop
2. Shutdown losses
3. Speed losses

These are the various losses in TPM. In this strategy the aim is to avoid losses of equipment, tools and energy etc the whole team has to be proactive in nature.

2. Autonomous Maintenance:

This is the second pillar in TPM hierarchy in this type of maintenance system every team will act as individual person or autonomous agent. Everyone has the responsibility to clean, inspect and contribute with various assets of organization. In autonomous maintenance everyone are involved in improving the quality of equipment functioning and its usages. All are responsible for their work that's why TPM is said to be total employee culture. This type of method improves safety of equipment by reducing accidents.

3. Planned Maintenance:

According to TPM planned maintenance minimizes the breakdown by controlling the downtime.

In this type of maintenance system proper shutdown of machineries must be done to recover the failures.

4. Training and Education:

TPM believes on training and education otherwise every employee will not trust each other.

Training is the only possible way of education to enlighten the knowledge of technicians or workers about the use and functions of machines. So, training and education act as main hub to sharpen the minds of worker about the functions of machines.

5. Early Maintenance:

The main objective of early maintenance is to improve the effectiveness of machineries well in advance before the failure occurs. Early maintenance means careful assessment and conditional analysis of equipment based on the everyday usages.

6. Quality Maintenance:

It is focused towards the customer satisfaction by delivering high quality products. Through focused improvement defects are eliminated from the process through effective maintenance procedures.

7. Office TPM:

Office TPM aims to improve the administrative functions or processes more effectively. This includes process and procedures that can be automated. The

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documents are maintained with proper labeling mechanism, sorting the files within the rack as per the standards etc . Office TPM aims for improving the standard office work culture in order to maintain the documents frequent usages.

8. Safety, Health &Environment:

The aim is to improve the safety by proper education and training provided to the workers every now and then. Safety maintenance of equipment's must be regulated every now and then for the concern of workers.

The motto of this pillar is to achieve zero defects and zero accidents within the shop or workplace.

1.3 Concept of overall equipment effectiveness

Overall equipment effectiveness is a common standard for measuring productivity of the organization This concept tries to define the percentage of manufacturing time maintained to be truly productive. OEE aims to benchmark the performance of the machineries compared with standards. OEE helps to improve the productivity of the manufacturing equipment.

The physical relationship of OEE (1) can be expressed as given below:

$$OEE = Availability * Performance * Quality \quad (1)$$

Where:

Availability = It measures the percentage of usage of the equipment throughout the time.

Performance = It describes the operating characteristics of the equipment subject to repair and other losses

Quality = It expresses the percentage of both good and bad part produced together

2 Literature review

This section describes the brief literature survey collected on TPM concepts as shown:

Ranteshwar Singh, Ashish M Gohil, Dhaval B Shah, & Sanjay Desai [1] - In this article authors have focused the difference between quality and manufacturing which are closely connected to the organization. over a period of certain time these two have emerged into TPM (Total Productive Maintenance) and TQM (Total Quality Management) respectively. In this paper author described the importance of TPM (Total Productive Maintenance) and its significant features. The concept was implemented in auto component manufacturing industry. Also, authors have suggested the concept of OEE for successful implementation of TPM.

Dip Kumar Patel & Prashant Singh Tomar [2] –The proposed article describes the efforts to minimize the machine downtime at manufacturing unit of switch gear situated in north Indian states. The problem focused primarily is idle time due to machine break down. In order to reduce the machine breakdown time TPM (Total Productive Maintenance) is carried out to improve the quality of equipment functioning. In addition to that the authors have described about the various pillars of TPM and OEE concepts.

Sivakumar Annamalai, Suresh D. [3] –The present article focuses about the self-directed maintenance namely TPM. TPM concept is incorporated with Overall Equipment Effectiveness (OEE) for enhancing the productivity of equipment. In the proposed work OEE concept is applied to measure the effectiveness of machines and equipment's with respect to the daily use. OEE stands as benchmark reference for all companies in order to maintain the tools and machineries with good working conditions.

Wan Hasrulnizzam et al. [4] – In present article the main focus is made on the use of office TPM for Lecturer room in the faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka. Selected as primary source for data gathering, Observation and Interview techniques used in this work. In the present work the main respondents considered are staffs and students. For the enhancement of Office TPM lecturer room was selected for further implementation using 5S concept. The results obtained from 5S concepts created a positive impression to all staffs and students of the university in Malaysia.

Jignasha P. Acharya & Maharshi J. Bhatt [5] - The entire work focused on the implementation of TPM and its various pillars to solve the manufacturing problem within the organization . Also in this paper focus on OEE concepts improves the success of industry by maintaining the factory machines with high working standards.

Wasim S. Hangad & S. Sanjay Kumar [6] –In this work authors have focused on medium sized industry for TPM implementation. Depending on the size industries are classified into three type's namely small, medium and large sized Industries .In this existing work deep focus is made on TPM challenges and implementation and its significant importance.

Rahul V. Dandage, Prasad K. Hajare, Manoj V. Dhebe, Amitraj U. Lad, Santosh S. Pinjari [7] - In this article authors have made key focus on laboratories available in technical institutions in India particularly they considered engineering institutions . In every technical institution there are various laboratories equipped with all latest instruments but the thing is how these instruments going to serve the need in future use. In this work TPM concept is focused for improving the quality and use of lab instruments for effective demonstration. Also in this work authors have given suggestion to use preventive maintenance in order to keep the equipment in good working condition.

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Vigneshwaran, Maran & Manikanadan [8] - The main purpose of this article is to improve the effectiveness of equipment using concept named TPM (Total Productive Maintenance) . In this paper both tangible and Intangible measures are discussed briefly to analyze the importance and implementation of TPM in many several applications such as Educational Institutions and Industries. In this present work authors conducted review by collecting several sources on Total productive maintenance and its applications. The literature focuses on TPM by enhancing Overall Equipment Effectiveness as well as Employee Morale.

Hemlata Vivek Gaikwad [9] - The article discuss about the purpose of Jishu Hozen one among the pillar of TPM activity aims to focus on zero defects, Zero accidents, Zero breakdowns and Zero wastages. There are three phases in the study namely planning, Observing and Analyzing. Organization formed a research team to do necessary analysis and experiments using the Jishu Hozen pillar of TPM. By implementing the TPM concept in industries employee can able to achieve the target of more than 85 % as per world class standards.

