SCIENTIFIC BULLETIN
OF THE POLITEHNICA UNIVERSITY TIMISOARA, ROMANIA
Transactions on MECHANICS
Vol. 60 (74) ISSN 1224 - 6077 Fasc. 1, 2016

MISALIGNMENT AS AN INITIAL IRREGULARITY IN GENERATING RISK IN THE EXPLOITATION OF TECHNOLOGICAL EQUIPMENT

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Abstract. *The content of this work was conceived with the aim to present vibrodiagnostic procedure for solving a specific problem misaligned mechanical parts within the concept of maintaining mechanical structure through proactive maintenance model, based on the risk as a function of the vibratory process generated in terms of technological engagement.*
Misalignment, as a phenomenon that accompanied the process of creation and exploitation of mechanical systems are emerging as the most common drawback that if the weather does not encompass engineering diagnostic procedures has serious consequences both for the system itself in terms of functional and available as well as the safety and the environment.
Keywords: *maintenance, vibrodiagnostic, misalignment*

1 Introduction

Due to the high technological demands of today's rotating machines are working on significantly higher speeds and under significantly higher loads than you had been the case earlier. Questions are requirements to reduce the weight of the rotor speed and total security. This trend makes rotating machines significantly "more vulnerable" to the consequences that usually lead to cancellation. There are a number of specific mechanical and functional problems in machines that can cause excessive vibration. Quality performed shaft alignment interconnected rotating machines, is one of the most important aspects for installation rotating machines, which can be used as starting irregularity in the early stages of exploitation pose a great risk to the stability of the process.

The vibrations are alternating change of a quantity as a function of time which describes the movement or position of the mechanical system, whereby the value of this size larger or smaller than a medium- or reference value.[1] Under mechanical vibration means the oscillatory motion of a rigid body relative to its equilibrium position under the influence of impurities coercive force (forced vibration), which is within the system changes in the direction or size and that can be determined or random. The termination of the facts disturbing force, the body performs periodic movement called free or own vibration. Unlike forced vibrations disappear from termination facts disturbing force, on its own vibration is possible to operate the change system design parameters (mass, stiffness, damping).

Regardless of whether they are artificially generated, or are a size that is changing analogously to change some physical size, these time functions are called signals and mark as a function of time - x(t). Signal is the size in the format electrical voltage, proportional to the size of the original mechanical (deformation, moving, speed, acceleration etc.), which follows in the process. Monitoring is carried out without interruption within a time interval. When it is a dynamic process that identifies the size (or more) that is of interest for analysis, and there is talk of signal analysis, as a carrier of information about the process, in conjunction with the analysis of the process.

Classification of vibration signal in the time domain can be made at a number of ways, depending on the criteria, such as duration and reproducibility. Signals vibratory process in relation to the repeatability and duration can be divided on the:

a) signals periodic process, in which the size of the observed waveform repeated at regular intervals and non-periodic signals of the process in which this repetition does;

b) signals the process of unlimited duration (stationary signals) and process signals limited duration (non-stationary signals).

The process of unlimited duration in the abovementioned division is anyone who takes

enough a long time that the conditions for its actual termination are in no way connected with the circumstances that led to its initiation. Methods of analysis of this process are not conditioned by his time duration and are the same for all processes of unlimited duration. In contrast, analysis of a process, which is essentially in its physical necessarily limited in time, such as for example stroke, will be carried out in a different way.

Non-stationary signals following major changes amplitude over time. As forms non-stationary signals, continuous and transient signals are of limited duration.

The general character of the vibrational motion can be expressed harmonic time function, whose parameters are the amplitude and period of oscillation of one of the kinematic parameter - displacement, velocity or acceleration. The basic parameters of identification vibration in the frequency domain represents the frequency, and amplitude in, alternatively, the amplitude displacement, velocity or acceleration. The third characteristic vibrations defining the movement and relative position of certain machine parts elements the time domain, is a phase.

Identification, specific causes of vibration implies the implementation of existing detailed vibration analysis, for what is certainly a very necessary and important knowledge frequency vibration. The frequency of vibration in this sense represents a very valuable tool for vibration analysis or diagnosis of machine condition.

The forces that cause the occurrence of vibrations usually occur during the rotational movement machine parts. Due to the change in the speed of rotation of mechanical components changes direction or amplitude of these forces, it follows that most of the problems related to vibration have frequencies that are directly related to the rotational speed. Tests and measurements can contribute to a further reduction of the number of possible causes of the problem of increased vibration. It is clear that knowing the frequency of vibration and how it is related to the speed of rotation of mechanical components representing an initial step in the process of analysis.

