Vibration Signal as a Support for the Processes Production Management in Enterprises of the Furniture Industry

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Abstract

Activities of maintenance services cover not only the performance of ongoing repairs, but, above all, the prevention of failures and downtime. Adopting preventive measures to maintain machinery and equipment in manufacturing enterprises has a significant impact on the timely execution of orders, which is why monitoring the state of the machine park is becoming common in robotic manufacturing enterprises. Currently, the most frequently observed diagnostic parameters relate to machine vibrations. Information on exceeding the permissible thresholds allows for appropriate reaction of maintenance services aimed at minimizing unplanned downtime. The diagnostic aspect is beyond dispute here. However, there is a question whether the vibration signal can additionally be a carrier of information about the production process - information that can be used at the stage of technological process assessment, or even at the stage of process control?

Searching for the answer to this question, one of machining centres for mass production of glued panels in the furniture industry was analyzed. Information obtained from maintenance services was confronted with information from standard vibration measurements. The article is an attempt to answer the question of how to properly use at the management stage knowledge of vibration signals generated by motors mounted on the production line.

Keywords: machine vibration, management, machining centre, furniture industry

1. Introduction

The technological process in enterprises serially producing furniture requires the use of specialized machinery and equipment adapted to specific features of the products. These facilities are machining centres in which working functions are simultaneously performed, which are the result of coupled working and auxiliary processes carried out in various interconnected machines and devices operated by specialist personnel [1]. The task of machining centres is to use the processed material to obtain an object of the desired shape, dimensions, accuracy and surface roughness [2, 3]. In addition to high technological and production efficiency, a high level of reliability of the machine parks is expected to be realized by eliminating the occurrence of defects that stop the flow of materials during the production process.

The article focuses on one of the elements of the machining centre, which is the milling tenoning machine. In the analyzed enterprise, the machines belong to the class of roll-through machine tools designed for processing wooden elements. The work of sawing machines consists in formatting boards to the net dimension and making tenon joints. The tenoning machine enables the machining of tenons and bridle joints, especially in the case of frame components or other square timber, as well as making the desired profile or chamfer. The machine tool equipment includes sawing, formatting and grinding aggregates. Machining of elements on milling tenoning machines is carried out by means of feed motion at high speeds [4, 5].

Daily operation of electrically powered milling tenoning machines carries the risk of wear or damage to motors driving, among others, sawing, formatting and grinding spindles. In the case in question, despite the periodic inspection of vibration measurement, it happens that motor damage occurs prematurely and it is impossible to clearly determine the time of trouble-free operation. The durability of motors given by manufacturers is only an estimated period and the actual working time until damage occurs depends on many internal and external factors. The influence of internal factors includes quality of workmanship, assembly precision, proper lubrication and working temperature. External factors affecting the technical condition of motors include the direct impact of the material being processed and the degree of load on the machining centre caused by the execution of the production plan. In order to determine the current state of machinery and forecast the time of trouble-free operation of motors, the company regularly checks vibroacoustic measurements. In principle, such an action should prevent the occurrence of failures and assist maintenance services in planning necessary preventive measures as well as prevent premature replacement of a functioning bearing [6]. The use of diagnostics is particularly important in the described example because machining centres are a critical element of the technological process [7]. Damage to motors causes costly repairs and several hours of production downtime (the specificity of the material being processed causes a layer of dust and resin to form on the surface of the motor, which is extremely difficult to remove). Of course, early detection of damage to the motor element can prevent failures of its subsequent elements, which in turn can lead to the destruction of the entire motor. This, however, is associated with unplanned high financial outlays. Despite the possibility of generating losses, the company often decides to maximize the use of motors until they are completely damaged [8].

The polemic of the diagnostic technician and specialist in the field of maintenance of the production line undertaken in the study will, in effect, answer the question whether strictly diagnostic vibration information will allow the assessment of the technological process. The use of such information at the stage of optimization of the technological process would allow, while not increasing costs, to increase the reliability of long-term operation of machines, and thus the efficiency of production.

2. Information from the vibration signal

The company conducts diagnostics of production lines based on the DIN ISO 10816 standard “Mechanical vibrations – Assessment of machine vibrations based on measurements of non-rotating parts." This standard was developed to ensure the reliable and long-term operation of machinery. It sets general conditions and procedures for measuring and assessing the vibration of non-rotating machine parts whose general assessment criteria relate to both operational and acceptance tests.