Yash Parik & Pranav Mahamuni [10] –In this paper the detailed research is carried on the various methods and processes to improve the quality and maintenance. TPM helps to improve the productivity of the manufacturing operations. TPM Pillars serves as effective guidance and support for successful implementation. In this article attempt has been made to TPM objectives, benefits and Overall equipment effectiveness.

I.P.S. Ahuja and J.S. Khamba [11] - The main purpose of this article is to conduct detail review on TPM and its implementation challenges.This paper focuses on Importance of TPM, Basic framework and its applications in machine maintenance in shop floor. Detailed survey is conducted by questionnaire technique.

Ravishankar V. Korgal & Anil S. Badiger [12] -In the fast-growing competitive environment TPM is the best focused philosophy used in all manufacturing enterprises in order to improve the productivity of the resources. The main role of this work is to review the concept of TPM in engineering educational Institutions. In this paper suitable effort has been made to implement the TPM practices in normal applications. This article strives for finding out the possible areas to implement TPM and its roles in Technical Institutions.

A. Sivanatham & N.M. Sivaram [13] - The present article focuses on the review about TPM concepts and applications. This article represents the basic origins of TPM, process guidelines and Case studies.According to the Total Productive Maintenance it is observed from the fact that TPM is most widely used concept in many countries.Therefore, TPM is considered to be world class strategy.

Muhammad Zubair et al. [14] – This article primarily focus on OEE (Overall Equipment Effectiveness). Since equipment is the main key important element in the production its quality must be fixed higher in order to perform much better. In this work evaluation of OEE (Overall Equipment Effectiveness) is carried out in local pharmaceutical industry situated in Pakistan. In OEE concepts there are three main parameters considered namely availability, Performance & Quality. OEE concepts will try to identify the area for identifying the bottlenecks in production line.

Lisbeth del Carmen Ng Corrales et al. [15] - This paper tells about the status of research carried out by the various authors on OEE concepts practiced in TPM implementation for machine as well as equipment maintenance . Authors have reviewed 862 articles out of that they took references of about 182 articles from highly indexed journals on TPM concept. Based on the review of literature following are the three key results noted by the authors. 1. The academic Interest in TPM has increased a lot in last few decades 2. Many no of authors developed model based on OEE concepts in TPM. 3. OEE is the emerging topic in the area of logistics operations and services. Moreover this research serves as base for future literature studies.

V. Ramakrishnan & S. Nallusamy [16] - In this present work the main aim is to implement the lean technique in TPM methodology in order to reduce the machine breakdown time within the shop floor unit. This study was conducted in foundry shop in a leading manufacturing industry situated in south Tamil Nadu. Also from the results of analysis it is confirmed that breakdown failure happens due to flaws observed in casting operation. After careful study suggestion has been given to reduce the overall lead time and breakdown time. Based on the result it is found that 20 percentage savings done in improving the breakdown time to minimal after incorporating the lean technique in TPM work culture.

G. Pinto et al. [17] - The present article describes the importance of maintenance in Industrial Sector. Even though there are many strategies used to tackle various productivity issues. This work was implemented in the industrial context. The methodology chosen here is Total Productive Maintenance (TPM). TPM uses maintenance activities which are derived from preventive maintenance. Based on the results it is observed that there was a decrease in breakdown due to failure by 38% this leads to increase in machine availability and Overall Equipment effectiveness.

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Melesse workneh Wakijra et al. [18] - The main objective of this work is to review the contributions of TPM in various dimensions within the organization. In this work significant importance is studied and evaluated by measuring the performance improvements. In the present work various factors like top management support and leadership, traditional maintenance policies and various initiatives taken during the implementation process of TPM.

A.Y. Ali [19] - The problem encountered in this work is frequent breakdown of equipment namely Xerox machine due to poor unpleasant work environment. Thus the above problems lead to disrupt exams and other productive work in the university. In this work TPM is used as modern approach by equipping the concept namely Overall Equipment effectiveness. Thus at the end authors have stated the outcomes of using TPM concepts in practical applications.

T. Ahamed et al. [20] - TPM helps to maximize the equipment usage and its performance. The goal of TPM is to improve the effectiveness through proper handling of tools by following the guidelines as framed by the top management team within the organization. The entire work was divided into two phases namely phase 1 and 2 respectively. In phase 1 the possible losses and the contributing losses which affect the process are addressed here. In the second phase TPM implementation and suggested training program is initiated by the management of company for smooth operation of processes.

Summary of literature:
Based on the above survey it is observed that several researchers have contributed their ideas on TPM which includes the integration of OEE concepts in enhancing the efficiency of machines and supporting equipments. In some research articles focus is made on 5S Concepts in TPM then followed by various pillars of TPM like autonomous maintenance, planned maintenance and quality maintenance are implemented for successive functioning of TPM.

3 Methodology

In this section the diversified survey (Table 1) is collected from around 27 respondents from various departments within the same organization. The methodology carried out for survey mechanism is through Google survey forms with 6 different questions as described below:

Table 1 The diversified survey

TPM (TOTAL PRODUCTIVE MAINTENANCE) - SURVEY FOR WORKPLACE MAINTENANCE

MANAKULA VINAYAGAR INSTIUTE OF TECHNOLOGY

Email *

QUESTION 1 How often your organization supports Total Productive Maintenance methodology

- ☐ very rare
- ☐ always
- ☐ few times
- ☐ none

QUESTION 2 Does your Institutes have enough resources to implement TPM strategy

- ☐ yes
- ☐ NO

QUESTION 3 Does your Institutes follow 5 S concepts in TPM Methodology as regular practice.

- ☐ yes
- ☐ NO

QUESTION 4 Does your Employees are trained enough to use TPM Guidelines in real time situations.

- ☐ yes
- ☐ NO

QUESTION 5 In a day how many times you keep your work system neat and clean by TPM approach.

- ☐ 2 times in a day

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- [ ] 1 time in a day
- [ ] 4 times in a day
- [ ] none

QUESTION 6 What type of Maintenance strategy you prefer to use in your work place for guiding the employees?

