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# Digital System for Dynamic and Vibration Analysis of a Centrifugal Pump Using the Teknikao Sdav Software: A Case Study

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***Abstract*** *— The purpose of the paper is to explain how the measurement and vibration analysis software works. A virtual example and a real example were used, defining their initial configurations and analyzing the graphics resulting from the analysis from the vibration analysis software and thus presenting the results of both tests. Understanding how to operate the vibration measurement equipment and analyzing the data obtained from a previously established configuration, this learning about the operational knowledge of dynamic systems is extremely important because the problems become simple to be solved. The analysis was carried in a virtual and real situation, of the centrifugal pump motor vibrations in the SDAV software made available by the Technical website. The problem analyzed was the rolling of seven rotating spheres, this defect fits as a mechanical system with gap defect and with an intensity of one hundred percent. These settings are the parameters adopted to determine the frequency limits of the defect, the resolution of the graph and the number of readings to be taken. When starting, the software will perform all the analysis and measurement of the defect, returning the results in graphs. For the calculation of useful power, it is known that the electrical frequency was thirty-three hertz (33 Hz), which multiplied by sixty, the approximate value of two thousand revolutions per minute (2000 RPM) was obtained. According to the results shown in the graphs, the functioning of machine is excellent, is in perfect condition for use, not presenting light or serious failure.*

***Keywords*** *— **SDAV Software. Vibration. Centrifugal Pump. Vibration Sensor. Failure Identification.***

## I. INTRODUCTION

In engineering, to correctly understand the elements presented in vibratory systems and the physics involved in them is paramount for designing of structures and machines, for example. Although in many cases, in the study of vibratory systems it is not possible to analyze the system only with one degree of freedom, systems with two degrees or more are very little approached in General Physics books. [1]

The analysis of vibrational systems is very important in Physics and Engineering. In the latter, vibrations are present in the design of machines, structures and vehicles, for example. The applications of the study of vibrations are diverse, among which we can highlight the analysis of resonance curves to avoid collapse in structures and the search for adequate damping, stiffness and mass ratios to provide safety and comfort in vehicles. [1]

The theory fundamental of machine dynamics and vibrations is the study of free and forced vibrations in

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mechanical systems. These studies are useful because they establish basic definitions understanding of theory fundamental concept. Can also correspond a solution to many real problems situations in manufacturing plant.

Mechanics is a branch of the physical sciences that deals with the resting state or the movement of bodies subjected to the action of forces. Rigid body mechanics is divided into three areas, static, kinematic and dynamic. Static studies the conditions of bodies at rest, kinematics deals with the geometric aspects of movement and dynamics analyzes the relationships between forces (cause) and movement (effect). [2]

A mechanical vibration normally occurs when a system is moved from its equilibrium position. Generally, when the system accomplish a return under a reset action, it exceeds position. The repetition of this process is known as oscillatory movement. The time interval required for the system to complete a movement cycle is called the vibration period. The number of cycles for unit of time defines a frequency, and the maximum displacement of the system measured from it is equilibrium position is called the amplitude of vibration.

## II. THEORETICAL FOUNDATION

Industrial Revolutions, as they are called, do not happen frequently. Since the beginning of mankind, there were four industrial revolutions, the most recent being the fourth identified as such. The other three were identified only when they had already occurred, while the fourth is in full development. It is fundamental to all who work both in industry, as in any branch of activity, knowing this process and to prepare for the future that has already started. [3]

The implementation of systems that can be used to locate people and objects in closed environments is one of the issues that are being discussed as one of the topics of the industry 4.0. [4]

To assist in saving energy, several technologies are being used in from of designing automated systems. These systems corroborate the benefit of people's lives and contribute to the community in general. [5]

The increase of world requirements for improved products joined to growing competition between companies in the global market makes the same seek processes that ensure lower costs allied to high productivity and high quality product. [6]

The training of an engineering professional must be broad, in his training curriculum it must cover diverse knowledge that goes beyond the field of exact sciences. [7]

The study of mathematical modeling and the developed prototype of damped free vibrations is extremely important for the engineering student to put into practice his knowledge acquired in the classroom, and also to become familiar with situations that may come true within the market job.

In the midst of the emergence of so many technologies and an unbridled growth of industrial and commercial needs, solutions are constantly being developed and implemented in the most diverse branches of business in order to provide an increase in sales and production. [5]

Industry 4.0 and the Internet of Things (IoT) are terms frequently encountered which are so concomitant to future production, labor and business. Both are closely interlinked with the increase of interconnectivity provided from IoT present in factories intelligent. [4]

The data generated in the term "4.0" is fully virtualized, that is, all information is collected dynamically to facilitate decision-making based on the big data tool, is stored in cloud computing and, as previously seen, the information is obtained through the IoT interface and corresponding software and protocols. [8]

There are software and hardware integrations that need to be made from the point of the communication interface with the sensor, to carry the data through structures of data communication networks, short and long distance, in addition to being necessary perform integration with servers and database. [9]