The analyzed company conducts vibration measurements for all electric motors in the line along with their assessment in accordance with the assumptions of the standard. The recorded vibration parameter is the speed amplitude [9, 10]. The measuring points are located on bearing supports, both on the drive and anti-drive side. Vibration speed registration is carried out during the operation of the machine. The measurement includes not only two points for each motor, but also three measurement directions for each measuring point. For this class of machines, the standard provides for threshold limits (assessment zones):

- A – vibrations of newly introduced machines,
- B – machines that are usually considered fit for unrestricted long-term operation,
- C – machines that are usually considered unfit for continuous long-term operation,
- D – vibration values in this zone are usually considered to be intense enough to cause damage to the machine.

The presented analyses cover the work of the facility in the period from August 2014 to February 2017, with measurements carried out at three-month intervals.

Figure 1 shows an example of the course of instantaneous vibration speeds for the motor driving the S6L spindle. Machine vibrations reach a very high level with one of control measurements on the drive side. Besides this one measurement, the vibration of the machine is at the vibration level of newly introduced machines. The results of vibration registration on the drive side indicate that in the entire period considered the machine was working properly. The high level of vibration coincides with the slowdown of the production line speed. During this period the line speed was reduced from 45 m/min to 30 m/min. This situation was observed on several other motors of the machining centre, but it was not a general reaction of the system. Could the change in line speed be a direct cause of such a large increase in vibration, thereby significantly exceeding the D threshold? The fact that a significant excess of the "permissible" level of vibration occurs on several line motors at the same time rather leads to the conclusion that it is caused by the performance of the production process and not by sudden failure of several machines at the same time. It was necessary to check the response of maintenance services to the situation and answer the question whether any actions were taken and, if so, which ones.

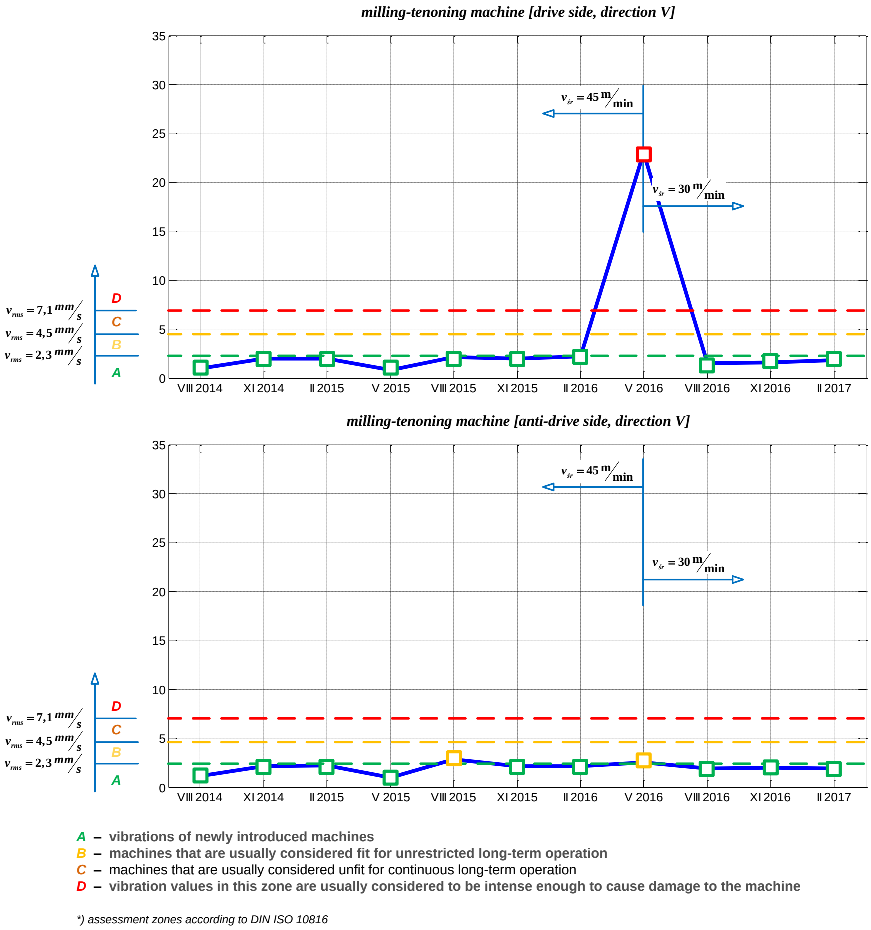

Figure 1. The course of momentary vibration speeds
of the motor driving the S6L spindle