- [ ] Autonomous Maintenance
- [ ] Corrective Maintenance
- [ ] Predictive maintenance
- [ ] none

Submit

The outcome of the survey is described as follows:

1. 55.6 % of the respondents gave positive feedback about TPM support within the organization.
2. 18.5% of the responded that only few times they used TPM support within the organization.
3. 25.9% of the respondents said very rare cases TPM resources are supported within the organization.
4. Only 11.1 % of the respondents said that the institute does not have effective TPM strategy.
5. 88.9% of the respondents said that their institutes have enough resources to have effective TPM strategy.
6. 74.1% of the respondents replied that their institutes have regular resources for 5S practices.
7. 25.9% of the respondents replied that their institutes will adapt to 5S practices.
8. 66.7% of the respondents said that their organization has well trained employees to use TPM Guidelines.
9. 33.3% of the respondents said that their organization has well trained employees to use TPM Guidelines.
10. 29.6% of the respondents said that only 2times in a day the work system was maintained neat and clean by TPM Approach.
11. 25.9% of the respondents said that only 1 time in a day the work system was maintained neat and clean by TPM Approach.
12. 37% of the respondents said that only 4 times in a day the work system was maintained neat and clean by TPM Approach.
13. 7.4% of the respondents said that none are not maintaining the work system neat and clean by TPM Approach.
14. 40.7% of the respondents preferred autonomous maintenance in workplace for guiding employees.
15. 25.9% of the respondents preferred predictive maintenance in workplace for guiding employees.
16. 33.3% of the respondents preferred corrective maintenance in workplace for guiding employees.

The above information is represented in the form of pie chart as described below (Figure 2 - Figure 7):

Figure 2 Respondent feedback

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QUESTION 2 Does your Institutes have enough resources to implement TPM strategy

27 responses

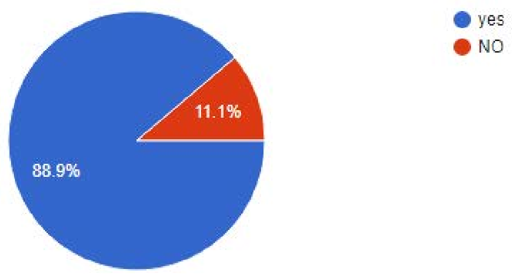

Figure 3 Respondent feedback

QUESTION 3 Does your Institutes follow 5 S concepts in TPM Methodology as regular practice .

27 responses

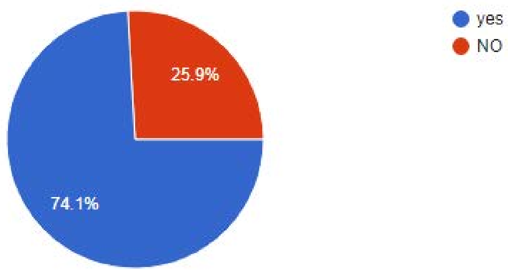

Figure 4 Respondent feedback

QUESTION 4 Does your Employees are trained enough to use TPM Guidelines in real time situations .

27 responses

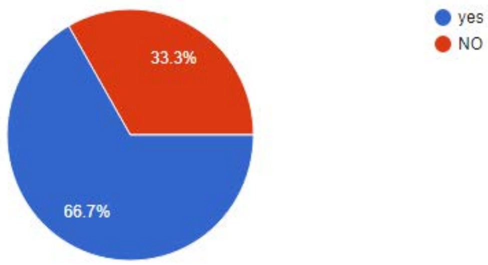

Figure 5 Respondent feedback

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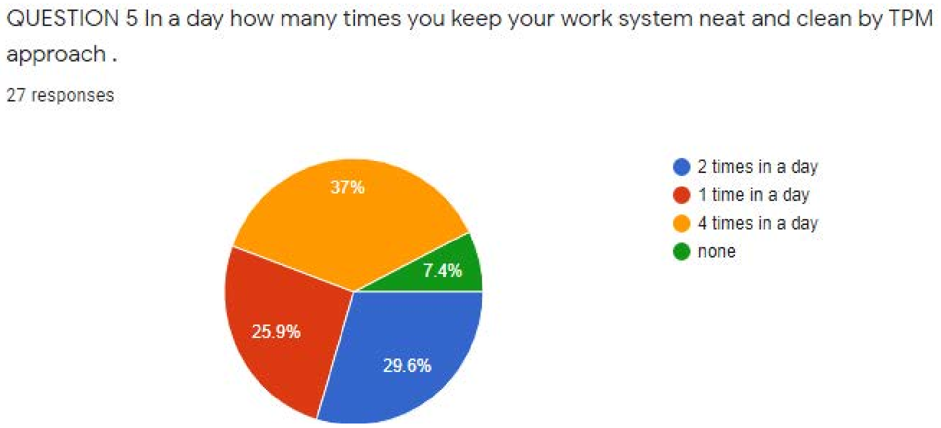

Figure 6 Respondent feedback

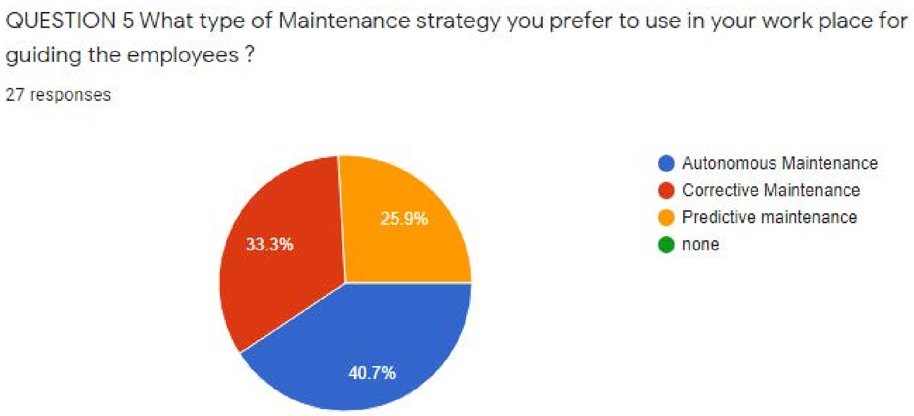

Figure 7 Respondent feedback

4 Case study

In this section attempt has been made to conduct detailed investigation on lab equipment maintenance using TPM strategy. Maintenance study was carried out in Higher Learning Technical institutions situated in south Tamil Nadu. The study conducted in the Department of Mechanical Engineering laboratories namely production technology lab, Metrology and Instrumentation lab, Material Testing and Metallurgy lab, Thermal lab and Design Engineering lab. The details of lab are shown in below figures (Figure 8 - Fugure 10):

Figure 9 Machine Shop

Production Technology lab:

Figure 8 CNC Laboratory

Metrology and Instrumentation lab:

Figure 10 Metrology Laboratory

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The specific focus of work is carried out in Production Technology lab especially Machine shop. In this study both 5S and scheduled maintenance is followed here in this study as described below:

5S in lab Equipment Maintenance:

Following are the steps followed in 5S implementation in lab setup as listed below:

1. First thing in machine shop sort out the unwanted materials away from the place that will not add any value.
2. Next thing set in order as per the sequence all basic facilities such as machineries, tools and equipment.
3. Next important job clean the machines daily in order to maintain it in better workable condition.
4. Then standardize the process to improve the setup time as well as through put time.
5. At last sustain in improving the effectiveness of work by maximizing the performance efficiency.

