FACTA UNIVERSITATIS
Series: **Working and Living Environmental Protection** Vol. 21, Nº 4, Special Issue, 2024, pp. 417 - 425
https://doi.org/10.22190/FUWLEP240910040J

Original scientific paper

VIBRATIONS MEASUREMENTS IN INDUSTRIAL PLANTS AND THEIR INFLUENCE ON MACHINES

UDC 534.13:621-1/-9

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Abstract. *In the field of industrial machinery condition monitoring, vibration analysis is a vital technique that helps engineers and maintenance specialists identify possible problems in intricate systems before they become expensive failures. Ensuring the best performance and longevity of industrial gear is crucial, especially in sectors that largely depend on intricate machinery. The proper selection and application of measurement tools and methodologies is one of the most important components of an efficient vibration analysis. This research analyzes the impact of vibrations on the performance of two distinct machines, as well as the different methods employed by the machine manufacturers in interpreting the vibration measurements.*

Key words: *vibration measurements, industrial machines, vibration impact*

1. INTRODUCTION

Vibration analysis has become a critical tool in the field of industrial machinery condition monitoring, enabling engineers and maintenance professionals to detect and diagnose potential issues within complex systems before they escalate into costly breakdowns. Maintaining the optimal performance and longevity of industrial equipment is of paramount importance, particularly in industries that rely heavily on complex machinery, such as automotive manufacturing, cement production, and petrochemicals [1].

Received September 10, 2024 / Accepted November 21, 2024
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One of the key aspects of effective vibration analysis is the selection and use of appropriate measurement techniques and equipment. Sophisticated vibration measurement devices with advanced signal processing capabilities are now widely available, allowing for the precise quantification and characterization of vibration patterns in industrial machines. These devices typically offer features such as multi-channel data acquisition, high sampling rates, and the ability to simultaneously measure overall vibration values, spectra, and time-domain signals across multiple axes.

The choice of measurement method and equipment is largely dependent on the specific application and the characteristics of the equipment under investigation. For example, in the case of NEMA AC induction motors commonly used in the petrochemical industry, the most common vibration measurement techniques include overall vibration levels, frequency-domain analysis, and time-domain waveform analysis [3].

Vibration analysis has proven to be a valuable tool for the diagnosis of a wide range of machinery issues, including bearing defects, unbalance, misalignment, and other mechanical faults [4]. By carefully analyzing the vibration signatures of industrial equipment, maintenance professionals can often identify the root cause of a problem and take appropriate corrective action before the issue leads to a failure or costly downtime.

The power of vibration analysis lies in its ability to provide early warning signs of impending problems, enabling proactive maintenance strategies that can significantly extend the useful life of industrial equipment [2-4].

By leveraging the insights gained through vibration analysis, plant operators and maintenance teams can optimize the performance and reliability of their machinery, ultimately contributing to improved productivity, reduced maintenance costs, and enhanced overall plant efficiency [2-4].

Devices and machines in operating conditions cause vibrations in the working environment in which they are located as part of the system along with other machines and the construction itself on which they are located. The impact of vibrations can be viewed from different aspects, and most often the focus is on the harmful impact on the worker, unsafe work and the impact on the building structure on which the machine is located. The measurement and analysis of vibrations have a significant role in the protection of workers who are in the environment and under the influence of vibrations and are subject to constant improvement with the aim of protecting people's health. However, there are other aspects of the impact of vibrations that are significant for industry, primarily the impact on precision machines that cannot work in the nominal mode of operation for which they were designed, precisely because of the existence of vibrations originating from devices and machines located in the immediate industrial environment. This paper will present the results of measuring the impact of vibrations on precision machines and objects in such a working environment.

2. VIBRATIONS MEASUREMENTS

The diagnosis and correction of motor vibration problems are of paramount importance in avoiding costly downtime and ensuring the efficient operation of industrial plants. Since vibration analysis can provide information about the underlying causes of vibrations, such as imbalance, misalignment, bearing problems, or other mechanical faults, it is a useful technique for identifying and diagnosing early machine and equipment failures [4].

