INTERPRETATION OF THE STATUS PARAMETERS OF MACHINING CENTERS IN THE FURNITURE INDUSTRY – CASE STUDY

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Summary: Publications consists of 6 chapters and aims to identify common characteristics that directly affect the continuity of the process in the audited company. The first chapter contains an introduction outlining the problem, while the second is the theoretical aspect of the work. The third chapter characterizes the observed object and shows the level relationship between the productivity of production line in relation to the effective time of production, and how much time is spent on resolving the failure. In the fourth chapter demonstrated the interpretation of indicators. The fifth part presents the concepts of interpretation requests and proposed a method of preventive measures to solve the problem of downtime, while depending on the indication and requests for interpretation of the third chapter. The sixth chapter is a summary.

Keywords: reactive maintenance, preventive maintenance, decision support, MTTR, MTBF, physical properties of the processed material.

1. Introduction

Technical objects maintainability, which is their property, indicates its adaptation to prevent and detect causes of failures, malfunctions and helps to remove them through technical actions carried out under certain operating conditions using established methods and measures [14]. Maintaining the efficiency of technical objects, it is the guarantee of orders and high-efficiency machines and equipment located in businesses. To predict properly amount of breakdowns it is necessary to check physical properties of processed materials.

Forecasting of prevention for machinery and equipment in furniture production plants always requires searching for the best criterion for assessing the ongoing relationship between the machine, proposed method of work and the type of manufactured elements. The basis for the construction of forecasts include machine properties such as vibration, temperature, noise or even information about the lubrication system (including pressure, chemical composition of grease/oil ant their physical properties) [15]. Such a recorded information collection regarding events occurring during operation helps identify alarming symptoms of machine malfunction that can be connected with the physical characteristics of the processed element. This means that there is a correlation, which should be taken into consideration both in the process of realisation of production order as well as in the plan of maintenance actions. Lessons learned, can support realistic assessment of the production plan, oblige to seek solutions for improvement, and increase the efficiency of production, through the use of planned preventive measures in a timely manner, depending on the intensity of a physical properties of processed element as measured characteristic of processed object. Observed direct impact of one or more physical properties of processed element on the machine, encouraged authors to further research on the essence of the problem.

Article attempts to find common dependencies that can be included in the overall planning model for prevention and for machines in furniture producing factories. Attempt to prove such dependence, the authors made based on the example of the press for wood glue board production in a large manufacturing company.

Although based on the analysis of the spread of the Pearson correlation and the example of data drawn from the company, there is no relationship between the actual failure rate and the number of manufactured items, the conclusion has been put forward that there is a correlation that should be taken into consideration in both the execution and planning preventive measures, helping determine the elements of the system that need to be repaired as a result of physical workloads of machine parts by the use of materials with different levels of processing. This characteristic or set of characteristics may be physical properties of processed element, such as the: mass, density, geometry, or, for example, length, directly affecting the efficiency of the machine, what helps to eliminate downtime or even failure. Often the data describing the operation of the machine are misinterpreted, and the real causes of production downtime remains a secret and are accepted as the natural way of working.

2. Theoretical aspects of the work

Preventive maintenance and renovation of machines are a key factors to control the production capacity of enterprises, eliminating the frequent and long-term failures disrupting the production plan execution [1]. Underestimation of the importance of maintenance actions leads to manufacturing cost increase by unplanned machine downtime, reproducibility problems as a result of lack or misinterpretation of data caused by improper analysis of breakdowns and procedures and standards ignoring [4, 16]. Getting the surveillance over machines, ie: periodic inspections, monitoring of ongoing actions, identification and diagnosis of wear parts and working groups, aims to prolong their lifetime and sustain required quality of the product [2]. The role of maintenance and financing their proper functioning are attributes of a well-functioning production company [17].