When the machine does not arise any problems with increased vibration at frequencies that directly correspond to the speed of rotation of the machine. Some problems, such as a relaxant, misalignment, resonance and impact force feedback, can often generate vibrations on frequencies that are two, three or sometimes several times greater than the basic rotational speed. Various problems in machines causing vibrations of different frequencies, indicating the special character of their observation and recognition.

This tells us of the need for applying better methods and equipment for alignment, But the real reasons for the levelling of quality lie in eliminating the consequences of the misaligned and this, reducing energy losses and extending the service life of mechanical components rotating machines. The professional public has information to precisely align shaft extends bearing life by a factor of 8, in class of large rotating machines. By addition, the reported savings of 7% in the overall maintenance and 12% increase availability of machinery. The advantage of the precision alignment and savings in power. At simple machine groups, documented the power savings of 11% on the basis of precise alignment.

2 Misalignment as vibration generator

Misalignment is a condition when the composite shaft axis do not coincide. If the axis of the shaft parallel but do not coincide, it is a parallel misalignment. If the axis of shaft meets at point, but are not parallel, it is the angular misalignment.

Parallel misalignment expressing the difference between the centers of rotation paired shaft measured at the intersection of the transfer movement of the drive to the driven shaft - this is usually the center of the coupling. It is expressed in units of length. Parallel misalignment products shear force and bending moment at the end of each compound of shaft. High vibration level at the second harmonic and the first produced in the radial (vertical and horizontal) the direction of the bearing at each end of the compound.

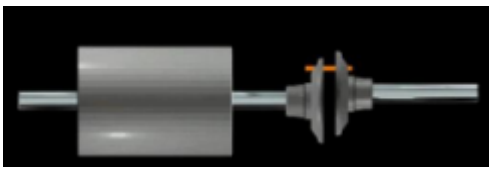


Fig. 1. Parallel misalignment model [2]

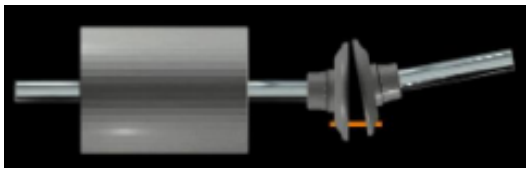


Fig. 2. Angular misalignment model [2]

Angle misalignment expresses the difference in the slope of a shaft (usually a shaft machines on which to perform corrections, the so-called. mobile machine) relative to the second evaporated shaft (shaft stationary machines). It can be expressed through the angle unit or usually expressed as a dimensionless mm / mm. The torque angle values bending on each shaft and strong vibration on the first accordion and a small vibration on the second harmonic in the axial direction on both beds that go counter stage.

All misalignment conditions that will be encountered in practice, the combination of the two previous basic types of misalignment. Alignment is carried out in two levels: horizontal and vertical. Each level has two components misalignment: parallel and angular, which in total gives 4 components for which corrects misaligned shafts: - horizontal angle, parallel to the horizontal, the vertical angle and vertical parallel.

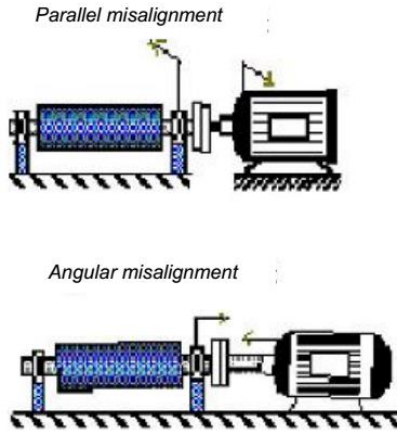


Fig 3. Parallel and Angular misalignment [3]

The way to distinguish misalignment and unbalance is the increasing speed of the machine. The level of vibration due to unbalance will increase in proportion to the square of the speed, while the level of vibrations caused by misalignment will not change. In addition to the peaks in the first and second harmonic, strong peak at the third harmonic is also connected to misalignment. In practice, also with a certain limit can perform another test with the engine without connecting. If there is still a high first harmonic, the engine is unbalanced. If the first harmonic persists, then driven component fails to unbalance or problems with misalignment.