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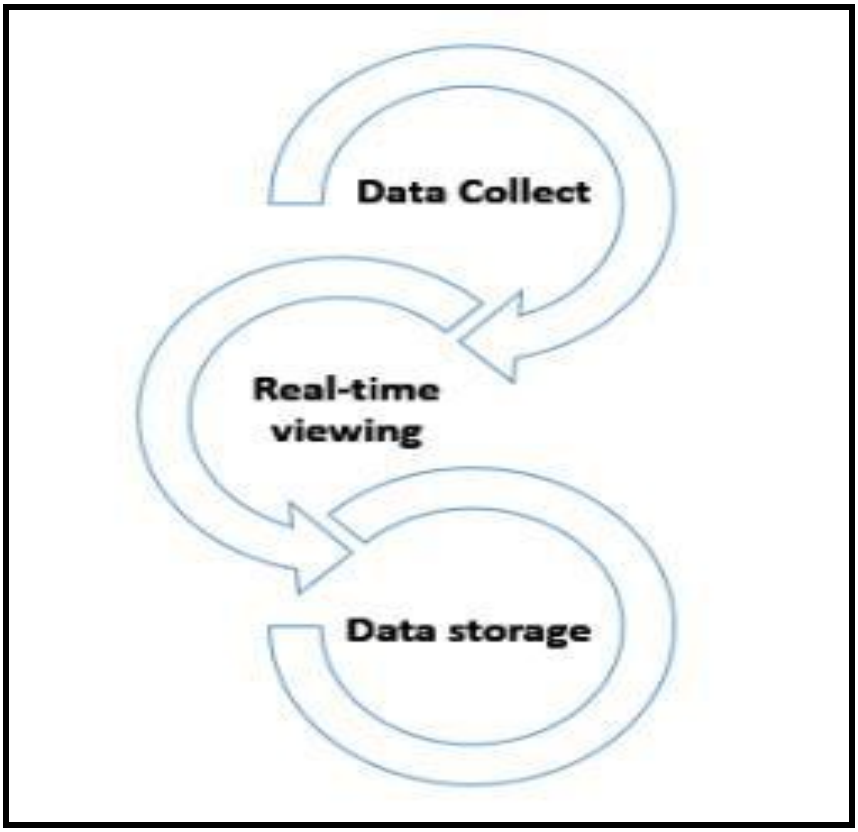


*Fig. 1: Control and Instrumentation. Source: [9]*

The future is intended to meet the demand for lead information directly to the local decision making, providing the metrological data for users of the equipment, for direct application in the production environment or field work, in real time. With all the technology and data available, intelligent and adaptive strategies of quality will be implemented, so the company earns a profit, productivity time, avoids wastage of raw material, uniformity in the batch produced and avoiding non-compliances. Assisting the manager of production and quality to create strategies to make decisions relevant to a good driving the production line. [3]

Due to the success achieved over time, there is a huge community of researchers and scientists who use this technology in their projects, because they are affordable, with easy acquisition of materials and sensors, applied in several projects. In some situations, controller boards can be developed independently without the need to purchase one in the national and international market. [10]

The fundamental paper objective is analyzing the functioning of software and to accomplish measurements with the equipment of vibration.

The analyzing of the data obtained from an previously established configuration is important, because with this learning the professional will have operational knowledge in real situations of failures and problems inside manufacturing plant.

This work contains analysis of a virtual and real situation of the vibrations of an engine in the SDAV software made available for free by the Tecnikao company website.

## III. METHODOLOGY

### 3.1 Virtual Machine Configuration

The simulation developed in the SDAV software, needs to make an adjustment in the virtual machine simulation shows in figure 2. The following parameters were adopted.