Following are the numerical data taken within the machine shop for 30 days as described below (Table 2).

Table 2 the numerical data taken within the machine shop

S.NO	Category	Before TPM	After TPM
1.	Total time	16 hrs	5 hrs
2.	Down time	15 days	6 days
3.	Run time	15 hrs	6 hrs
4.	Availability	60%	80%
5.	Performance Efficiency	65%	90%
6.	Quality rate	60%	84%
7.	OEE	23.4%	60.48%

According to world class standards for manufacturing OEE must be 85% but here the observed OEE value obtained after implementing TPM is said to be 60.48% (Figure 11). There is some difference significant difference between the observed value and standard value.

From the above data it is clearly observed that there is lot of misconception of TPM implementation due to the following challenges as described below:

1. Lack of technical support teams.
2. Lack of awareness about the concept of TPM from learning stage.
3. Poor implementation procedures.
4. Lack of coordination within the team members.

These are the above reasons for obtaining poor OEE score even though after implementing TPM in machine shop environment.

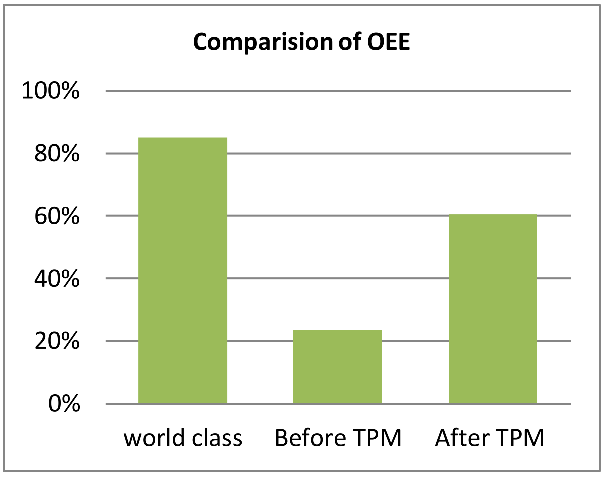

Figure 11 Comparison of OEE

From graph 1 (Figure 11), it is clearly understood that observed OEE value is far less compared to world class standards. Based on the above reasons the organization has to take some remedial measures in improving the effectiveness of TPM. Thus this case study clearly describes the challenges and various views within the machine shop environment. The main thing which is commonly noted here is lack of technical maintenance and other support facilities in addition to that top level management vision is not much clear in forming the guidelines for TPM implementation in work place. Hence strong focus is made on to improve the 5S and other maintenance systems within the work area.

5 Conclusion

TPM has become the key important business strategy for improving the enterprise planning and development in various ways starting from planning to implementation and execution level. The effective TPM implementation helps to optimize the machine performance in terms of productivity. It is highly important to understand the basic philosophy of TPM and its features in manufacturing systems. In highly competitive environment following TPM practices will lead the organization to go for high scale of production. Thus TPM Prove to be the best competitive strategy followed in manufacturing organization.

In this paper attempt has been made to review the various literatures of TPM and its future extensions followed by data collection through Google survey obtained from around 27 respondents within the same organization. In addition to that case study is also presented here to highlight the TPM challenges applied in lab setup of technical higher learning institutes.

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MINIMIZING OF RISKS IN THE WORKPLACE USING SIMULATION SOFTWARE

Matus Marticek
The Technical University of Kosice, Faculty of Manufacturing Technologies with a seat in Presov, Department of Industrial Engineering and Informatics, Bayerova 1, 080 01 Presov, Slovak Republic, EU, matus.marticek@student.tuke.sk
Lucia Knapcikova
The Technical University of Kosice, Faculty of Manufacturing Technologies with a seat in Presov, Department of Industrial Engineering and Informatics, Bayerova 1, 080 01 Presov, Slovak Republic, EU, lucia.knapcikova@tuke.sk (corresponding author)

Keywords: risk assessment, manufacturing, injection moulding, simulation software.
Abstract: The purpose of risk assessment is to provide information for decision-making. It compares the resulting risk obtained from the analysis with the risk criteria based on the legislation. If the level of risk is undesirable, the organization must take measures under the legislation to reduce or eliminate the risk. There are also cases where the risk assessment leads the company to a repeated analysis and the decision to terminate the investigation due to negligible, resulting risk. The paper focuses on using simulation as a supportive tool to minimize the risk in the workplace of injection moulding plants. It was eliminated bottlenecks and designed suitable injection moulding arrangements to ensure the safety and health of workers at work.

1 Introduction

The basic goal of the proper functioning of every company is to ensure safety and health at work in the system-man - machine – environment [1]. Despite implementing all available measures to increase safety, health protection, and awareness of compliance with the organization's safety and health policy at work, it does not rule out the occurrence of an undesirable situation that leads to accidents at work. If such an undesirable situation occurs, it is necessary to follow the applicable legislation [2]. Occupational health and safety can be defined as the state of the workplace, which gives assurance that in compliance with rules such as technological procedures, safety regulations, etc., no situation would endanger workers' health [1]. To create safe work, which is required to develop and implement a system of measures such as: legislative, economic, social, organizational, technical, medical, and educational [2].

1.1 The main concepts by risk assessment

The term danger, translated from the English word "hazard", represents a source or situation that has the potential to harm: the health of the worker, i.e., damage, injury, or occupational disease, to the work environment and property, or combinations thereof [2]. Properties or capabilities of the machine, workers, material, etc., may cause damage or a negative phenomenon. It is a source of threat. Hazard identification is the process of identifying whether a hazard exists. This process also determines what the danger may be. The identified risk is then assessed, and one of the following options is selected [3]:

- interruption of the process due to a danger that is incompatible with the damage they may cause,
- take immediate corrective action to eliminate or reduce hazards arising from the hazard;
- termination of the analysis, due to negligible hazards,
- continuing to identify the risk.

