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IMPROVEMENT OF THE PRODUCTION PROCESS WITH THE USE OF SELECTED KPIS

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Abstract: Faced with ever-increasing customer demands and global competition, companies are forced to look for production reserves, increase efficiency and productivity. Hence, the need to monitor the use of the machine park has arisen, making it possible to identify waste and production reserves in the implemented technological processes. The aim of the article is to evaluate the effectiveness of the production line of internal frame doors and to analyze the correctness of the use of selected key indicators of the production process effectiveness. This article proposes a response to the problems formulated in manufacturing companies, including practical aspects of the use of specific measures to assess the effectiveness of the use of technical infrastructure. The solutions presented in the article can be used in practice for improvements in production units.
Keywords: OEE, KPI, production line, improvement

1. INTRODUCTION

Currently, in manufacturing companies we can observe an increasing level of use of advanced machinery and equipment. This is related to the competitive struggle, the need to maintain the existing customers and acquire new ones. Failure-free, smooth operation results in efficient production and improved financial results. Downtimes, breakdowns, uneven work causes stress, losses and the need to take action, which often generate additional costs. The application of modern infrastructure also forces a shorter and shorter product life cycle, shorter response times to changes and reduction of unit prices (Berlińska, 2013; Pacana et al.,2014; Ostrapko, 2018).
In times of intense competition, both the price and the quality of the product is an important issue for customers. The price of offered products may be lowered without reducing the quality of products due to appropriate use of equipment used in the production technological process (Panaca, et al. 2015; Gola and Świć, 2012; Świć and Gola, 2010). Optimization of the continuous operation time of devices and their functionality

is an important issue related to increasing the company's productivity and level of competitiveness in every industrial sector (Malindzak et al., 2017; Walczak, 2015). In many companies, a large part of the machinery could certainly function more efficiently. Research shows that most machines produce less than half of what they could produce, while the total use of resources is in the range of 30-50% (Mikler, 2005). The issue of efficiency in the use of machinery and equipment becomes more important when it is treated as one of the variables that make up a company's success. On the other hand, the key way to increase the level of effectiveness within the maintenance of technical resources of the company is to introduce the *Total Productive Maintenance* (TPM) concept into the organization (Rychter, 2005; Furman, 2014; McKone and Weiss, 1998). TPM is a system that allows companies to use their machines and equipment in the most efficient way. With TPM it is possible to gradually minimize the risk of unplanned disruptions of industrial processes (Mielczarek and Krynke, 2018; Wielgoszewski, 2007; Pacana, 2018; Ahuja and Khamba, 2008).

The main task of the TPM concept is to systematically strive to maximize the availability, quality and efficiency of the machines and equipment used. The TPM *Overall Equipment Effectiveness* (OEE) basic indicator is adapted to the analysis of the identified elements. This indicator allows to monitor and improve the efficiency of the production process in terms of losses in the operation of the machine park (Brzeziński and Klimecka-Tatar, 2016; Oechsner et al., 2003; Muchiri and Pintelon, 2008; Elevli and Eleveli, 2010). In industrial practice, however, many different performance indicators are used, including for example KPIs (*Key Performance Indicators*). Their values refer to specific technical objects in operation and to the activity of maintenance organizations (Loska, 2013; Wolniak, 2017; Ulewicz, 2003).

Companies are forced to constantly search for production reserves, increase production efficiency and productivity and reduce production costs. Therefore, it is necessary to constantly monitor the level of efficiency of the use of machinery, enabling identification of waste and production reserves in the implemented technological processes. As a result, the aim of the article was to assess the effectiveness of the production line of internal frame doors and analyze the correctness of use of selected key performance indicators of the production process, as well as to demonstrate the possibility of implementation of the presented indicators in manufacturing companies with a similar specificity of the products.

2. PURPOSE AND SUBJECT OF THE RESEARCH

The aim is to evaluate the effectiveness of the production line of interior frame doors and to analyze and evaluate the correctness of the use of selected key performance indicators of the production process.

The subject of the research were internal frame doors. The product is characterized by a very solid construction, because both frames and crossbars are made of solid MDF material. In the production of this type of door, a new stile frame technology is used, which is based on avoiding places where the veneer joints can be seen. Increased weight of the wing, lack of visible veneer joints, strong construction, the use of double-blade hinges or solidity of workmanship are factors that significantly affect the aesthetics and quality of the product.