Figure 2 shows the course of momentary vibration speeds of the motor driving the S12L spindle. In this case, we also observe an increase in vibration, which coincides with the time of reducing the speed of the production line, with the difference that this increase occurs simultaneously on the drive and anti-drive side. In addition, it is worrying that after recording the first significant instance of exceeding the D threshold (vibration values in this zone are usually considered intense enough to cause damage to the machine) with the next measurement vibration speeds are even higher. Looking at the measurement results of the anti-drive side, we see that the motor mainly worked in zones where machines are considered unfit for long-term operation. Was corrective action taken in this situation? The results of vibration measurement allow us to state that such actions were not taken.

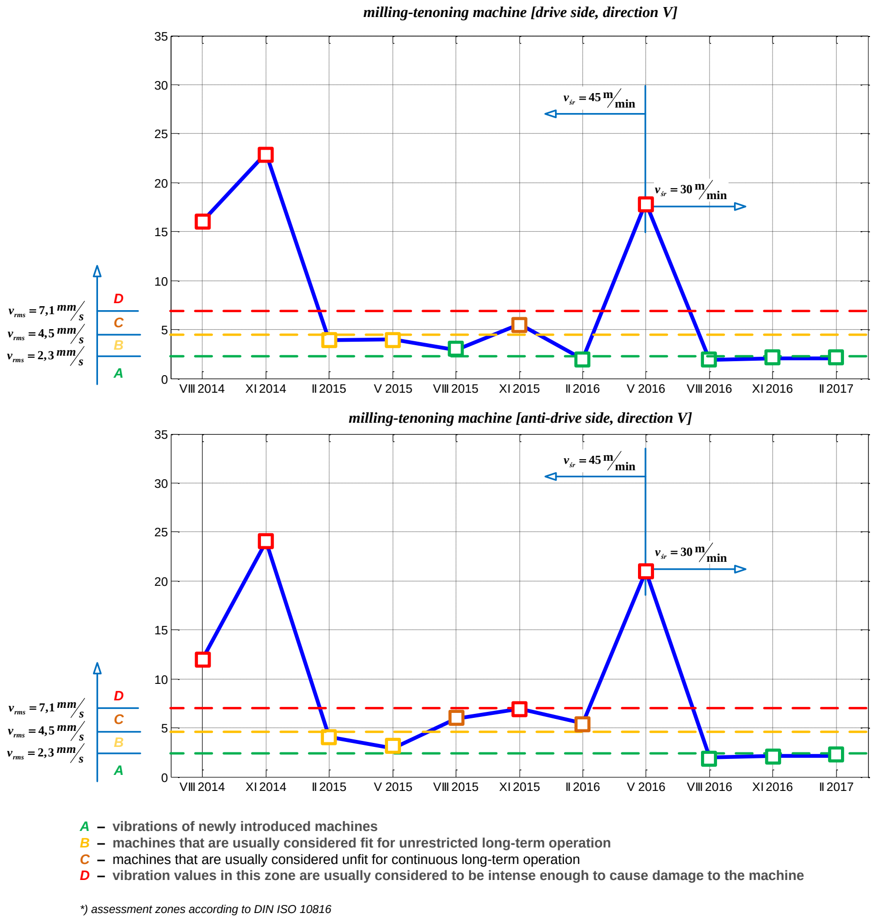

Figure 2. The course of momentary vibration speeds
of the motor driving the S12L spindle

In the case of the motor driving the S13P spindle (Fig. 3), no increase in vibration was observed when the production line speed was reduced. Measurement on the anti-drive side indicates that the "safe" level of vibration is only slightly exceeded. In the next measurement, however, we observe, like in the case of the S12L motor, the long-term operation of the machine in a zone that should exclude the machine from operation.