A threat is any activity that leads to a dangerous situation. It represents a danger that causes negative phenomena such as injury or damage in a specific space and time in the machine–human-environment system [3]. The stage of hazard identification is followed by the identification of the threat and at the same time its analysis. This process determines the hazards that arise from the hazards and lead to an accident, damage, or another negative phenomenon, so it is important to decide on the event and manner of the probable negative hazard in the machine-man-environment system [4]. This section is important to realize that one hazard can cause multiple threats. A risk is a situation in which a negative phenomenon occurs. At the same time, when a negative phenomenon occurs, the consequences of this phenomenon occur. It is a quantitative and qualitative expression of the degree of threat. The likelihood of an adverse event leading to injury, damage to health, or harm is assessed. It involves identifying, recognizing, and assessing existing, potential, and emerging risks that are likely to lead to a negative phenomenon [1,4].

The risk identification process must consider the risks, regardless of whether the given source of risk is under the control of the organization, but also if the individual sources of risks and their causes are not obvious [3]. It

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must include an assessment of the effects and consequences. It is important to consider the wide range of consequences, even if the individual sources of risks and their causes are obvious. It is also necessary to consider what may happen while considering possible adverse causes and circumstances that point to the consequences they could have [4,5]. All-important causes and consequences should be taken into account. Risk analysis is an important step in determining whether risks need to be addressed in a given system and what method to use to determine risk [1,2]. It provides information on individual sources of risk and the positive or negative consequences and probabilities that may occur. Its task is to identify the factors that affect the consequences and their likelihood [5]. A combination of consequences and probabilities most often expresses the risk. In terms of the purpose of the analysis, available resources, information, and data, the analysis can be qualitative, semi-quantitative, or quantitative [6]. The main essence of risk assessment is determining the degree of risk of the analysed risks in the machine-human-environment system [5]. The risk assessment includes an analysis of the occurrence period, hazard identification, analysis of the probability and consequences of existing adverse events [6]. The paper aims to identify the risk in the workplace of injection moulding machines using a pre-simulated process.

2 Methodology

The point method was chosen as a linear function to identify the risks at the injection moulding workplace. The chosen method is also based on the insufficient elaboration of the analysis by safety technicians and the development of a written document on risk assessment at the workplace.

2.1 Work activities of employees at the workplace of injection moulding machines

The workers at this plant are divided into two groups: a sorter and a press [7].

The main activities of the sorter are [1,3]:

- Setting up machines.
- Starting machines.
- Visual inspection of machines.
- Production process control.
- Inserting and selecting a mould from the machine.
- Relocation of moulds and materials.
- High lift truck control.

The insertion and selection of the mould from the machine are performed using a gantry crane on presses 820 S and 920 S and a forklift on other injection moulding machines. The replacement is performed by a sorter, which must perform when selecting a mould [3]:

- Ensure the connection of the moving and immovable part of the mould.
- Attach a locking panel with a holder for the permanent link of the mould.
- Disconnect the regulator used for heating and cooling the mould.
- Securing the mould against falling by crane or forklift.
- Disconnect the ejector.
- Mould release - release of clamps.
- Mould selection from the injection moulding machine.

The main activities of the press worker are [1,5]:

- Removal of mouldings.
- Visual inspection of mouldings.
- Packing and storage.
- Filling of dryers.
- Filling the tanks with granules.
- Auxiliary training for the sorter.
- Ensuring cleanliness and order in the workplace.

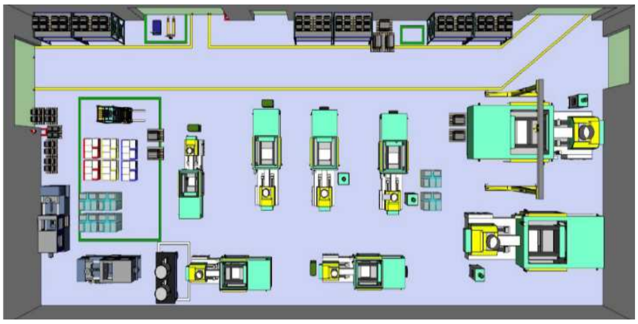

Figure 1 Current state at the injection moulding plant

At certain intervals, the press selects a container into which the finished mouldings from the injection moulding machine fall and then inserts an empty container to catch other mouldings [3]. This activity is followed by a visual inspection of the finished mouldings. It is important to check the correctness of the finished moulding in detail.

2.2 Simulation software solution

Simulation is an experimental method in which we replace an entire system with a computer model [4]. It is possible to perform several experiments on such a model, to evaluate them. Optimize and apply the results to a whole system. No other method or theory allows you to experiment with a complex system before it is put into operation [5]. No different algorithm would enable you to "play" in a few minutes of complex computer processes that last weeks or months. It is a perfect decision support tool for various levels in the enterprise [4]. The reason for using the simulation is that analytical methods (collective service theory, service networks, linear programming, etc.) have limited use in solving practical problems [1,4]. New requirements emerge for flexibility throughout the corporate organizational structure, new decentralized, modular organizational units, and new work organizations (teamwork, simultaneous engineering). One of the other reasons for using the simulation is the humanization of

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workplaces [7]. The environment in production and assembly workplaces is often unsatisfactory many times beyond the tolerance of the law (working overhead, in cramped conditions, huge time stress, in unnecessary noise, and at high temperatures).

2.1.1 Tecnomatix Plant Simulation

Tecnomatix is a product line from Siemens PLM Software that includes several software tools for different production areas that can be interconnected [4,7]. The tools in the Tecnomatix series enable industrial companies to use the concept of digital enterprise in practice, i.e. plan and design production, design, verify and optimize processes and production resources in a digital environment. Accurate digital modelling, simulation, and 3D spatial visualization allow professionals working together to develop, visualize and analyse future production processes. Such an evaluation will allow key design decisions to be implemented and approved on time and on a broader understanding [4]. This will reduce errors that would otherwise occur at the start of production. Digitization allows processes to be prepared faster and more accurately, while simulation and optimization in the development phase ensure that a significant product is produced the first time, without the need for additional costly and time-consuming changes in a real factory [8]. Plant Simulation is a module for dynamic simulation-creation of a structured hierarchical model of production plants, lines, processes, transport, etc. [9]. Thanks to the dynamic design review, we can identify bottlenecks, define the workload of individual workplaces/operators, determine the system's throughput, etc.

3 Results and discussion

The riskiest situations in injection moulding machines are the fall of a load and slipping - the fall of a person [10]. They penetrate especially when using a forklift and filling dryers and injection moulding tanks. These situations can seriously harm the health of workers. Figure 2 shows a critical point in the placement of the presses.