- Utilized RPM: 2000 RPM.
- Frequency in Hz: 33.33

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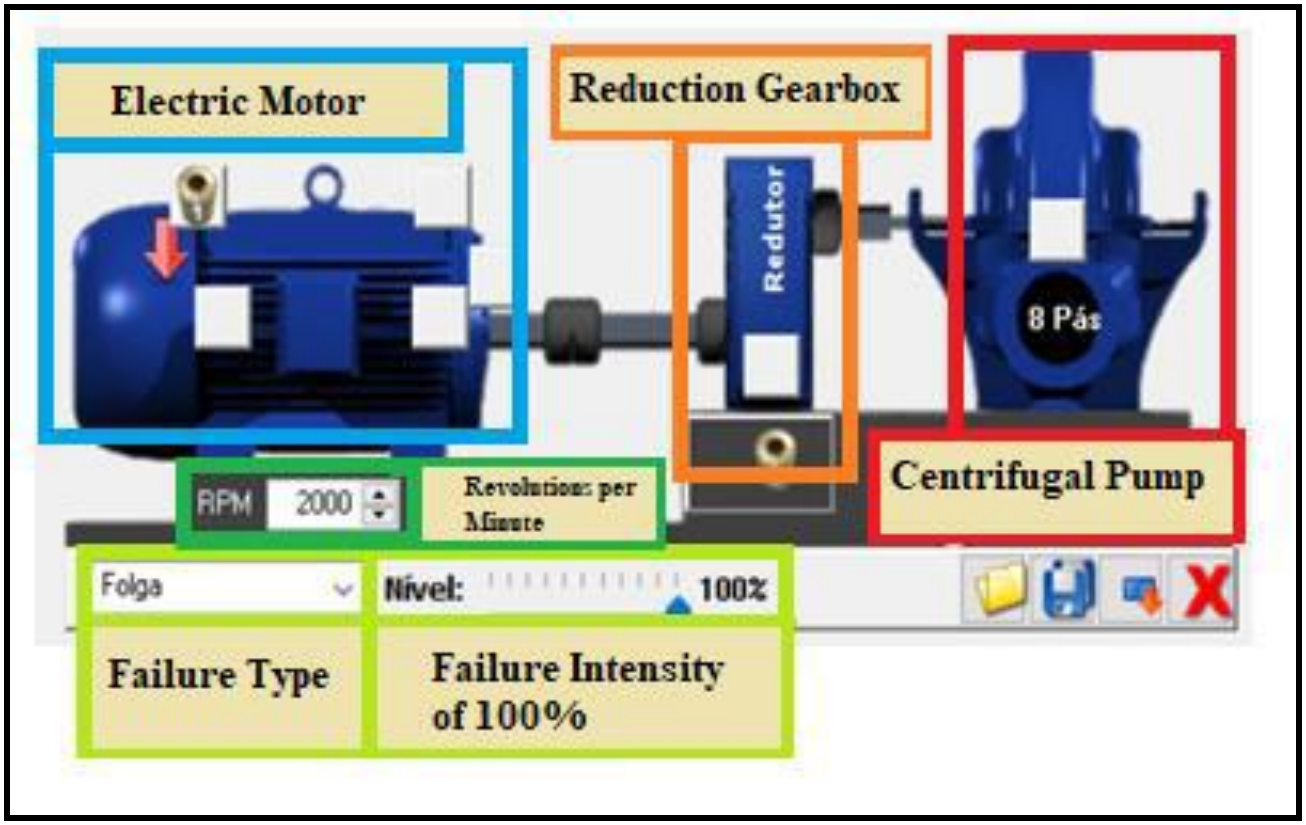


*Fig. 2: Virtual Machine Simulation. Source: Authors (2020)*

It is worth mentioning that frequency obtained through the RPM, divided by sixty. The Table 1 shows the settings used at software.

*Table. 1: Settings Used at Sdav Software.*

*Source: Authors (2020)*

| Data Used in the Software | | | |
|---|---|---|---|
| **Supplements** | **Speed** | **Envelope** | **Acceleration** |
| **Lines** | ***16 K*** | ***16 K*** | ***16 K*** |
| **Maximum Frequency** | ***500 Hz*** | ***1 Khz*** | ***500 Hz*** |
| **Averages** | ***3*** | ***3*** | ***3*** |
| **High Pass** | ***5*** | ***5*** | ***5*** |

The settings shown in table 1 are the parameters adopted to determine the frequency limits of failure, the resolution of the graph and amount of readings carried out.

The select defect was defect in bearing, with an intensity of 100%. When starting the simulation, software will do all the analysis and measurement of the failure, supply at graphs results, but results in a according to the configuration selecting of failure.

### 3.2 Speed and Acceleration

The Figure 3 and 4 respective, shows the speed and acceleration of the electric motor, with the obtained frequencies, it is possible to identify the specific failure in the item 3.4 bellow, can to observe best.

### 3.3 Envelope

The Figure 5 shows the graph of the envelope where, once again, it is possible to visualize the due failures, is possible visualize of peak frequency failures, frequency failures is of 5 Hz.

### 3.4 Failure Identification

In Figure 6 it is possible to notice the harmonic corresponding to the graph, it can be observed by the red dots in the frequency peaks.

How the virtual failure was stipulated at 100% and the failure frequency calculation is in 33.33 Hz, the gap failure is shown in the three graphs in 33.33 Hz frequency peaks, how stipulated.

At the highest peak is the failure determined in the bearing, if we multiply by sixty hertz (60 Hz), the same failure will be repeated cyclically.