3. TECHNOLOGY USED IN THE PRODUCTION OF THE PRODUCT

The stile technology is characterized by covering the flat surface and door rim with

CPL laminate with a thickness of 0.2 mm, with a significant level of resistance to scratches and abrasion. This laminate has many important technical advantages. It is characterized by: high resistance to abrasion, impact, scratches, high temperatures and UV radiation. The use of this type of material enables the use of doors in the so-called "difficult" rooms - exposed to higher temperatures, humidity or above-average exploitation. Table 1 presents a shortened technological process - technological operas in which there is a change of shapes, physicochemical properties, external appearance of the processed material or a permanent change in the mutual position of individual parts of the product.

Table 1
Brief description of the technological process

No	**Name of the operation**	**Device/station**	**Operation**
10	Cutting slabs	Rover C6/ Panel saw	cutting of MDF boards
20	Fabrication of components	Assembly stand	processing of vertical and horizontal frames
30	Veneering	Edgebander Stefani	double-sided gluing of MDF board
40	Veneering	Edgebander Stemas	frame wrapping
50	Fitting	Assembly stand	door leaf hardware
60	Drilling	Drill Askla	drilling holes for locks, pins and hinges
70	Pivoting	Askel's tenoning machine	journals for vertical and horizontal frames
80	Assembly	Assembly stand	fittings installation
90	Application of the film	Stefani veneer maker/ Stemas	application of touchwood foil on vertical shoulder straps
100	Shortening	Askel's saw	shortening of vertical and horizontal frames
110	Ironing	Diaphragm press	final pressure of the door leaf
120	Control	Test stand / assembly stand	in-process control; acceptance inspection; final inspection

Source: own study

The stile technology is a solid alternative to the plate technology. In contrast to classic constructional solutions, it offers a much more durable door construction. The technology guarantees an exceptionally strong construction, because the door elements are made of full MDF material (straps and crossbars).
The company uses the integrated IT system Comarch ERP XL, which, thanks to the possibility of planning and scheduling production, enables efficient production management. Fig. 1 shows the stock of raw materials for the production of one finished product - internal frame doors.

Lp.	Towar	Ilość	Jm.	Cena netto	Wartości Netto	Wartości Brutto	Rabat	Nazwa
00001	S31_L10Z3_PLYTA	3.2400	m2	1.70	5.51	6.78	0.00%	Płyta
00002	S32_L10Z3_OKLEINA	5.6200	mb	0.90	5.06	6.22	0.00%	Okleina
00003	S33_L10Z3_PLYTA_WIOR_	1.6200	m2	2.44	3.95	4.86	0.00%	Płyta wiórowa otworowa
00004	S34_L10Z3_RAMIAK_PION	2	szt.	3.74	7.48	9.20	0.00%	Ramiak pionowy
00005	S35_L10Z3_RAMIAK_POZ	2	szt.	2.80	5.60	6.89	0.00%	Ramiak poziomy
00006	S36_L10Z3_OKLEINA_CPL_	3.4100	m2	1.80	6.14	7.55	0.00%	Okleina CPL kolor jesion
00007	S37_L10Z3_ZAMEK_DRZ	1	szt.	3.35	3.35	4.12	0.00%	Zamek drzwiowy
00008	S38_L10Z3_ZAWIAS	2	szt.	1.38	2.76	3.39	0.00%	Zawias metalowy
00009	S39_L10Z3_USZCZELKA	5.6200	mb	0.41	2.30	2.83	0.00%	Uszczelka
00010	S310_L10Z3_LOGO_FIRMY	1	szt.	0.40	0.40	0.49	0.00%	Logo firmy
00011	S311_L10Z3_OPAKOWANIE	1	szt.	0.80	0.80	0.98	0.00%	Opakowanie kartonowe

Fig. 1. Warehouse stock for one product - Comarch ERP XL

4. METHODOLOGY

The effectiveness of the process of technical infrastructure management in an enterprise depends to a large extent on the type and amount of information collected about machines. If we are not aware of the problems and where they occur, we are unable to prevent or eliminate them. The collection of useful information on the basis of which the right decisions are taken at the right time, as well as the provision of targeted action and appropriate responses, constitute a constant challenge for the information system in enterprises. The performance, quality and availability index, which are components of the OEE, is used to assess the company's performance. The calculation sheet (Table 2) presents the analysis of data necessary to calculate the indicators used in the company for the first machine involved in the production process - Rover C6. To calculate specific indicators, data from 2019 were used.