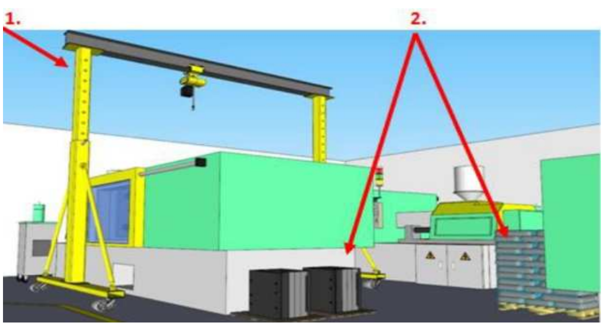

Figure 2 Demonstration of critical places in the area of injection moulding machines

Legend to Figure 2: 1. Gantry crane 2. Moulds and granules outside storage areas.

To reduce the risk of load falling, a proposal was made for the application of a bridge crane (Figure 3). With the help of this crane, all activities related to the transfer of loads can be performed, i.e., the forklift and the current gantry crane will be taken out of service.

Figure 3 Relocation of injection moulding machines at the workplace

Removing unused equipment creates space for further storage of moulds and materials (Figure 4).

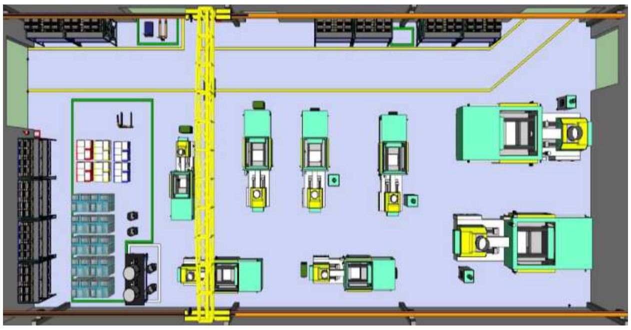

Figure 4 A view of the operation of injection moulding machines with proposed solutions

Using simulation in operation, where the simulated model of the injection moulding machine is simulated, it essentially represents a certain simplification of reality [11]. Therefore, the created model mustn't be simplified, distorted, or even completely abstracted from the system properties we want to examine using computer simulation (Figure 5).

Figure 5 View of the proposed bridge crane

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4 Conclusions

The simulation model serves as a template for designing and developing the actual state and results in faster and error-free commissioning. The connection of the central control computer with the simulation model will enable its commissioning before the device is deployed [12]. Behaviour during the start-up can be played out according to different scenarios. This is important when you are putting in during normal operation, and a smooth transition to the new equipment is required. With the help of the model, the company's service personnel can be trained for the new system and specifically prepared for specific equipment conditions.

The preliminary test of the daily deployment plan of the facility will draw attention to the needs of the readiness of personnel and operating resources due to the utilization of the facility. The paper aimed to use simulation software to increase the risk assessment in injection moulding machines, where, based on simulated conditions, the daily plan can be adjusted and re-tested in time if necessary. After testing the model, experiments were performed in which various options for system improvement are sought, and their impact on the modelled system is verified.

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INFLUENCE OF BALL TO POWDER RATIO AT MECHANICAL MILLING ON THE COERCIVITY OF SOFT MAGNETIC COMPOSITES

Tetiana Rudeichuk
Technical University of Kosice, Faculty of Manufacturing Technologies with the seat in Presov, Institute of Manufacturing Management, Bayerova 1, 08001, Presov, Slovak Republic, EU, tetiana.rudeichuk@tuke.sk (corresponding author)
Robert Maciazsek
Pavol Jozef Safarik University in Kosice, Faculty of Science, Institute of Physics, Department of Condensed Matter Physics, Park Angelinum 9, Kosice, Slovak Republic, EU, robert.maciazsek@student.upjs.sk
Frantisek Onderko
Pavol Jozef Safarik University in Kosice, Faculty of Science, Institute of Physics, Department of Condensed Matter Physics, Park Angelinum 9, Kosice, Slovak Republic, EU, frantisek.onderko@upjs.sk
Martin Tkac
Pavol Jozef Safarik University in Kosice, Faculty of Science, Institute of Physics, Department of Condensed Matter Physics, Park Angelinum 9, Kosice, Slovak Republic, EU, martin.tkac@student.upjs.sk
Denisa Oleksakova
Technical University of Kosice, Faculty of Manufacturing Technologies with the seat in Presov, Institute of Manufacturing Management, Bayerova 1, 08001, Presov, Slovak Republic, EU, denisa.oleksakova@tuke.sk

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Abstract: Soft magnetic composites (SMCs) represent specific and useful class of materials with expanding application range. They are intensively studied to reveal its large potential for their properties improvement. These soft magnetic compacted powdered materials are used in a variety of electromagnetic applications such as computer, relay, disk drive, printer, hearing aid devices and others. The aim of this work was determination the coercivity of iron based SMCs prepared from iron particles, which were milled with different intensity.

1 Introduction

Magnetic materials are very famous and important for engineering and technical practice. These materials have revolutionized in materials research, physics, electronics and electrical engineering. Magnetic materials and their products are used in the construction of magnetic circuits, in generators, transformers, electric motors, cores of the coils, sensors and also as storage media in IT technology. Some of magnetic materials are known for many years and some of them have only been discovered in recent decades. It can be expected that the advancing development of newly discovered magnetic materials will bring their using in areas where they have not been used before.

Physicists and engineers also take advantage of electromagnetism in the production of magnetic materials, as everything around us, from elementary particles to galaxy clusters, has more or less different electromagnetic properties.

2 Soft magnetic materials

Today, magnetic materials occupy important economic position. These materials can be distributed by various physical and magnetic properties. We know that according to the arrangement of the basic magnetic moments of the atoms of which the material is composed, we distinguish between diamagnetic, paramagnetic and ferromagnetic materials [1]. Ferromagnetic substances are usually metals or alloys based on 3-d transition elements Fe, Co, Ni and according to basic magnetic properties, for example coercivity, can be divided into soft magnetic materials and hard magnetic materials [2].

Hard magnetic materials mostly known as permanent magnets are characterized by a wider hysteresis loop and a high value of the energy product, which indicates how much energy the permanent magnet creates in its surroundings. These materials are difficult to magnetize and demagnetize, they have high values of coercivity. They include for example neodymium magnets, hexagonal ferrites, rare earth magnets (Samarium Co5) and others. They are mostly using for digital storing of information in computer industry, telecommunications, magnetic filters, but also as in measurement and control technologies [2-3].