2.1. The evolution of the maintenance

Stanislaw Legutko has distinguished three periods when the approach to maintenance has changed dramatically (Figure 1) [19, 20].

a) Reactive Maintenance

Emergency maintenance service dates back to the period from beginning of the operation of the machines till the Second World War. As the number of machines was relatively low, failures did not have a major economic impact on businesses and the functioning of the maintenance departments was considered to be an ancillary activity. Repairs were focused on lubrication or replacement of structurally simple parts. The machines were repaired at the time of failure, preventive measures were not used and repairs were not performed by skilled personnel.

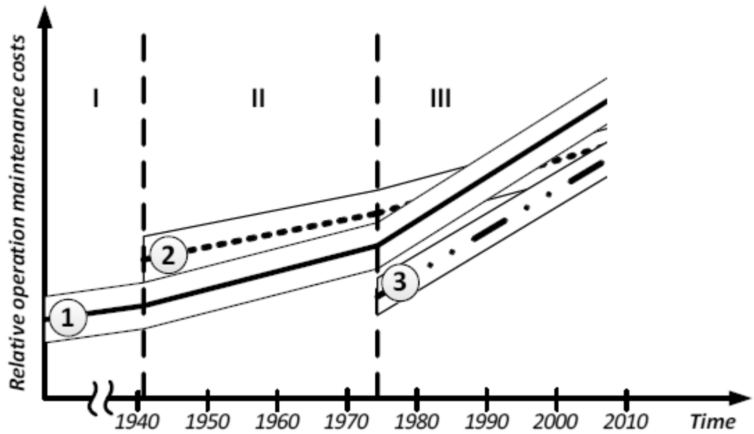


Fig.1. Three periods of development (I, II, III) and three methods (1, 2, 3) of machines operation maintenance: 1) reactive maintenance – actions taken when failure appears; II), 2) preventive maintenance; III), 3) predictive (proactive) maintenance – inspections, counteracting, technical parameters monitoring, engagement of machine operators in maintenance actions, RCM, TPM, 5S

b) Preventive Maintenance

Preventive maintenance is dated since the Second World War. In the absence of access to the labor force and the high demand for industrial products, the period, necessitated the mechanization facilities development. Machinery were refined and numerical control has been implemented. Their service and renovation require higher qualifications of personnel. Initially attention was focused on performance, not on its ergonomics. The task of the machines was constant work and the operating costs were not taken into consideration. The effect of competition in the market pressured to take remedial action and focus on operating costs. The first concept focused on introduction of planned-preventive renovations at specified intervals and/or after a certain amount of work. The particular amount of labor applies both to the wear of the component in the machine and to perform a particular production batch of the product. The characteristic of the preventive maintenance concept was:

- damage prevention concept creation,
- planning and control of maintenance importance increase,
- machinery and equipment lifetime extension.

These actions were a reaction to equipment reparation cost increase, depending on the manufacturing processes of equipment condition and, above all, an increase of the capital invested in the production unit. The development of technology, the cost of equipment, operation and market demands have forced the companies to expand the concept of remedial action for completely new machines, since the first day they were implemented into production process.

c) Predictive Maintenance

The modern concept of maintenance dates back to the mid-seventies of the twentieth century. The idea behind the concept is a failure-free operation of machinery and equipment over their lifetime. The main objective is striving for perfection: zero failures, no loss, incurring minimal operating costs and zero inventory. Modern approach to the subject is going to be achieved by [21]:

- manufacturing processes automation and robotization,
- technical diagnostics development,
- modern management systems,
- operating costs control,
- health standards, safety and environmental protection increase,
- changes in the awareness of employers and employees on the machinery operation.

The tasks of predictive maintenance should:

- introducing tools for decision support, risk assessment models, the intensity of damage and interpretation of the obtained results,
- cooperation of all areas of the enterprise in order to improve the performance and efficiency of the technology park.