Table 2
Calculation sheet for OEE, W1, W2 indicators for 1 change of analysis - Rover C6 machine

Calculation sheet		
Indicators and their variables	**Method of calculating the indicator**	**Measure**
Availability (A)		
a. Shift working time fund		480 minute
b. Planned downtime of the machine		33 minute
c. Working hours	a - b	447 minute
d. Unplanned machine downtime		21 minute
e. Net life span	c - d	426 minute
f. Availability rate	e / c x 100	95.3%
Performance (P)		
g. Number of products manufactured		140 entity
h. Design time per unit processing of the product		3 minute/ entity
i. Utilisation rate	[h x g] / e x 100	98.6%
Quality (Q)		
j. Number of deficiencies		10
k. Quality ratio	[(g - j) / g] x 100	92.9%
OEE		
l. Overall equipment effectiveness	f x I x k x 100	87.3%
W1		
m. Scheduled production quantity		140 entity
n. Number of non-compliance (deficiencies + difference between production plan and implementation)		0
o. Production quality indicator	[(m - n) / m] x 100	92.7%
W2		
p. Quantitative indicator of production	g / m x 100	-

Source: own study

In addition to OEE, other KPIs are also used in the enterprise to monitor production, such as the production quality indicator (in the study marked -W1). This indicator is used to measure the stability of a production plan over a given period of time. In order to measure the ratio shown, the number of non-compliant intermediate products of the product shall be counted. The W1 value is the difference between the planned number of semi-finished products realized by a particular machine/machine and the number of semi-finished products delivered to the next workstation and finally from the production line to the warehouse. Due to the "just in time" production conducted in the company,

any discrepancy between the number of finished semi-finished products and the plan is accepted as an error (excess or insufficient number of semi-finished products in relation to the implementation plan).

The company also uses an indicator to monitor production, which measures the quantitative deviations in the manufacturing process (in a study marked as W2). Within W2, the quantity of semi-finished products produced is considered in relation to the planned production quantity (determined on the basis of maximum capacity, taking into account the availability of resources, constraints, bottlenecks and sales data).

5. ANALYSIS OF KEY PERFORMANCE INDICATORS

W2 is a quantitative meter which does not take into account the type of semi-finished product but refers only to the quantity. Therefore, the W2 indicator cannot be used to account for groups of intermediate products (therefore, in the relevant fields in Table 3 the sign "x" has been placed in the relevant fields, meaning that it is not possible to calculate). This indicator should be used for analyzing lines, production cells or companies in general. The relations between the W1 and W2 indices in relation to the stations involved in the production of interior frame doors during 1 and 2 shifts are presented in Table 3.

Table 3
Calculation sheet of the W1 and W2 index for 1 and 2 shifts for production benches

	Rover C6	Assembly stand	Edgebander Stefani	Edgebander Stemas	Assembly stand	Drill Askla	Askel's tenoning	Assembly stand	Stemas veneer	Askla saw	Diaphragm press	Total
Change I												
Planned number of products	140	112	140	112	168	448	224	168	56	112	28	28
Quantity produced	140	98	130	97	143	372	186	140	41	91	20	19
Difference in production	0	-14	-10	-15	-25	-76	-38	-28	-15	-22	-8	x
Number of erroneous products	10	15	22	17	28	76	42	29	15	30	9	x
W1 (%)	93	87	84	85	83	83	81	83	73	73	68	x
W2 (%)	x	x	x	x	x	x	x	x	x	x	x	68
Change II												
Planned number of products	140	112	140	112	168	448	224	168	56	112	28	28
Quantity produced	140	108	135	105	144	376	188	139	46	92	22	21
Difference in production	0	-4	-5	-7	-24	-72	-36	-29	-10	-20	-6	x
Number of erroneous products	5	7	9	16	28	72	38	31	10	21	7	x
W1 (%)	96	94	94	86	83	84	83	82	82	81	75	x
W2 (%)	x	x	x	x	x	x	x	x	x	x	x	75

Source: own study

W1 indicator shows the level of implementation of the production plan during two production shifts of internal stile doors. Due to the specification of the tested product (the need to carry out subsequent production operations on the semi-production produced during the implementation of the first and second technological operation), failure to implement the implementation plan in one operation entails consequences in the form of inability to implement the plan in the next operation. The implementation of the production plan during the I shift decreased from 93% to 68%. The constant value (73%)

occurred during the operation carried out on the Semas edge banding machine (application of touchwood foil on vertical frames) and Askla saw (shortening of vertical and horizontal frames). The percentage of implementation of the plan has gradually decreased over the course of amendment II, to 75%. In the research on the effectiveness of the production line of internal frame doors, the following indicators were compared: the values of partial indicators and the OEE result indicator, as well as the W1 and W2 indicators. This overview is presented in Table 4 for the individual machines in 2 shifts.