Due to thermal expansion or aggregation, the best state for the purpose of these tests is achieved at a stable temperature, so the imperative need for the measurement of vibrations for determining misalignment execute the operating temperature of the machine.

From the description of the angular and parallel mistuning, it can be seen that the frequency of the first, second and third harmonics important. It is important to accurately determine the speed of starting the machine and it is necessary to analyze the data in the horizontal, vertical and axial direction. Measurement in the axial direction is very important in determining the misaligned. Vertical and horizontal level can be very high, however, as opposed to the unbalance, it is not necessary to be equal (Figure 4). In fact, one will have more than twice the amplitude of the second.

Today, in the application, there are several methods by which it is possible to achieve acceptable results. These methods range from extremely primitive, such as optical evaluation methods Alignment, to methods that involve the use of lasers.

Generally, these methods can be divided into three groups:

- The optical method of eliminating misalignment
- Method using mechanical micrometer
- Laser systems for shaft alignment

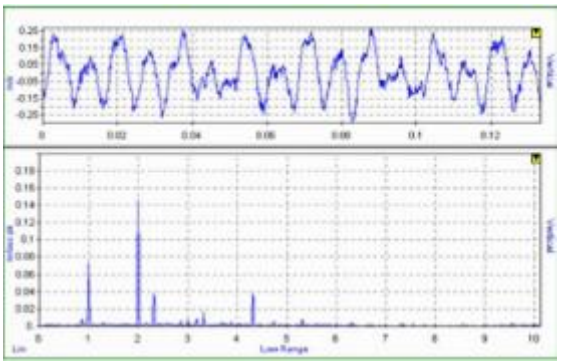


Fig. 4. Characteristic time and frequency range of vibrations that are the result of misalignment

Optical methods, quite often applied, Figure 5. Since the human eye, in terms of "resolution" is very limited and that can vary from person, alignment accuracy of this method is very limited. Correction values washers which are placed under the supports of the machine is estimated based on the experience of engineers with experience who analyzed the machine must be great to know. Sam correction procedure is performed from a number of attempts until the responsible engineer is judged that there has been sufficient quality of bringing in a common axis.

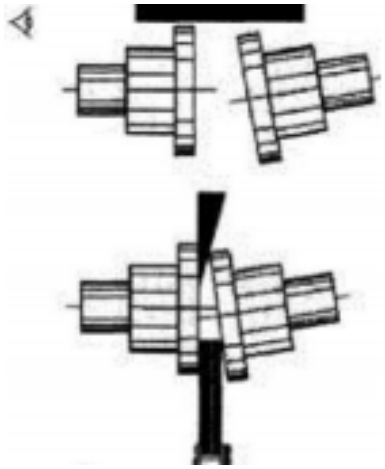
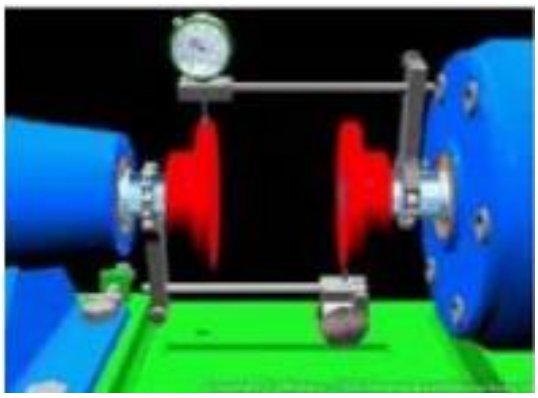


Fig. 5. The optical method of eliminating misalignment [4]

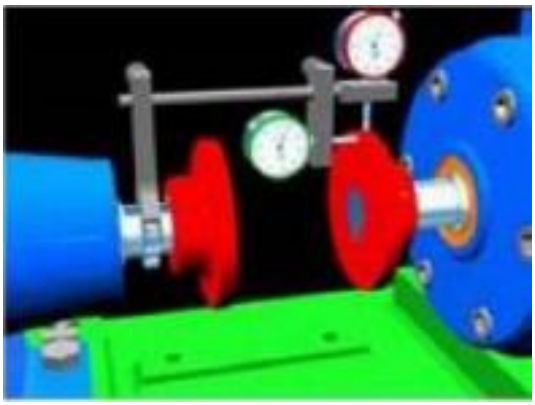
Method using mechanical micrometers in our engineering practice frequently used method of bringing the common axis of Figure 6. This method is significantly more accurate and more reliable than

the previous method, since it allows the measurement accuracy to 1/100 mm or 10 times more accuracy compared on the method. However, in practice it is usually a multiple alignment accuracy is reduced due to operator errors due to not taking into account the compensation of holders of mechanical micrometers. With this method, we distinguish between two basic ways of using mechanical micrometers:

- Rim face
- Reverse dial indicator



a) Reverse dial indicator



b) Rim face

Figure 6. The method using mechanical micrometers: a – method reverse dial indicator, b - method rim face [4]

Laser Alignment Method represents the most advanced method of eliminating misalignment, whereby the accuracy of the method is 1/1000 mm, Figure 7. No micrometers holders who can enter measurement error, there is no need for interpolation results and the subsequent calculation of the correction values, and what is very important, the method is very repeatable. Instead of mechanical micrometers, this method uses laser transmitters and detectors placed within the units are mounted on the shaft ends to be connected via connectors. The laser beam from each unit affects the surface of the recording laser (PSD - Position sensitive device) to another unit. Measured values are taken in three positions and these are usually situations "9-12-3" hours or, if the system allows the small corner that is. less rotating shaft. CPU shows the measured value at any time (both during measurement and during the application of a correction under the presser foot moving machines): the amount of parallel and angular misalignment.

Figure 7. Laser shaft alignment method using EasyLaser system Damailini [5]

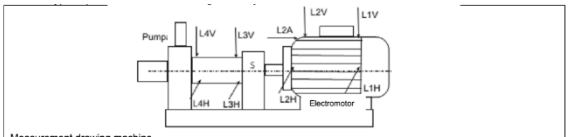
3 Elimination of initial inaccuracies

It is very important in engineering practice to develop tools based on risk as an element of management process and prevent the consequences of misalignment as an irregularity entered in the safety process. If we deal with objective reality will conclude that misalignment almost negligible facts at the end of the investment process. Control Organization - checks with a third party as a modern tool based on the quality of their managers is almost invisible. The investor usually takes care to close the financial construction, and technical problems leaves the service of maintenance and service of protection at work that take account of the security process. This is reason enough to be at the level of these business functions to develop a procedure that clearly involves checking the misaligned in the phase of taking technological equipment from suppliers - the producers, in accordance with the general directive on safety has imperative character. The reason is to check the residual risk estimates and the manufacturer gives to the management. Secondly, it creates the cornerstone for monitoring of technological equipment to ensure timely implementation of corrective measures and guidance level of risk acceptable to the authority of the owner of the process.

An example of the process of reconciliation - establishing alignment powertrain and working machines in the real model is presented in Table 1, on which are marked measurement points, and in Table 2. The characteristic frequency of misalignment system. In Table 3 are given the characteristic parameters of the system after the

establishment of alignment and in Table 4, characteristic frequency of the system after the establishment of alignment

Table 1 Typical parameters of the misalignment system

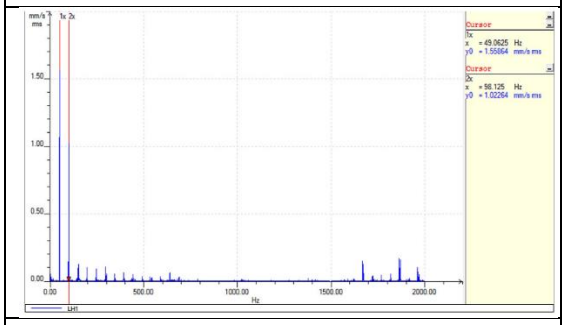


Measurement drawing machine

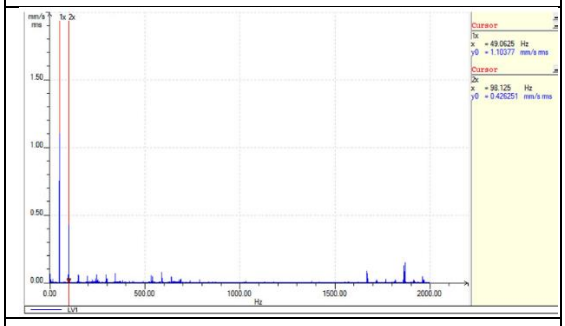
Pump		The Machine					
Manufacturer		Tip			Location		
Machine component		Measuring point					
ELECTROMOTOR		L1H	L1V	L1A	L2H	L2V	L2A
P_{em} = 7.5 kW	v[mm/s]	2,4	1,6		5,3	7,2	
N_{em} = 2940 °/min	BCU	0,24	0,3		0,1	0,28	
N_{emtre} = 2940 °/min	other parameters						
		L3H	L3V	L3A	L4H	L4V	L4A
PUMPA	v[mm/s]	4,8	7,4		2,8	3,3	
Npump =2940 °/min	BCU	1,07	0,86		0,75	1,2	
Npumptre=2940 °/min	other parameters						