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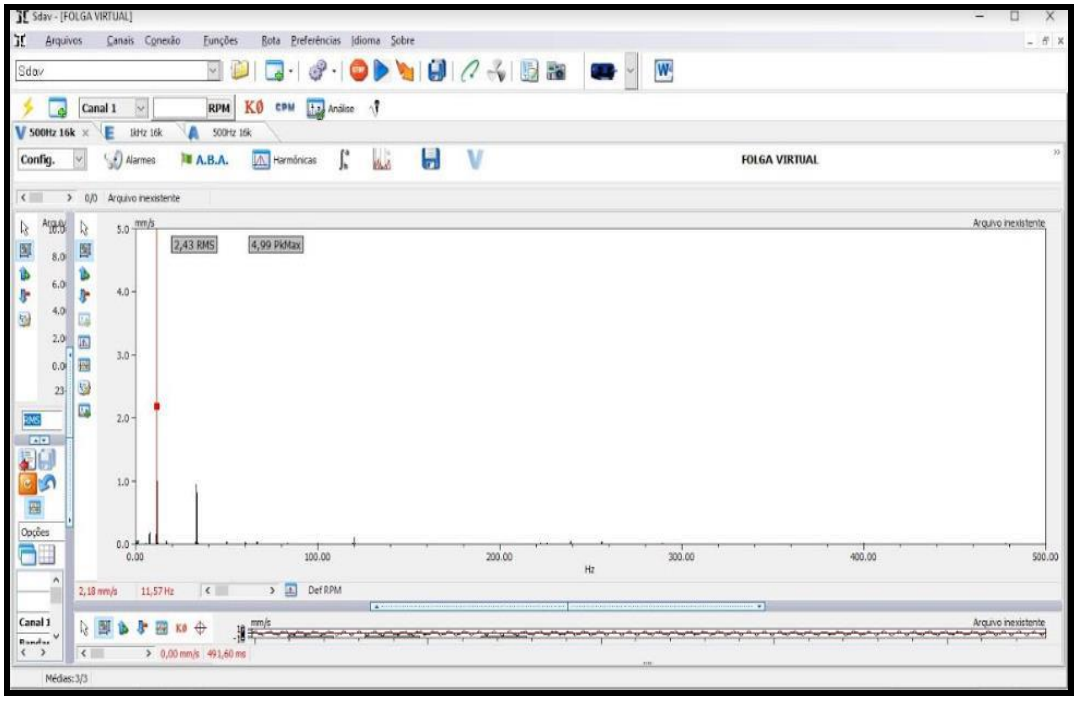