2.1. Decision support in maintenance

With a range of available methods used for pattern recognition, analysis and correlation of events, statistical data analysis and monitoring of alarm thresholds [8], the selection of parameters were connected with a set of information depending on the machine work time, the method of routing observation and its credibility, forecasting methods depending on the forecast horizon, the minimum number of components necessary for time series prediction, and run time operation. Choosing proper methods of measurement and assessment, may allow a better understanding of the relationship between condition of the object, acting determinant for future installation of machines with similar working profile. Depending on the severity of the implemented technology decisions are taken for proper planning of maintenance and repair. Modern science is able to perform an analysis based on large amount of data, which sets the condition parameters. The future model should strive to take into account quality characteristics and non-technical aspects, therefore, the authors propose to take into account more factors aimed at generating better-predictions [15]. Predictive model should include: measurement data (residual processes and external conditions), data on production plans, maintenance data [15]. Authors of the study see the need for generating information based on the physical characteristics of the processed elements for single and heterogeneous elements in the production process. In a situation where based on production plans were made regular maintenance activities and technical failures occurred anyway, direct parameters of processed material should be taken into consideration. It will become a major factor in the occurrence of unplanned outages and failures due to material properties or external factors such as temperature, etc.

Based on the contemporary models of prevention in the production, standardization activities were developed. Machine manufacturers advising up to perform certain maintenance tasks after a specified operation time. The verification can be carried out by making, for example, measurements of noise and vibration which helps extend the life cycle of a machine or time to failure [18]. Interesting is the possibility of making an irregular but effective maintenance actions, dependent of the production plan implemented in a short period as week. Continuous changes forcing to search for new and better methods of maintenance and repair.

3. Interpreting the condition of glue board press on the basis of collected data – case study

Wood processing for glue board preparation in example described below, is formed by bonding together wooden lamellas that thickness varies between 16,5 to 19,6 mm and width is between 32 to 68 mm, depending on its subsequent use. The process of gluing solid pine lamellas or a combined with micro-fingered lamellas, initially joined to secure right length, then glued at the width in the press. Elements glued together are called glue board panels and are prepared to fulfil quality specification demands, by elimination of features not acceptable in desired quality grade. Elements after gluing are seasoning several hours to cool down then are calibrated on thickness by sanding operation and sent for further processing. An example of the press used in the furniture company is shown on Figure 2.

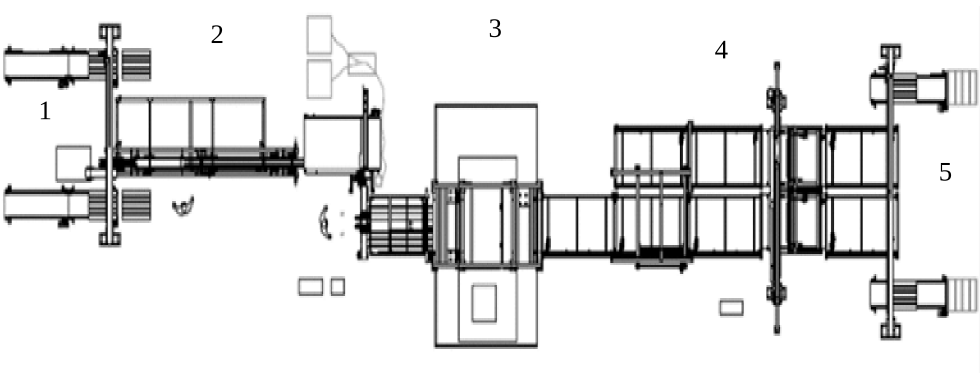


Fig.2. Press for glue board: 1 – feeder, 2 – sorting table, 3 – gluing press, 4 – conveyor, 5 – stacker (source: based on data from production company)

Typical gluing process in the press takes about 3minutes. The machine works in 3 shifts mode and is operated by a one operator and the employees responsible for sorting lamellas and reparation of ready panels.

Assessing the performance of the press is used square meters per hour index. The time is calculated based on a single load of the press. Because the distribution of detail in the press is constant, the highest efficiency achieved for long elements and the lower for shorter. Taking into account the planned number of components recalculated to square meter, gluing time and setup time can be used to calculate processing time for required batch of elements.