Various methods and types of vibration measurement are employed in the industry, with sophisticated devices and analysis techniques being widely available [3]. The proper selection and application of these methods can significantly improve the accuracy and reliability of vibration measurements, leading to more effective diagnostics and condition monitoring [4].

One of the key aspects of vibration measurement in industrial plants is the understanding of the different sources of vibration and their influence on machine performance. Factors such as motor speed, load, and environmental conditions can all contribute to the observed vibration patterns, and a comprehensive analysis is necessary to identify the root causes of the observed vibrations.

In a study on motor vibration problems, it was found that the proper data collection and analysis techniques can accurately determine the true source of the vibration, allowing for the implementation of appropriate corrective measures [7-10].

We notice that it is important to look at the operation of the surrounding devices, as well as the base on which it is placed, when the location of the machine is being installed [11].

In this paper, we consider the effects of vibrations on two different types of machines, the measuring machine HEXAGON type GLOBAL S and the production machine META V1800, the recommended and measured values of vibrations in its working environment, as well as their influence on the operation of that machine. Measuring machine "HEXAGON" type GLOBAL S has specified requirements regarding vibrations at the place of installation in order to be able to achieve the declared accuracy. The manufacturer, taking into account the technical solutions applied in the construction of the machine, defined the criteria that the machine's base should meet and submitted it as a condition for the customer to fulfill as an element of the contract declaring the machine's performance.

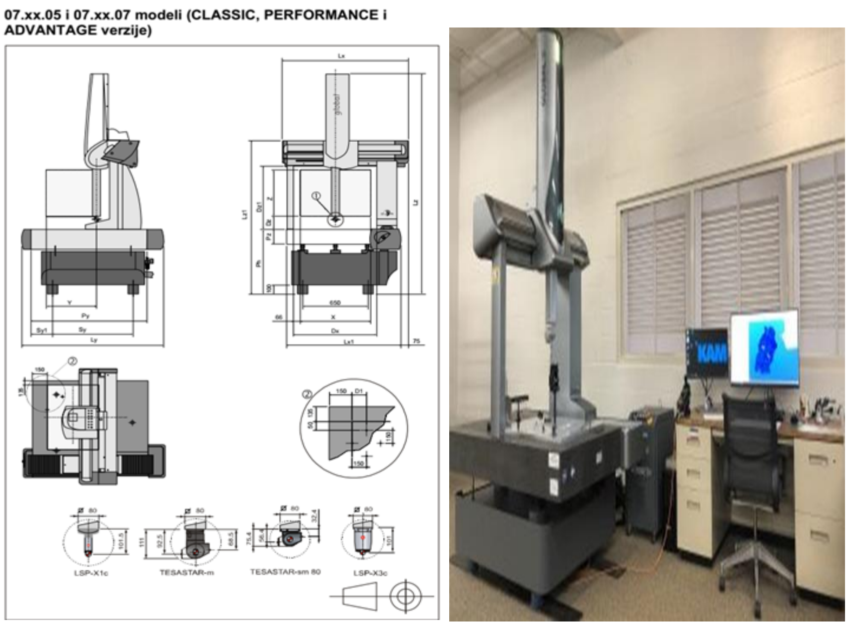

Fig. 1 a) Dimensions of the Hexagon Global S machine, b) appearance of the measuring machine in real space

Figure 1 presents the dimensions, functional schematics and representation in the real working environment of the analyzed machine. The manufacturer has fully defined the measuring points, the type and range of the measuring device that should be used to control vibrations, as well as the criteria that the substrate should meet at the place where the machine is installed.