*Fig. 3: Speed window at Sdav software. Source: Authors (2020)*

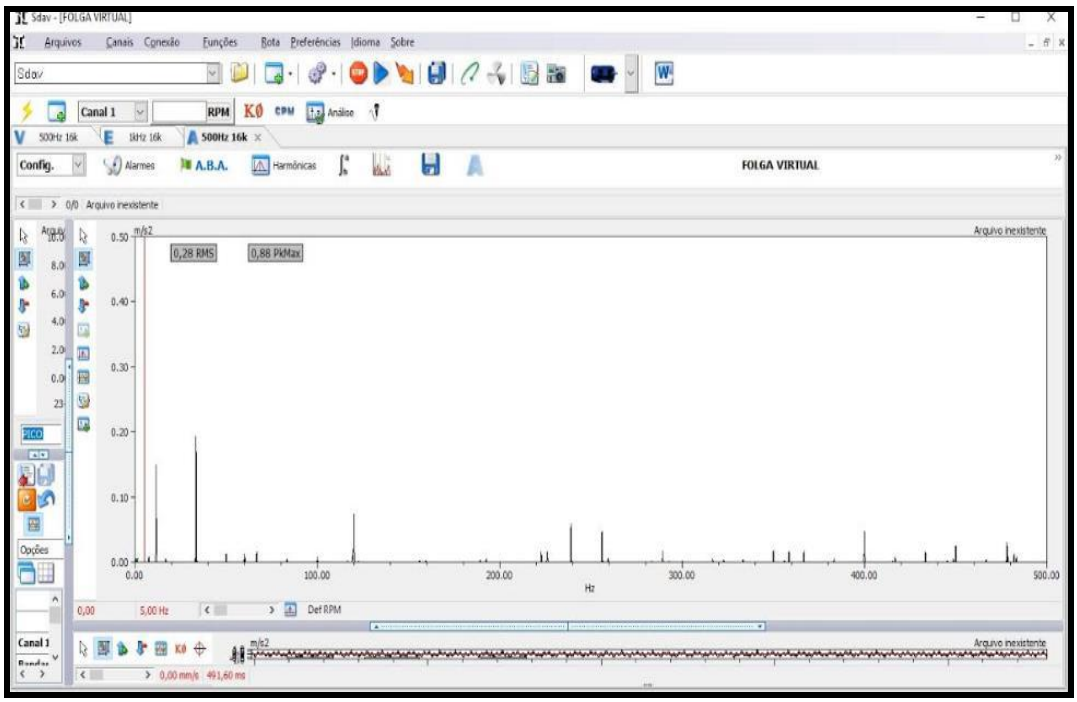


*Fig. 4: Acceleration window at Sdav software. Source: Authors (2020)*

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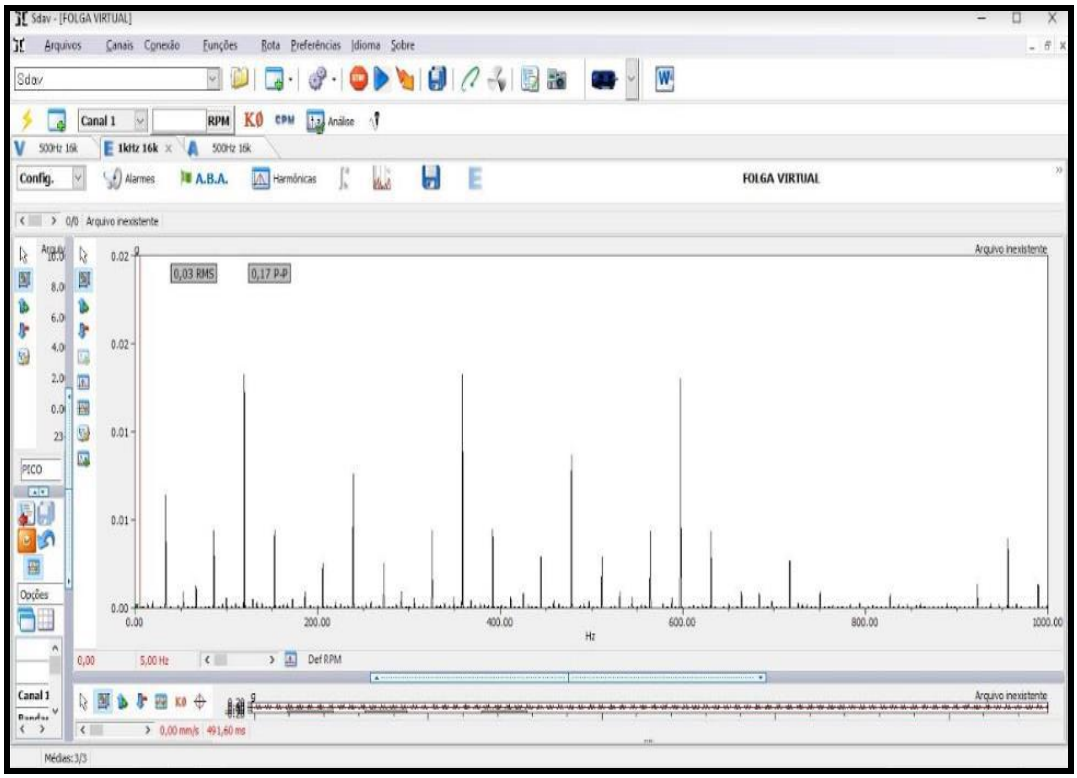