Assessing the object based on the ternary system failure criteria [3, 7] first group depends on the operational efficiency in terms of technical aspects, focusing on observation of the failures at the time of damages, or corrective actions carried out by the maintenance service. The second group focused on preventive actions carried out by the machine operators and maintenance service on preventive actions. In this case, each activity before and after the damage is economically justified. The third group are the downtime activities dependent on the current methods of organization management and standards accepted for processes [6]. The structure of stop times and downtime are shown in Tab. 1.

Tab. 1. The average percentage share of downtime in the overall implementation of the production plan in analysed period (source: own study, based on company documents)

STOP TIME CATEGORY	**TECHNICAL FAILURES - CORRECTION**	**PREVENTIVE ACTION STOP TIMES**	**ORGANISATION STOP TIMES – PROCESS PARAMETERS CORRECTION**
CHARACTERISTICS	failures directly affecting the efficiency of the equipment, i.e. : pneumatic, mechanical, electrical, adhesive system, right angle of element, sensors, generator, tray, tape, micro stop.	total downtime indirectly influencing the efficiency of the equipment, i.e.: settings calibration, change of setup, cleaning, PM maintenance, tool change, activities related to security	actions that could in the future performed without stopping the line after coordination of actions with the operators, i.e.: lunch break, trainings, lack of material on the line, problem of the product quality
% SHARE OF STOP TIME IN PERIOD OF OBSERVATION	7,81	12,29	8,24

Categorization of information takes considers the following assumptions: distributions of proper working times of processing object, duration of downtimes for damage removing, impact of damage and preventive maintenance on the unit cost of the product [6].

The article describes two indicators, on the basis of which the maintenance services in the enterprise analyzing production lines. The [9, 11, 12] MTTR, was calculated, based on the failures on the technical level, which are directly related to the suitability of the system, showing its technical condition. MTBF is the sum of all downtime because it focuses on machine availability, impressed determinant in the production planning and exploitation of machines. The results are summarized in Tab. 2.

Tab. 2. Indicators in audited company

Month	I	II	III	IV	V	VI	VII	VIII
MTTR	14,76	12,94	15,25	15,87	21,85	17,94	13,18	14,61
MTBF	1,31	1,26	0,92	1,09	1,90	1,19	1,03	1,15

These results were considered as unreliable data, because the number of so-called. "micro-stops" distorted the real picture of occurring emergency events. In view of illegible information, it was decided to examine the indicators MTBF and MTTR, without the participation of "micro-stop" events, where time does not exceed 5 minutes (Tab. 3).

Tab. 3. Indicators in audited company

Month	I	II	III	IV	V	VI	VII	VIII
MTTR	148,36	145,68	200,87	202,13	165,20	221,05	234,71	138,06
MTBF	8,56	8,82	5,05	6,97	10,40	8,10	8,91	6,00

To identify the relationship between the productivity of the line with respect to the effective production time and the time that is devoted to the elimination of the fault, Pearson linear correlation coefficient has been applied (Tab. 4).

Tab. 4. Pearson linear correlation

Pearson correlations		
Line	MTTR to current meters	MTBF to current meters
	-0,319	-0,465

Obtained results of correlation showed weak dependence, so the theoretically does not have effect at that stage on the efficiency in operation of the line. Interpretation of the results can be concluded that technical failure at this level was acceptable and does not jeopardize the process of production. Based on the data for the established plan to press, the efficiency of the machine shown 70% of OEE (Overal Equipment). So we can assume no relationship on the basis of such performed measurement. This situation occurs when the manufactured parts on the machine are heterogeneous. So they show some features of which is independent in relation to the failure of the plan on the basis of indicators MTTR and MTBF, which is not acting interdependence. The compound can occur in the case where production produces the same elements with same physical properties, such as floor panels. Measurement, in the current situation requires a focus on specific physical characteristics, that have influence on failures and their elimination.

4. The search for correlation according to the characteristics of produced elements

Since the correlation between variables is weak, a link between the general data of the calculated sum of the index value in relation to his individual characteristics has to be found. In case of press failure, and already collected data, can be shown what part of the machine mechanism is causing failures most often and where you need to plan corrective action or repairs. High frequency of failure occurrence in the sub-assembly of machine can also indicate checkpoints for manufactured items until the problem is solved. Take actions to eliminate its occurrence and assign extra time in case of such a relationship.