Table 2. Characteristic frequencies of misalignment system

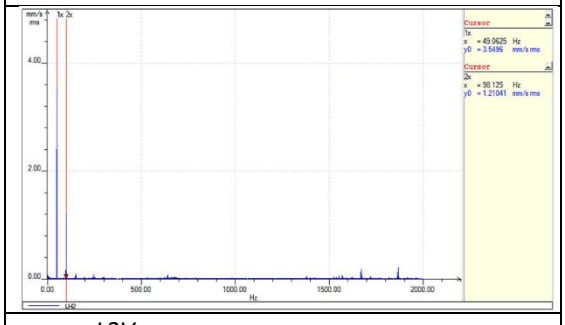
L1H



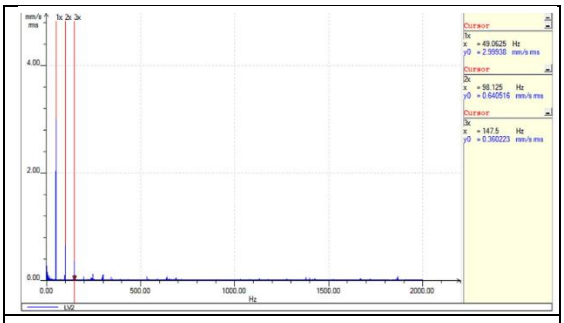
L1V



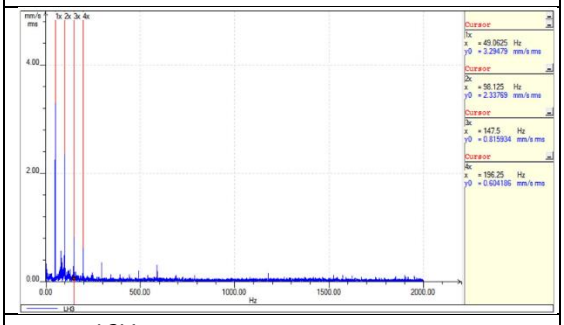
L2H



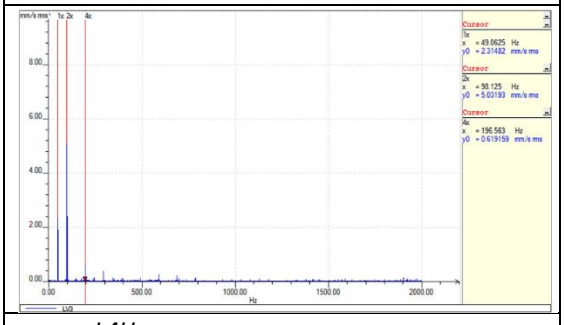
L2V



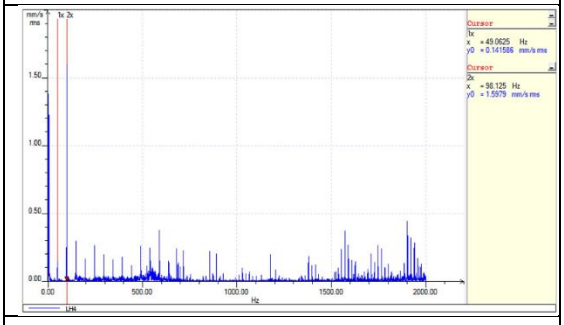
L3H



L3V



L4H



L4V

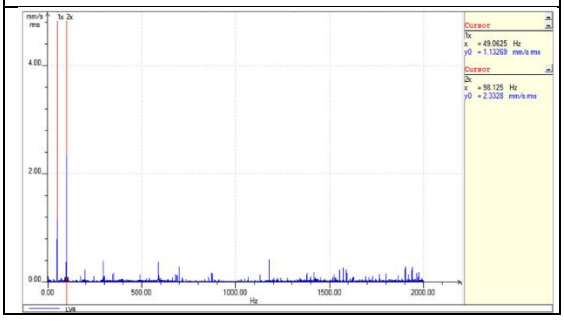
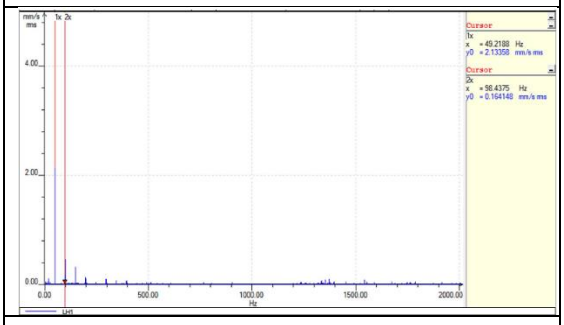