Fig. 5: *Envelope window at Sdav software. Source: Authors (2020)*

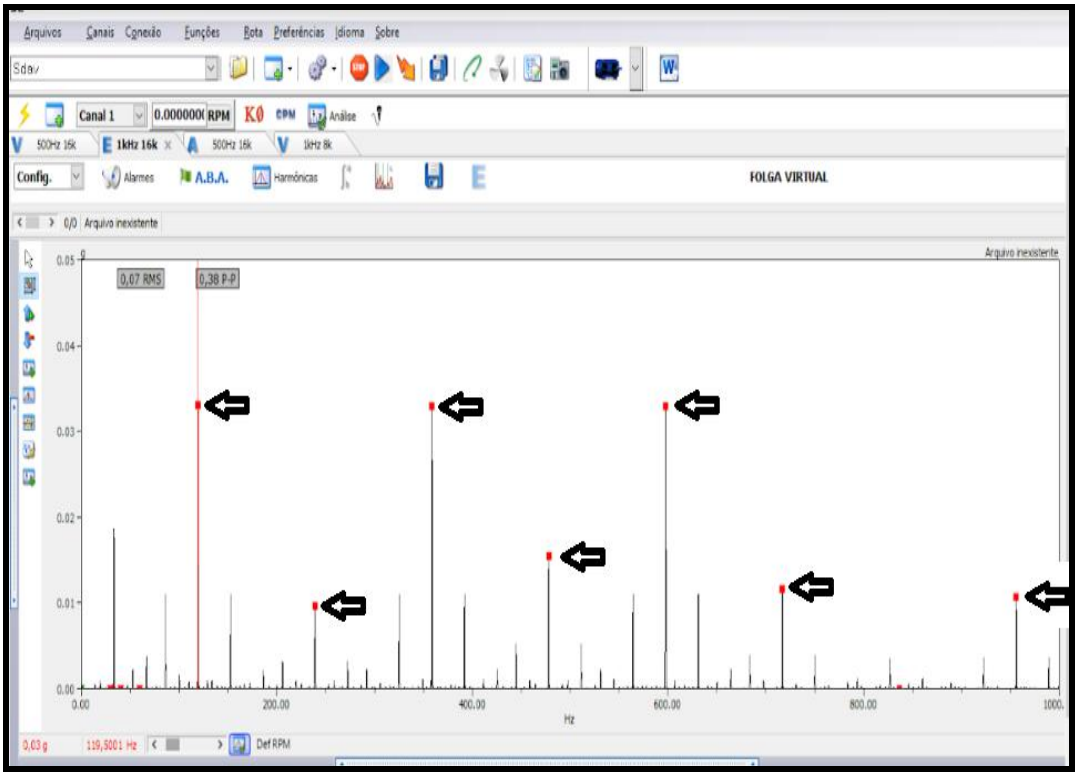


*Fig. 6: Failure Identification Window at Sdav software. Source: Authors (2020)*

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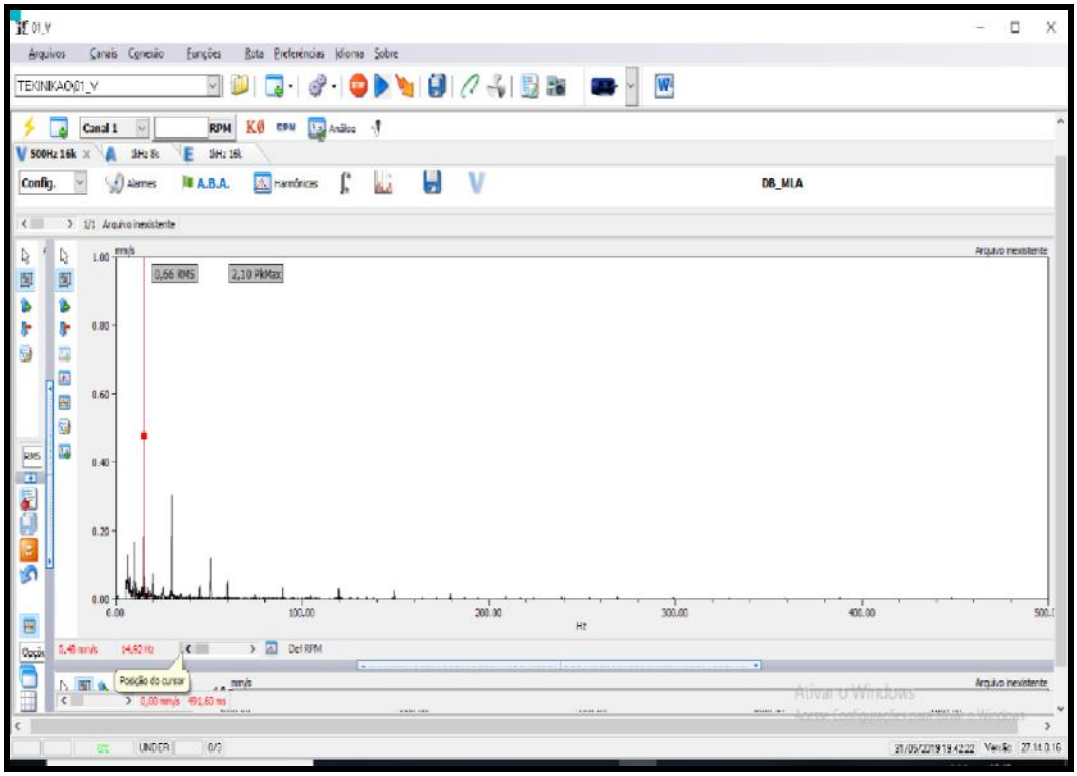