By making distribution of produced components by long, medium and short, the selected the physical feature will be length, that stands for a mass. After systematizing produced lamellas into three groups, the highest failure rates was recorded for short and medium lamellas. Also in the case of these elements, failures occur frequently, and though their disposable did not exceed 5 minutes then their total monthly occurrence were standing for about 50% of all technical failures (Tab. 5.).

Tab. 5. Pearson linear correlation

No.	less than 5 min	5,0-14,99 min	15-14,99 min	30-60 min	more than 60 min
≥700mm	0,430	0,763	0,261	-0,110	-0,130
699mm- 500mm	0,920	0,533	0,383	-0,106	-0,447
≤499mm	0,803	0,342	-0,033	0,065	-0,227

Based on the performed measurements it is concluded that the biggest problem are the failure of micro downtimes as a result of the production of short and medium components. While unfit object at this stage of observation for other failures, requires the maintenance of so far undertaken renovation and repair activities according to the schedule of maintenance services [6].

5. Improving actions taken in audited company

5.1. Monthly production planning model in relation to physical characteristics of produced object

In relation of the currently implemented gluing process in the press, planning of the execution of orders in production, the problems associated with the failure rate in the production of short and medium elements, require additional time assignation needed for execution of the batches planned for a month. Comprehensive information collected by factory, should allow for the interpretation that such a failure is constant in appearance, and until the problem id solved there has to be taken into allocated additional time to produce elements with described features enhancing failure. Example of collected data presented in Tab. 6.

Tab. 6. Analysis of production plan implementation in relation to micro-stops

	Running metres produced in successive months					
Length of elements	1	2	3	4	5	6
L<=500	58 688	71 627	79 673	75 224	62 321	64 550
700>=L>500	84 511	104 864	89 420	92 606	50 695	76 508
L>700	176 388	212 104	236 846	217 196	221 546	246 238
Sum of running meters	319 588	388 596	405 939	385 027	334 562	387 296
	Percentage share of running metres produced in successive months.					
	1	2	3	4	5	6
L<=500	18%	18%	20%	20%	19%	17%
700>=L>500	26%	27%	22%	24%	15%	20%
L>700	55%	55%	58%	56%	66%	64%
	Total micro-stops in successive months [min]					
	1	2	3	4	5	6
Micro-stops:	927,13	1 198,60	1 139,25	1 107,13	593,93	1 000,83

The next step was to simulate the need to run additional shifts as the function of the short and medium components base on the data summarized in Tab. 7.

The month no. 7 presented in Tab. 7, characterizes lack of continuous production due to planned activities of facility maintenance, but expected outcome based on the established plan shows that the problem is repetitive and until its elimination would already at the planning stage assume the costs related with additional shifts running. Month number 8 with regular production shows full compliance with forecasted production time increase.

5.2. Preventive activities related with press

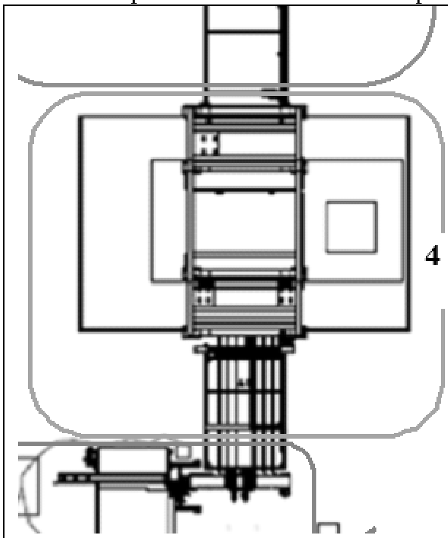
The concept of additional preventive activities implemented by the maintenance services till the time of installation of new formatting saw for cutting pressed glued panels from short elements joined together to extend length. Example in Tab. 8 shows the range of maintenance for the area of the press.