Soft magnetic materials are characterized by a narrower hysteresis loop, high permeability value and low coercivity, they are easily magnetized and demagnetized. These include Fe, Ni, Co alloys, various amorphous and polycrystalline alloys and are used for example in the cores of coils. For soft magnetic materials the most important is to have low value of coercivity as possible to prevent energy losses and high permeability. Because of their ability to be easily to magnetize and demagnetize they are

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actively using in progressive brunches of technologies, starting from transformers [2] and finishing with cosmology and medicine depending on type of materials [4-6].

3 Soft magnetic composite materials

The fact that metal ferromagnets generate eddy currents perpendicular to the direction of magnetic induction when they are re-magnetized in alternating magnetic fields is well known. If the magnetic induction flux flowed in the entire cross section of the homogeneous ferromagnet, the reduction of the magnetic field by the eddy currents and thus the reduction of the magnetic induction flux would be considerable. This undesirable phenomenon is partially eliminated by filling the cross-section of the original ferromagnet with thin sheets coated with an electro-insulating coating, so that the eddy currents flow only in a smaller thickness of the ferromagnet and thus reduce the magnetic flux much less than in the previous case. A further reduction is possible if a large number of small mutually insulated particles are deposited in the cross section, in which a further reduction in the effect of eddy currents has occurred. We can say that the concept of further reduction of eddy current over magnetization losses is successfully fulfilled by soft magnetic composite materials (SMCs) [2,4-6].

SMCs are generally compacted ferromagnetic powder particles which are coated with a thin layer of inorganic insulation, because of its better temperature resistance. Those powder particles are randomly arranged with each other what forming a heterogeneous structure. SMC have lot of advantages over other soft magnetic materials. For example, SMCs combining better microstructure-operational conditions (such as isotropic 3D behaviour and mechanical stability, higher permeability and saturation induction constant for a wide range of frequencies and lower coercivity which minimizes energy loss) than the main commercial soft magnetic materials, which is the electrical steel (1.878 billion tons produced in 2020 in the world [7]). Besides, SMCs have a high potential in use also because of low-cost production and environmentally friendly recycling [8]. Therefore, developing of new technologies, especially in the electrical industry and powder metallurgy, has brought new possibilities for the use of the SMCs materials. So, today, we can see them to be used as transformer cores [5], but they can also be used in motors [9-13], inductors [14-15] or generators [16-19].

4 Preparation of samples

SMCs could be possibly made from different soft magnetic materials with adding nonmagnetic inorganic or organic layer constituents for insulation. As ferromagnetic powder particles could be used pure iron or its alloys (Permalloy, Supermalloy, Fe-Ni-P, Fe-Si, Fe-Co, Fe-Co-V, Fe-Si-B-Nb-Cu etc.) [20].

We have prepared three types of compacted (ring form) samples of iron SMCs (S1, S2, S3). We have used Alfa Aesar high-purity iron granules (99.98%, granule size 1-2 mm), which were milled for making ferromagnetic powdered composites from needed fraction particles.

Over the past several years the method of mechanical milling was widely spread in order to exploit it to produce a variety of equilibrium and non-equilibrium alloy phases and posses further possibility for research work and application of permalloy. The advantage of this process technology is that the powder can be produced in large quantities and the processing parameters can be easily controlled [21]. Various types of mills are used to prepare powders by mechanical milling. The mill usually consists of a milling vessel into which one or more balls are placed together with the powder. The milling vessel and balls are made of sufficiently hard materials (for example steel, agate, tungsten carbide). We know several types of mills, which differ from each other in their capacity, milling efficiency, the construction of the mill or in the principle of operation.

Mechanical milling is a process that requires the optimization of several parameters, such as type of mill, milling speed, time of milling, type and size of milling medium, ball to powder ratio (BPR), atmosphere and temperature of milling. These parameters are not completely independent of each other and their use results from the nature of the grinding process. The weight of the milling balls to the weight of the powder (BPR - Ball to Powder Ratio) has a significant effect on energy, performance and milling time. The higher this ratio, the shorter the milling time required to achieve the desired state. The mechanical milling could be possibly made in different types of mills (planetary ball mills, vibratory mills, mixer mills, rotor mills, knife mills, etc.), but for our experiments we choose planetary ball mill PM100 from Retsch (Figure 1), because of its powerful and quick milling with speed control, which makes possible to make a reproducible result for each sample.

Figure 1 Planetary ball mill Retsch PM100 (in Institute of Physics, Faculty of Science, P. J. Šafárik University in Košice)

We have prepared three types of samples of SMCs of pure iron with different BPR (Table 1).

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Table 1 The conditions of mechanical milling for powdered SMCs of Fe

The name of sample	The time of milling (min.)	The rate of milling (rpm – rate per minute)	BPR
S1	120	500	3:1
S2	120	500	6:1
S3	120	500	9:1

After the preparation of powdered samples (Figure 2, a) by mechanical milling in planetary ball mill (Figure 1) we used a vibrating mill (Figure 2, b) to sieve a powder fraction and to select powder with fraction smaller than 400 µm. So we prepared powder samples with required mechanical properties (Figure 2, c).

Figure 2 a) powder after mechanical milling at millng vessel, b) vibrating mill FRITSCH with sieves , c) powder after sieving (in Institute of Physics, Faculty of Science, P. J. Šafárik University in Košice)

Next step in preparation of those samples was preparing a layer of insulation on the powder surface to prevent energy losses by minimising the eddy currents. Exist different type of insulation which could be organic, inorganic or organic-inorganic coatings and the process of coating can be made by one of the following methods "wet" or "dry".

The dry method based on the principle of attaching smaller pieces of lubricant on ferromagnetic powder, which make it eco-friendlier method, but with less homogeny isolation of powder particles. In case of wet method arise more consistence isolation layer, because the liquid phase is used as substance for disperse organic or inorganic chemical.

We decided to choose Stöber method for insulation iron powder. The liquid phase was made from isopropyl alcohol (320 ml), distilled water (64 ml), tetraethyl orthosilicate (TEOS, 98 %, 32 ml) and ammonia (8 ml) for coating of 10 g of iron powder. The stirring was continued for 16 hours divided for two sessions by 8 hours each using a MICROSTAR 7.5 control propeller mixer from IKA (Figure 3).