Table 3. Characteristic parameters of the system after the establishment of Alignment

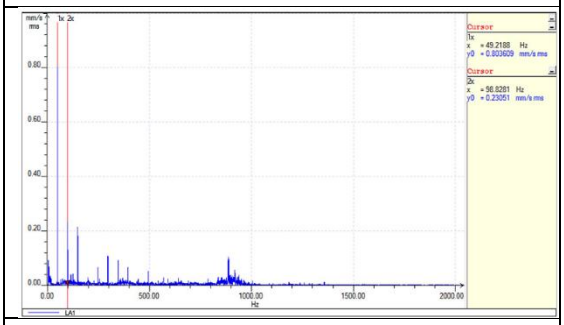
		L1H	L1V	L1A	L2H	L2V	L2A
ELECTROMOTOR P_{em} = 7.5 kW N_{em} = 2940 ^{0}/min N_{omtre} = 2940 ^{0}/min	v[mm/s]	2,4	1,5		1,5	2,3	
	BCU	0,24	0,23		0,1	0,28	
	other parameters						
		L3H	L3V	L3A	L4H	L4V	L4A
PUMPA *Npump =2940 ^{0}/min* *Npumptre=2940 ^{0}/min*	v[mm/s]	4,8	7,4		2,8	3,3	
	BCU	1,07	0,86		0,75	1,2	
	other parameters						

Table 4. The characteristic frequency of the system after the establishment of alignment