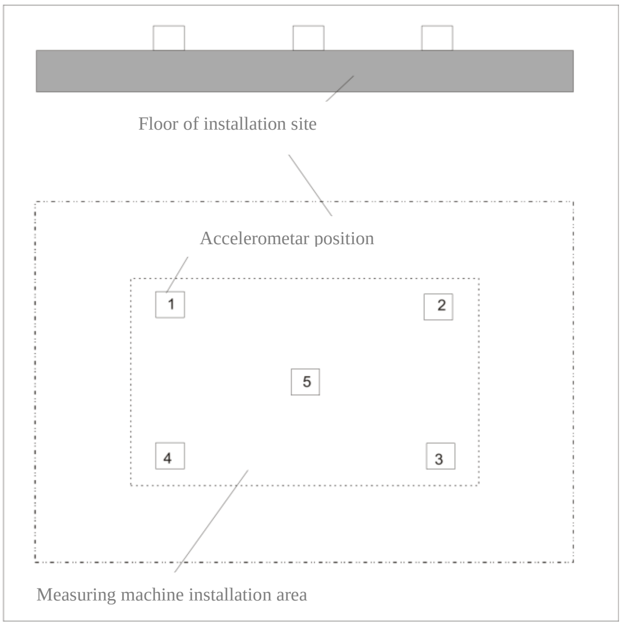

Fig. 2 Arrangement of measuring points for the installed machine

Figure 2 shows the arrangement of accelerators and measuring points for a machine placed on the floor without an anti-vibration pad in a real environment. It is noted that measurements are taken at five characteristic points on the substrate, according to the manufacturer's instructions.

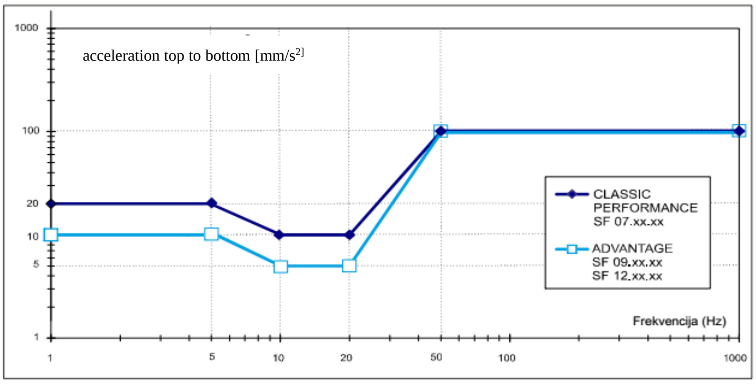

Fig. 3 Maximum vibrations allowed at the installation site (Passive anti-vibration support)

Figure 3 shows the maximum permissible vibrations at the characteristic points, given by the manufacturer, the first line represents the values for optimal operation in real conditions when classic accuracy of the machine is necessary, and when increased accuracy of the machine is required, the recommended values are read on the bottom line. By issuing detailed instructions on vibration measurement points on the base, the machine manufacturer protects himself from possible misunderstandings in the use of the machine and has prepared technical solutions for the operation of the machine in an environment that does not meet his requirements from the point of view of vibrations, so in those cases, anti-vibration support is used and other technologically available solutions.

Fig. 4. Bruel&Kjaer Vibroport 80 with piezoelectric acceleration measuring cell AS-063

For the purposes of writing this paper, the vibration of the substrate was measured at the place of installation of the machine, using the Bruel&Kjaer Vibroport 80 device with piezoelectric acceleration measuring cell AS-063, which is shown in Figure 4. The results were processed in the REO software of the same manufacturer. In order to avoid drilling the industrial floor at the installation site, an inertial weight (large mass) was used, to which the measuring cell was attached. The measurement results are tabulated according to the measurement scheme provided by the machine manufacturer.

According to the detailed instructions of the machine manufacturer, all filters and measurement ranges were set with the REO software, which was highlighted by the machine manufacturer in their request.

Table 1 Measured values in measuring points

Measuring point	v_{pp} [mm/s]	a_{pp} [m/s^2]	g_{pp} [m/s^2]	FFT [peack]	f [Hz]
MT1V	14.55	0.154	0.0688g	0.010 [m /s^2]	0.60
MT1H	8.60	0.303	0.0186g	0.014 [m /s^2]	3.70
MT2V	15.86	0.358	0.0822g	0.302 [m /s^2]	50
MT2H	98.37	0.456	0.0542g	0.136 [m /s^2]	50
MT3V	17.61	0.387	0.0260g	0.245 [m /s^2]	50
MT3H	55.03	0.313	0.0308g	0.247 [m /s^2]	50
MT4V	7.41	0.280	0.0288g	0.265 [m /s^2]	50
MT4H	5.35	0.305	0.0925g	0.282 [m /s^2]	50
MT5V	12.75	0.926	0.116g	0.295 [m /s^2]	50
MT5H	11.63	0.599	0.0541g	0.288 [m /s^2]	50