One of the methods how to prepare material in bulk is to compact the powder. Powder material prepared by mechanical milling is subsequently compacted by uniaxial or multiaxial pressure hot or cold. After pouring the powder of a given weight into the compression die and closing the compression chamber, the evacuation is started by means of a rotary and turbomolecular pump. When the desired vacuum is reached, induction heating of the powder to the desired temperature begins. At this temperature (pressing temperature) the required uniaxial or multiaxial pressure (in MPa) is applied. After the set application time of the compaction, the compacting is completed and the bulk samples have the same diameter as the die in which they were compacted.

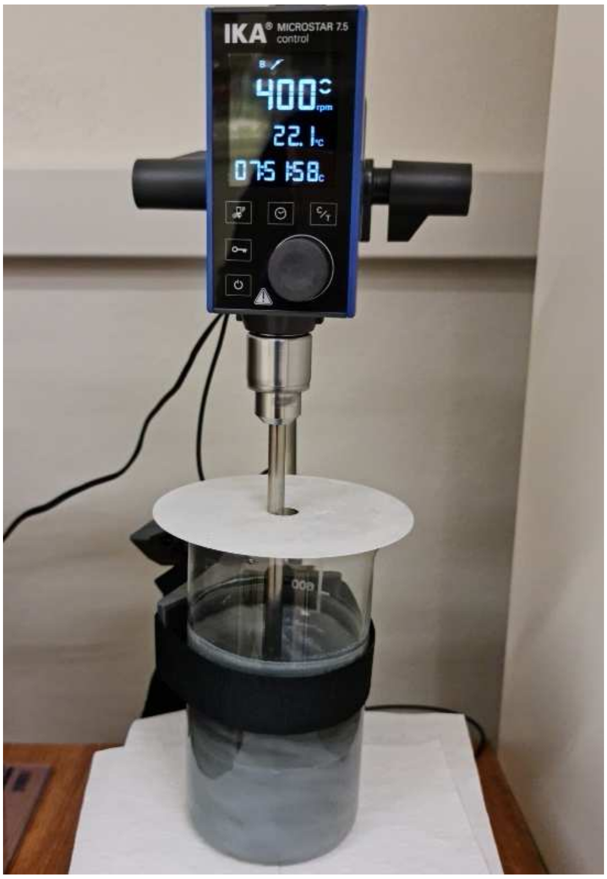

Figure 3 MICROSTAR 7.5 control propeller mixer from IKA (in Institute of Physics, Faculty of Science, P. J. Šafárik University in Košice)

After powder insulation, our samples were ready to compact into a ring shape of soft magnetic composite materials. For the compaction was used the LTVAT ZT-

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25-20Y (Figure 4) pressing apparatus, which allows the compaction at temperatures up to 1000 °C.

Figure 4 LTVAT ZT-25-20Y machine for the compaction (in Institute of Physics, Faculty of Science, P. J. Šafárik University in Košice)

In our case, samples were compacted for 3 minutes at 400 °C up to 700 MPa. Thus prepared powder (Figure 2 a) and compacted SMCs iron samples (Figure 5) were used for the determination of the coercivity.

Figure 5 Compacted ring-shaped SMCs iron samples

5 Experimental part

The ring-shaped samples (S1 – S3) of SMCs Fe/SiO2, with outer diameter 24 mm and inner diameter 18 mm, were produced for analysis of influence 16 h insulation process and BPR for high-purity iron SMCs on its coercivity.

The most technical applications of magnetic materials based on revealing spontaneous magnetization. It could by possible because of magnetic hysteresis (showing changes in magnetization and energy losses in one premagnetization cycle) for which, one of the most important physical value is coercivity. In fact, it is one of the most relevant magnetic property for ferromagnetic materials in general and of SMCs materials specifically. Both hysteresis loop and coercivity are highly related to structural defects (interstitials, vacancies, dislocations, surface defects etc.), because they are the main source of the pinning centres that prevent the movement of domain walls.

In our case, we measured coercivity field strength value for our samples by using Foerster KOERZIMAT 1.097 HCJ (Figure 6) at the room temperature. We choose that measuring system because it can be applied to material in deferent shape and also to both hard and soft magnetic materials.

Results of coercivity evolution of Fe/SiO2 powders and compacted samples with increasing BPR from 3 to 9 are shown in Figure 7 and Table 2. These graph represent correlation between intensity of iron granules milling (BPR) and the compaction at high pressure to ring-shaped samples with coercivity value. This mean that after pressing we could not just have made a constant shape of SMCs material, but also removed some of inner structural defects.

Figure 6 Foerster KOERZIMAT 1.097 HCJ (in Institute of Physics, Faculty of Science, P. J. Šafárik University in Košice)

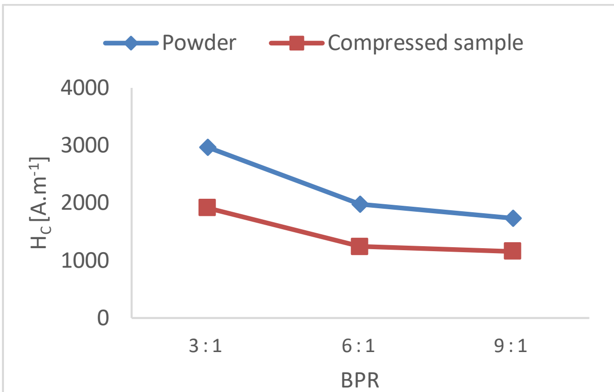

Figure 7 The values of the coercivity of powder and compacted SMCs of Fe

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Table 2 The values of the coercivity of powder and compacted SMCs of Fe

Sample	Coercivity, H_c [A.m^{-1}]		BPR	Mass of the compressed sample, [g]
	Powder	Compacted Sample		
S1	2968	1911	3:1	3,694
S2	1979	1236	6:1	3,704
S3	1730	1156	9:1	3,794

6 Conclusions

The three compacted SMCs of Fe were prepared with the different condition of mechanical milling. Mechanical milling and subsequently of the compaction of milled powder are an alternative ways of the preparing solid materials of various shapes and sizes. In order to achieve the required physical and magnetic properties, it is necessary to study magnetization processes, select the appropriate chemical composition of the material, determine the correct procedure for preparing powder materials suitable for compaction, select the appropriate type of alloy as a milling precursor (for example BPR), know the morphology of particles and compaction properties.

The value of the coercivity decreases with the increasing of ball to powder ratio. The monotonous decrease of the coercivity with BPR for compacts can be explained as follows: the higher BPR leads to the smaller mean size of the powder particles, that are less deformed at compaction, what leads to the lower probability for creation structural defects for domain wall displacement.

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