Tab. 7. Analysis of production plan implementation in relation to micro-stops

	Plan for running metres of production for next 2 months	
Length of elements	7	8
L<=500	46 369	64 355
700>=L>500	21 100	70 747
L>700	131 042	258 666
Sum of running meters	198 511	393 769
Percentage share	7	8
L<=500	23%	16%

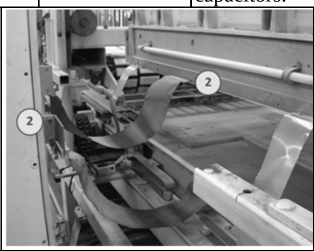
700>=L>500	11%	18%
L>700	66%	66%
Forecasted result:	753,80	1 046,21
Registered micro-stops:	637,12	1 043,45
Deviation:	116,69	2,76
Deviation %:	18%	0%
Need for additional shifts:	**2,00**	**3,00**

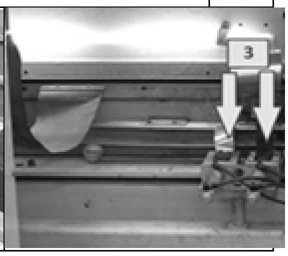
Tab. 8. Example of the maintenance scope for press line elements.



Zone no. 4 – Press/Generator			
No.	Where? (Press)	Activities	Mark if performed
1.	Chain conveyor before press	Inspection, exchange if needed	
2.	Track, gear, track slides	Inspection	
3.	Gear motor chains, track gears	Inspection, exchange if needed	
4.	Track wheels.	Lubrication.	
No.	Where? (Generator)	Activities	
1.	Trombone	Inspection and exchange of used parts	
2.	Press – tables – generator	Inspection of brass connection	
3.	Press – tables – generator	Cleaning of brass holdfast	
4.	Generator	Filter cleaning	
5.	Generator	Generator cleaning	

No.	When?	Where?	Tasks to be performer	Who?
1.	every 2nd month	Trombone	Inspection, exchange of worn elements of trombone.	
2.	every 2nd month	Press - tables - generator	Inspection of brass connections between Generator and press, exchange if needed.	
3.	every 2nd month	Press - tables - generator	Cleaning of brass fast holders positions: Short, Mid, Long.	
4.	every 2nd month	Generator	Induction-volume filter LC cleaning.	
5.	every 2nd month	Generator	Generator cleaning – lamp, reducers, capacitors.	





5.2. Conclusions

The interpretation of the obtained data requires knowledge of the production process in the company. Assessment based on common indicators may lead to false conclusion that the machine is functioning properly. More often, the personnel operating the machine, get used to the situation and cope with problems on their own. Micro-stops, which are a prelude to a major failure indicate that the process is not correct and adjustment of the device to the physical characteristics of processed element is needed. In the above example, workers often clean press, not because it is dirty but because the adhesive residue left on the belt makes it impossible to work properly. The fact of numerous stops of the machine is not surprising to anyone. An alarming number of stops of less than 5 minutes, did not indicate a specific problem as downtime can be related to any of implemented process aspects. These and similar situations at the present stage of the operation of businesses do not arouse anxiety. In the future, however, as long as you can plan the regeneration of the machine, it will be difficult to clear it of dirt accumulated during the execution of production orders, and which today do not last once more than 5 minutes.

Focusing on the analysis based on the physical characteristics of manufactured items affecting failure, eliminate redundant equipment stops by focusing on preventive actions and will help to understand the processes occurring in the production. The search for solutions allows for more efficient work of the line as well as the relief of certain activities, which certainly could be eliminated.

6. Round-up

The concept of a model taking into account the physical characteristics of the workpiece including the previously used measurement methods such as vibration, temperature, noise, and many others, could generate new concepts of maintenance activities. This work could proceed according to the current needs of companies, as is the case in the method Just In Time, affecting the machines efficiency, while raising awareness of all participants involved in the production process and its execution.

The concept is an attempt to find a correlation between the two planes affecting the maintenance services in the area of industrial production of furniture with the use of high-speed production lines, what is further research area.

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