*Fig. 7: Speed Window Measurements at Sdav Software. Source: Authors (2020)*

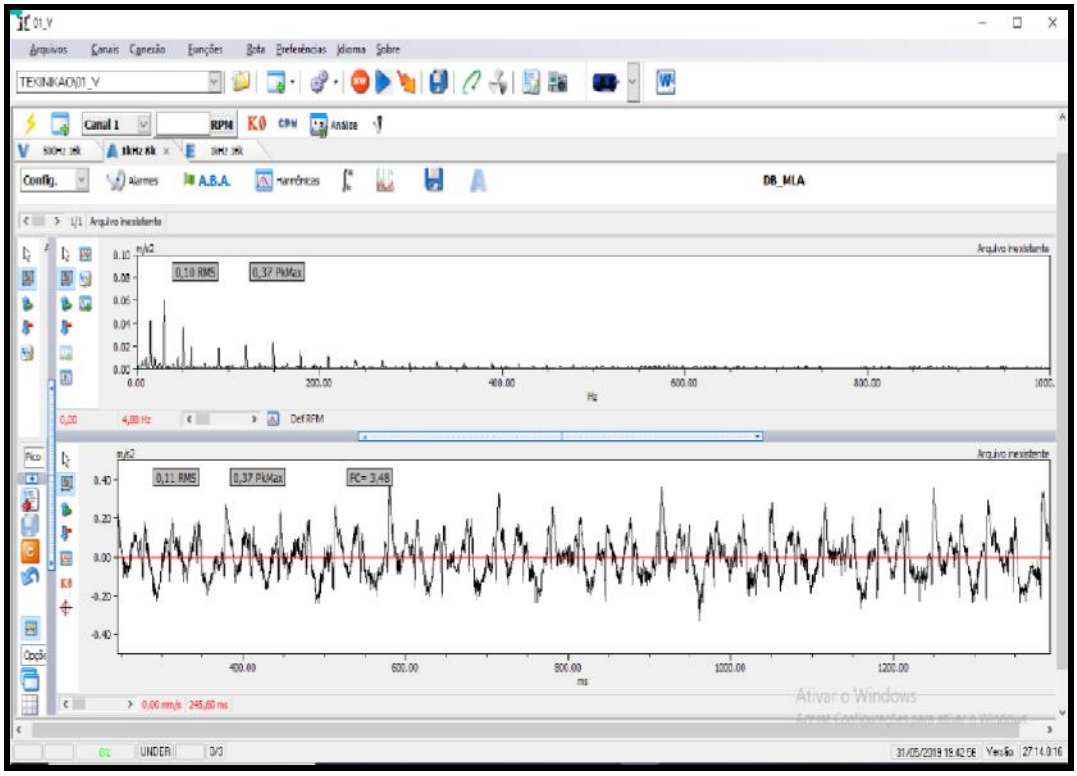


*Fig. 8: Acceleration Window Measurements at Sdav Software. Source: Authors (2020)*

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### 3.5 Analysis of collected data

The calculation of useful power of motor, it is known that the electrical frequency was thirty-three hertz (33.3 Hz), was multiplied by sixty, and we obtained the value of approximately two thousand rotate per minute (2000 RPM). The difference between the rotations real and virtual means the total energy lost or dissipated during the operation of the motor. According to the value compared to the graph in the image above, the engine is working fine. The machine is in perfect condition for use, without presents failure.

The importance of works of this nature demonstrate the results of interdisciplinary knowledge in engineering solutions under current demands in the presentation of viable alternatives that can be improved in future research and in the creation of products. [11]

## IV. RESULTS

### 4.1 Conclusion on virtual measurement

The work enabled us to learn to operate and to analyze data obtained through vibration analysis in a coherent way in to software and real test in laboratory. The program makes it possible to analyze and simulate damages such as bearings, reducers, faults, which can be analyzed separately or together.

It also favored the concepts maintenance predictive, being extremely important to using the equipment and sensors measuring, to monitoring the machines. These in order to obtain real data of the operation of the machine to facilitate failures visualization.

### 4.2 Configuring a Measuring the Rotating Assembly of a Real Machine

The centrifugal pump it is located in fluid laboratory of mechanical engineering department of UNISAL -Salesian University Center of São Paulo, the pump centrifugal was used to demonstrate analysis of vibrations in a real experiments, so using the software Sdav to applications of measurement vibration in machines reals. Important to mention the settings for the actual measurement are the same as used for virtual machine in software. The electric motor rotation speed is indicated by red points on envelope graph disposed in Figure 5. How machine chosen for actual measurement was a laboratory machine, which was recently purchased, that is, a new machine, expected result in equipment failures find is null. The datasets has were obtained through sensors fixed in the machine, together with the software configuration. The several parameters and data obtained to be analyzed and come to a conclusion to check on there is any failure.

### 4.3 Images of the equipment used

#### 4.3.1 Horizontal Measurements

- ***Speed***

Speed measurements, shown page 8 with figure 7.

- ***Acceleration***

Acceleration measurements, shown page 8 with figure 8.

### 4.4 Comparison of Results Obtained

In Table 2 shows the values obtained being compared.

*Table. 2: Comparisons of Values Obtained at Sdav Software. Source: Authors (2020)*

| Comparisons of Values Obtained | | | |
|---|---|---|---|
| Real | | Simulated | |
| *Speed* | *Acceleration* | *Speed* | *Acceleration* |
| *14,92 Hz* | *4,88 Hz* | *11,57 Hz* | *5 Hz* |

### 4.5 Tests and Field Measurements

To use the equipment, according to the specificities calculated and simulated in the virtual environment, these specificities can be designated as for example: RPM and frequency. It was necessary to use a variable frequency drive (VFD), because through this device it is possible to work electric motor of the pump run in a correct version of frequency, this case was 33.33 Hz, this frequency was designated in variable frequency drive (VFD), can to observed in Figure 9 the utilizing of the VFD.

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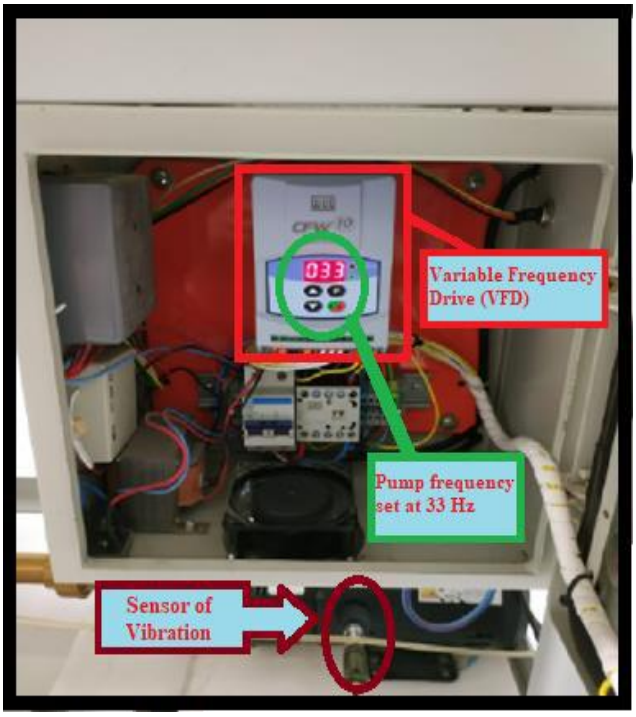