The measured values, in the measurement points shown in Fig. 2, are given in Tab. 1 and represent measurements in all 5 characteristic points in two axes, vertical and horizontal, due to the operation of the surrounding machines in operation. All values are below the permissible for the “classic” and “advantage” operation of the machine, while at point MT2H, a slightly increased value appears compared to the remaining measured values. At the frequency of 50 Hz, at which the measurement was performed, the permissible vibration level is 100 [mm/s], and at this point, the value was measured at 98.37 [mm/s].

In addition to this approach to machine vibration measurements where the manufacturer declares its requirements, there is also a different approach by machine manufacturers. Namely, they ask to establish the impact on the surface where the machine is placed, and the manufacturer's design team decides whether and to what extent the measured vibrations affect the operation of their machine. Although such an approach is different, it actually contains the need to protect certain technical solutions of very expensive and unique machines. Thus, the impact of the machine's operation with shock effects on the base where the machine is installed was measured.

Fig. 5 Considered production machine in operating condition

The operational state of the manufacturing machine META V1800 is depicted in Fig. 5, which was analyzed in terms of the vibration level and the effect of its operation mode. Unlike the first case, where the manufacturer defined the required operating conditions, with this type of machine, the measurement results, shown in Tab. 2, were submitted to the machine manufacturer to assess whether the measured vibration levels would have an impact on the operation of this production machine.

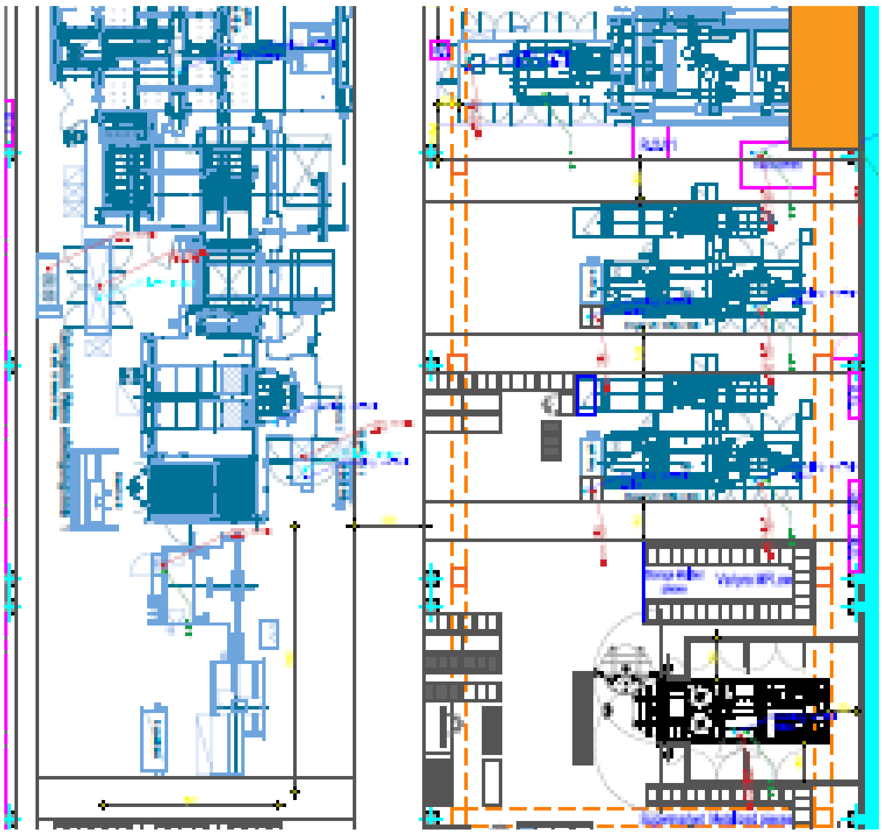

Fig. 6 Display of the arrangement of machines in the production plant

Figure 6 shows the layout of the machines that influence the production machine, where analyzed production machine is shown in black and researched the influence of the rest of the production plant on its operation.