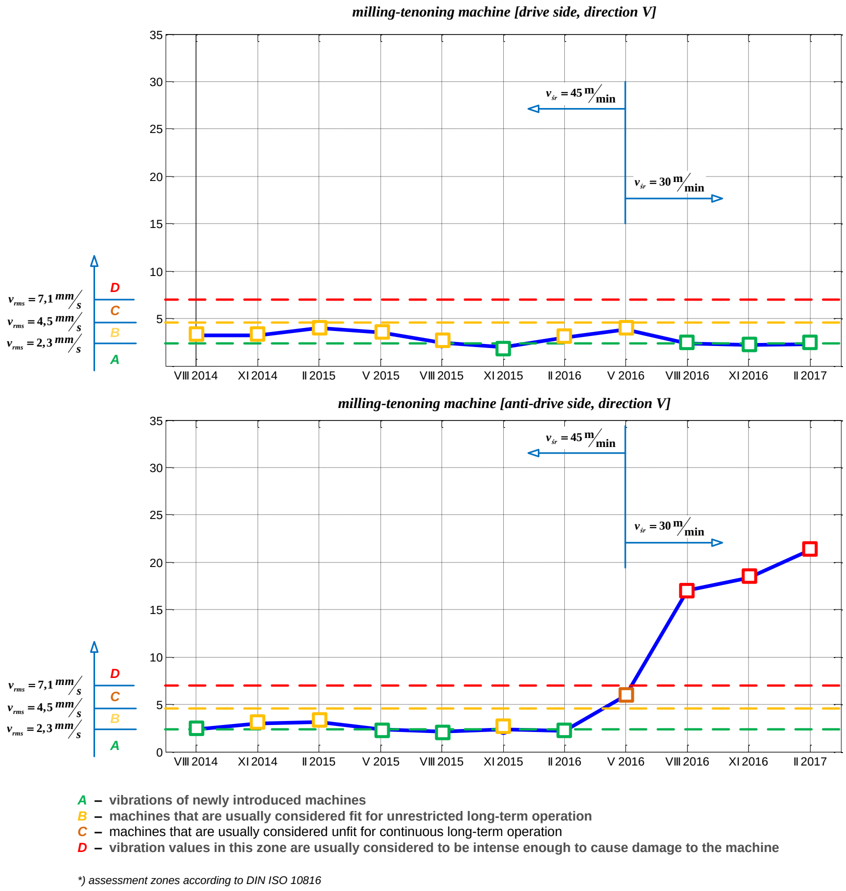

Figure 3. The course of momentary vibration speeds
of the motor driving the S13P spindle

The conclusions drawn from the observation of standard vibration measurements enable us to state that the vibration signal can allow to infer about the correctness of the technological process carried out at the analyzed machining centre. However, final inference requires that information obtained from vibration measurements is confronted with information on actions taken by maintenance services.

3. Information from maintenance services

The machining centre described in the article is mainly intended for the production of large-dimension elements (theoretically it was designed in such a way). High working speeds with high demand of aggregates for power meant that motor components were subject to excessive wear, which ultimately led to frequent failures as a result of machining large profiles. The decision to reduce the conveyor speed significantly extended the time of trouble-free operation of the technical system. Let us return to the comments presented in the previous chapter. The results of vibration measurements showed the work of motors in the zone in which the dynamic state of the milling tenoning machine was classified as “unacceptable”. The results of standard vibration measurements were compared with information collected by maintenance services. The information obtained from the company stated that exceeding the “permissible” levels of vibration resulted mainly from poor technical condition of bearings and improper balance of the tool. The diagnostic technician's recommendations included the necessity to carry out repairs involving the replacement of bearings as well as cleaning and balancing the tools. The decision of maintenance services was to increase the time the element went through the machining process (the speed of the milling aggregate did not change). From the perspective of the technical systems, the decision, mainly based on the knowledge possessed by maintenance services and servicing employees, was right. However, it is necessary to consider the efficiency of operating such a centre [11]. The decision slowed down the process of motor degradation only to some extent, because as a result of subsequent diagnostic measurements the dynamic condition of the milling tenoning machine was classified in zone C – “temporarily permissible”. The company consciously slowed down the technological process without exploring the essence of the problem. Activities undertaken were short-term. A direct consequence of the decision will be a short downtime caused by a failure (a random event occurring during the performance of a task). However, at this point it is worth considering whether losses associated with the inefficient use of the production line will not be higher. The analysis of the total availability of the facility proved that it was effectively operated at 45%. The remaining time is stoppages when theoretically the facility remains fit to be used. Practice shows that extensive knowledge of the facility is not fully utilized in activities undertaken by maintenance services and by persons responsible for controlling the course of the production of elements. As a result, financial losses are directly related to the major overhaul of the motor. Costs caused by the inefficient operation of the machining centre are not calculated .In a situation where it is possible to perform 100% of the order, the operator enters the “slow speed” code into the system and performs about 70-80% of the order [12, 13]. From his perspective, this is the right thing to do, because otherwise he would be forced to enter the “electrical failure” code, where the technical system would remain in a state of inactivity for 4 to 6 hours.