Table 4
Values of OEE indices of individual machines for I and II changes

	Change I						**Change II**					
	A	P	Q	OEE	W1	W2	A	P	Q	OEE	W1	W2
Rover C6/ Panel saw	95	99	93	87	93	Total – 67.9	97	97	96	91	96	Total – 75.0
Assembly stand	99.8	83.6	99.0	82.6	86.6		97.9	93.9	97.2	89.4	93.8	
Edgebander Stefani	92.5	83.3	90.8	67.0	84.3		95.7	86.5	97.0	80.4	93.6	
Edgebander Stemas	89.3	95.1	97.9	83.2	84.8		95.7	96.1	89.5	82.4	85.7	
Assembly stand	93.6	65.8	97.9	60.2	83.3		93.6	66.2	97.2	60.2	83.3	
Drill Askla	98.9	83.6	100	82.7	83.0		98.9	84.5	100	83.6	83.9	
Askel's tenoning machine	98.3	81.4	97.9	78.3	81.3		98.3	82.3	98.9	80.0	83.0	
Assembly stand	89.1	68.3	99.3	60.4	82.7		89.1	67.8	98.6	59.6	81.6	
Stefani veneer maker/ Stemas	92.7	54.0	100	50.0	73.2		92.7	60.5	100	56.1	82.1	
Askel's saw	99.4	77.9	91.2	70.6	73.2		99.4	78.8	98.9	77.5	81.3	
Diaphragm press	91.1	48.8	95.0	42.2	67.9		91.1	53.7	95.5	46.7	75.0	
Average	94.5	76.4	96.5	69.8	-		91.1	78.8	97.2	73.3	-	

Source: own study

The W1 indicator complements the information provided by the OEE indicator. They analyze the value of the individual components of the OEE index for I and II, changes from Table 4 can be observed in the area of machine availability values showing practically over 90% of the value, which indicates a low incidence of unplanned machine downtime on the production line. The values of the next component - Quality (Q) - indicate a low level of production of non-compliant products, constituting an average value of 2.8-3.5% of production. Such a high value was achieved due to the fact that this indicator measures the number of non-compliant products, not including planned but not realized products. Performance Ratio (P) is a coefficient that compares the current pace of work to a standard (or maximum) pace. Performance = 100% means that the process has been completed at the required pace. The level of production during I and II shifts indicates that the machinery on the production line was not fully utilized. In fact, the OEE values for all machines on the production line are at a satisfactory level, but there are large discrepancies in the implementation of individual semi-finished products. They concern the implementation of a much smaller number of semi-finished products than planned. Finally, in the course of both changes, approximately 70% of the production plan was implemented. Therefore, high OEE values may result from a much smaller number of semi-finished products required for the execution of individual operations than planned, and therefore, e. g. longer time available for the preparation of a workstation or less haste in the processing of the semi-finished product.
It is clear from this example that not only the value achieved by the OEE indicator can be suggested, but also the interpretation needs to be complemented by data from W1. It can therefore be concluded that the W1 indicator is complementary to the OEE indicator and that the compilation of these indicators provides complete information on the effectiveness of the production process analyzed in aggregate and for individual machines.

6. DISCUSSION AND CONCLUSION

Properly selected indicators are a key element in the proper use of controlling in the organization. The indicators used in the production process require their inclusion in the structure and management system of the company. Monitoring the production process through the use of indicators is a tool that helps to control the organization and indicates the current problems of the company, thus enabling dynamic response and documentation of activities and effects.

The selected indicators for monitoring the production process presented in the study are used in the analyzed company to perform their basic functions, enabling the tracking of the production process in the area of its efficiency and effectiveness. The analysis of the components of OEE indicators allowed us to conclude that they correspond to theoretical assumptions, while the last two of the presented indicators inform about the qualitative and quantitative conformity of the manufactured products. Due to the specification of the tested product (the need to carry out subsequent production operations on the semi-production produced during the implementation of the first and second technological operation), failure to implement the implementation plan in one operation entails consequences in the form of inability to implement the plan in the next operation. As a result, the indicator analysis showed that the level of implementation of the production plan was finally 67.9% and 75.0%. The completed inconsistencies eliminating the forged product from further processing contributed to an increase in the level of productivity at workstations dealing with product finishing. Due to this specificity, the average level of productivity of a production line (measured by OEE) is in the range of 42.2-90.6%, which may be erroneously considered a satisfactory or even good result, but taking into account the values of the plan implementation rate, the achieved values indicate a low level of efficiency of the production process.

The solutions presented in the article concerning the monitoring of the production process can be used in the practice of improvements in manufacturing companies e.g. heavy-duty machines design (Domagala, 2013; Domagala and Momeni, 2017), control (Filo, 2013; Filo, 2015), maintenance (Domagala et al., 2018a; Domagala et al., 2018b) and repairing (Fabis-Domagala, 2013; Fabis-Domagala and Domagala, 2017).

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