Measurements were made at 24 measuring points in a grid around the machine and it was concluded with the consultation of the manufacturer that the values obtained from the measurement did not affect the operation of this machine, therefore further exploitation of the machine was started. In the first example, we had only 10 measuring points instead of 24 in the second example, and the main reason is that for the first we had recommendations and given measured values for non-obstructed work whereas the second manufacturer insisted that we measure in every point given in the instructions.

Table 2 Results of floor vibration speed measurements in the vertical direction

Measuring point	Vibration rate RMS (mm/s)	Vibration rate Peak-Peak (mm/s)
MT1	0.23	0.59
MT2	0.13	0.81
MT3	0.44	0.58
MT4	0.14	0.89
MT5	0.56	0.58
MT6	0.19	0.72
MT7	0.36	0.76
MT8	0.17	0.67
MT9	0.38	0.75
MT10	0.31	0.56
MT11	0.18	0.83
MT12	0.33	0.66
MT13	0.29	0.54
MT14	0.38	1.12
MT15	0.28	1.19
MT16	0.31	0.78
MT17	0.32	1.38
MT18	0.51	1.48
MT19	0.38	0.64
MT20	0.22	0.73
MT21	0.42	0.75
MT22	0.65	1.49
MT23	0.69	1.38
MT24	0.63	1.67

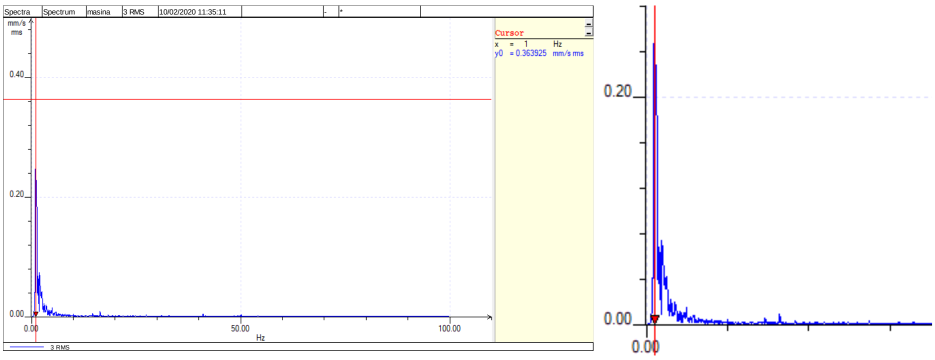

Fig. 7 Frequency diagram and enlarged part of the diagram from 0-30Hz, at one measurement point

Figure 7 shows a characteristic frequency diagram of measurements at one measuring point. Results and frequency diagrams were given to the machine manufacturer, who used them to determine that the operation of one production line did not affect the machine's operation so the machine was installed as intended and has been working for a long time without technical problems.

3. Conclusion

There are standards and norms for many aspects of the effect of vibrations, but they are mainly concentrated on the effect on the environment: servers or man as a working environment and construction objects as a working environment. In this paper, the machine is viewed as a working environment because it can only function under the conditions set by the manufacturer and according to the requirements regarding vibrations transmitted by the foundation. Manufacturers have different business policies to define what kind of vibrations are allowed for the operation of their machines or to ask for a vibration measurement to be performed and to conclude for themselves whether the vibrations present in the environment affect the operation of their machine. But in any case, modern and expensive machines also represent objects on which vibrations have a significant impact, and it is necessary to normalize the level of vibrations acting on the machines.

It is the fact that in addition to the workers who work on certain machines and the impact on the foundations of buildings, vibrations also affect the work of other machines and devices that are in the immediate environment, and this influence is absolutely important for precision and production machines with high-level accuracy.

Acknowledgement: *This research was financially supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia, according to contract No.451-03-47/2023-01/ 200148.*

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