4. Conclusions

To summarize, one gets the impression that the company has knowledge of the technical condition of motors. However, this information is not fully consulted with persons responsible for the performance of the production plan, or it is not used constructively. The presented results of standard vibration measurements show that with the appropriate combination of information from maintenance services and information obtained through technical diagnostics, one can properly control the production, management and repair processes, thereby increasing production efficiency and reducing maintenance costs. Including in the inference additional information about the mass of manufactured elements would allow to perform a comprehensive assessment of the state of the machine park and the course of the machining process. Information about the mass of manufactured elements and knowledge about their impact on the occurrence of failures can help in better planning of renovation and management tasks. Appropriate management of decision-making, preventive and corrective actions will reduce the occurrence of failures, which will result in a higher probability of timely execution of the process and reduce the costs related to failures.

References

1. J. Dietrich, *System i konstrukcja*, Wydawnictwo WNT, Warszawa, 1985.
2. T. Karpiński, *Inżynieria produkcji*, Wydawnictwo WNT, Warszawa 2013.
3. K. Szwedzka, M. Jasiulewicz-Kaczmarek, *Determining maintenance services using production performance indicators*, Research in Logistics & Production, **6**(4) (2016) 361 – 374.
4. T. Gawroński, *Technological process optimization for the pretreatment of solid wood furniture elements*, Forest Products Journal, **59** (2009) 63 – 68.
5. T. Gawroński, *Optimization of CNC routing operations of wooden furniture parts*, The International Journal of Advanced Manufacturing Technology, **67**(9) (2009) 2259 – 2267.
6. M. Jasiulewicz-Kaczmarek, P. Drożyner, *Maintenance Management Initiatives towards Achieving Sustainable Development*, In: P. Golinska et al. (eds.): Information Technologies in Environmental Engineering Environmental Science and Engineering, Springer - Verlag Berlin Heidelber, (2011) 707 – 721.
7. K. Szwedzka, P. Szafer, R. Wyczółkowski, *Efficiency of complex technical systems – case study*, Topics in Intelligent Computing and Industry Design, **1**(1) 148 – 154.
8. L. Drelichowski, W. Bojar, M. Żółtowski, *Elementy zarządzania eksploatacją maszyn*, Wydawnictwo Uczelniane Uniwersytetu Technologiczno–Przyrodniczego, Bydgoszcz, 2012.
9. C. Cempel, *Mechanical Vibrations – Introduction* (in Polish), Poznań: Wydawnictwo Politechnika Poznańska (The Publishing House of Poznan University of Technology), 1982.
10. C. Cempel, F. Tomaszewski, *Diagnostics of machines* (in Polish), Radom: MCNEMT, 1992.
11. M. Jasiulewicz-Kaczmarek, *Integrating Lean and Green Paradigms in Maintenance Management*, In: E. Boje, X. Xia, (eds.), Proceedings of the 19th IFAC World Congress Cape Town, South Africa., 4471 – 4476.
12. M. Jasiulewicz-Kaczmarek, K. Szwedzka, *Were our leaders ready to implement the changes? – a case study*, in: X.-G. Yue, N. J. R. Duarte (eds.), Proceedings of the 2016 International Conference on Economics and Management Innovations, part of Advances in Computer Science Research, 57, 267 – 271.
13. M. Jasiulewicz-Kaczmarek, T. Bartkowiak, *Improving the performance of a filling line based on simulation*, ModTech International Conference - Modern Technologies in Industrial Engineering IV, IOP Conf. Series: Materials Science and Engineering 145, Iasi, Romania, June 15-18, 2016.