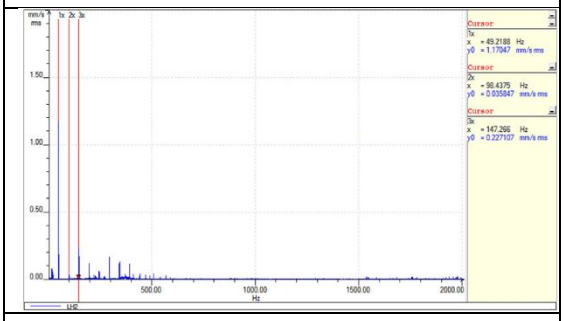
L1H



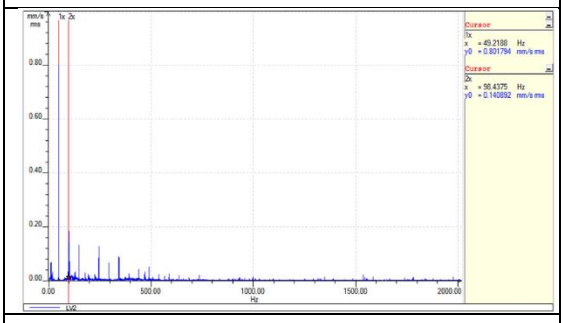
L1V



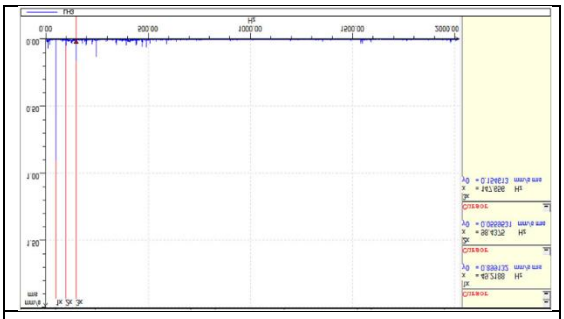
L2H



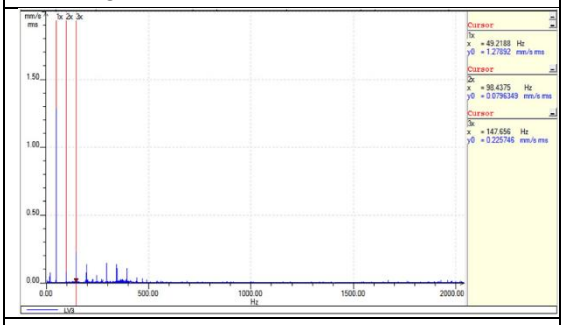
L2V



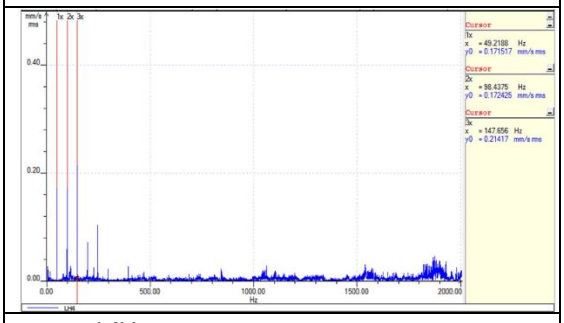
L3H



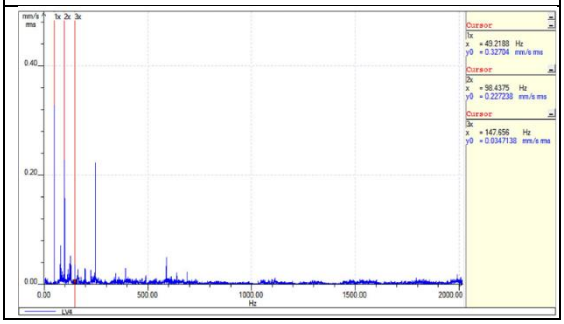
L3V



L4H



L4V



4 Conclusion

The main advantage of using vibration in the technical maintenance of mechanical systems is the possibility of timely detection of irregularities in the machine before What came to her unplanned outages, without the need to stop the machine and its dismantling during the implementation process of measuring, or monitoring changes in levels of vibration.

Proper analysis of data on vibration mode, creates a picture of the state of risk the development trend of the same function of time and the process of exploitation, which indirectly effectively mapping the production domain to continuous operation particularly complex and expensive mechanical

systems, as well as reducing maintenance costs. In addition, to meet the demands for providing higher efficiency, longer life, higher reliability and operating safety of mechanical systems.

Misalignment is undoubtedly the most common defect with the mechanical system, which vibrodiagnostic procedures and spectrum analysis notes, creating a platform for adequate and timely intervention, which provides techno-economic meaning the implementation of such activities in engineering practice.

References

[1] ISO 2041: Mechanical vibration and shock

[2] Mobius Institute – iLearn Vibration software

[3] The Rationale of Monitoring Vibration on Rotating Machinery in Continuous by Operating Process Plant, Brüel & Kjær, ASME paper No 71-Vibr-96

[4] http://mehatronika.gomodesign.rs/osnove-laserskog-poravnanja-vratila/ Accessed: 2016-5-29

[5] http://www.mesures-et-tests.com/p/4847/easy-laser-e530 Accessed: 2016-5-28

[6] Ličen H., Zuber N.: Prediktivno održavanje rotirajuće opreme na bazi merenje i analize mehaničkih vibracija, „Tehnička dijagnostika" - god.VI - br.1, Beograd, 2007

[7] Adams L. Maurice, Jr.: Rotating machinery vibration, Marcel Dekker Inc., New York, USA, 2001.

[8] Introduction to Vibration Measurements, Lecture Note, Brüel & Kjær Sound and Vibration Measurement A/S, Norcross, Georgia, USA, 2003

ALINIERE GREȘITĂ CA NEREGULARITATE INIȚIALĂ GENERATOARE DE RISC ÎN EXPLOATAREA UTILAJULUI TEHNOLOGIC

Rezumat *Conținutul acestei lucrări a fost conceput cu scopul de a prezenta o procedură de vibrodiagnostic pentru rezolvarea unei probleme specifice in cazul nealinierii pieselor mecanice, în cadrul conceptului de menținere a structurii mecanice prin modelul de întreținere proactivă, bazată pe risc ca o funcție a procesului de vibrație generat din punct de vedere tehnologic.*

Nealinierea, ca un fenomen care a însoțit procesul de creare și exploatare a sistemelor mecanice sunt în curs de dezvoltare ca fiind cel mai frecvent dezavantaj. Dacă nu sunt prevazute proceduri de diagnosticare poate avea consecințe grave atât pentru sistemul în sine, în ceea ce privește funcționarea precum si siguranța mediul înconjurător.