*Fig. 9: Frequency Specification at Measurements of Pumping System. Source: Authors (2020)*

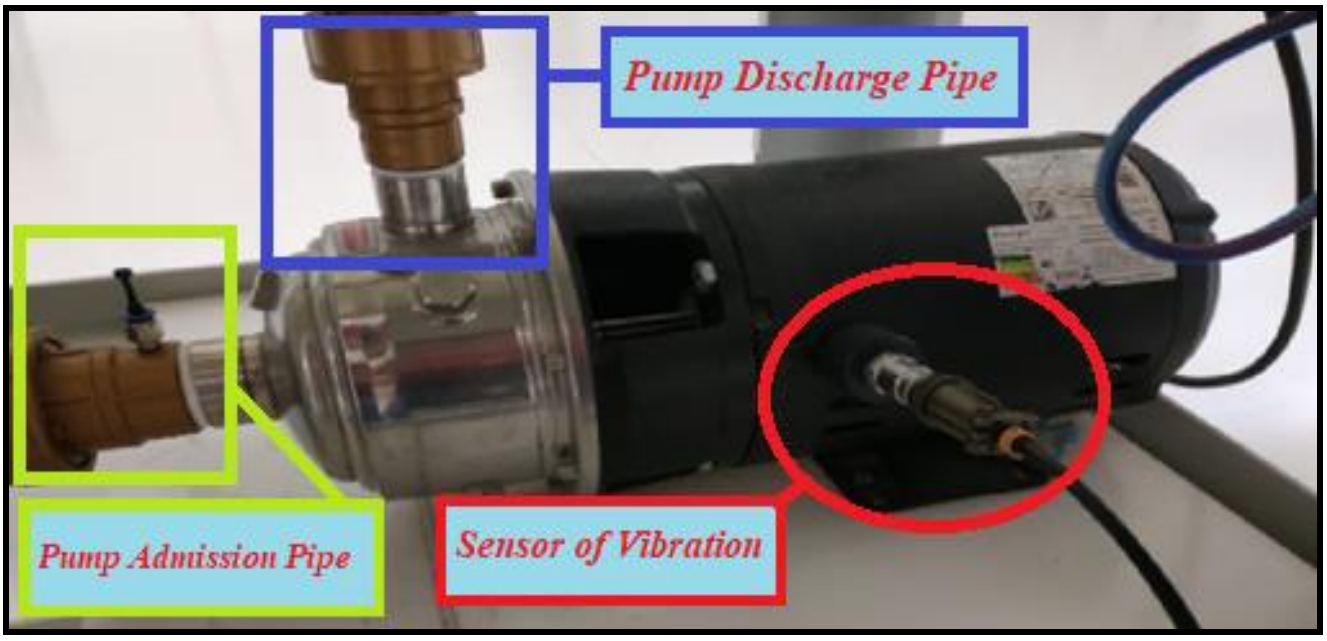


*Fig. 10: Vibration Measurements at Centrifugal Pump of UNISAL. Source: Authors (2020)*

Centrifugal pumps are far more ubiquitous than turbines in the turbomachinery market, therefore being more readily available to the consumer. [12]

It is worth mentioning that for the vibration measurement was using sensor horizontally position, the sensor of vibration was placed in perpendicular position of discharge pipe.

Other relevant factor that contributes to continuity of research and improvement of the prototype is that the municipality is located in the Paraíba Valley region, located in the state of São Paulo, consisting of a fertile and relevant scenario regional, national, international and multinational industry, thus concluding the effective ness for the industries. [13]

Thus, it is necessary that those responsible for the industrial process must fully understand the manufacturing process to which they are inserted. [14]

When companies seek to observe their production system, in order to see possibilities, realize the potential of lucrative opportunities exist through the insertion of technological innovations [15].

To search for new technologies and to map new scientific and technological developments capable of significantly influencing a scientific and technological institution, is the main role of technological prospecting [16].

Research and innovation through an articulated view of knowledge requires an inter, trans and multidisciplinary approach [17].

Most of innovation studies and researches are not related to innovation measurement and, in general, it only addresses some innovative actions in terms of products, services or processes. [18]

## V. CONCLUSION

The concluded that the analyzes made in the SDAV software were effective so that the student could have an experience with vibration analysis in a simulation software, learning to identify failures located in motors for that it is corrected, addition, the analysis performed on a real motor was extremely important, since the data obtained through a computer simulation and measurements carried out in fields, presented plausible and coherent results, validating the data analyzed virtually in the software and showing its effectiveness simulating complex mechanical systems and also being an auxiliary tool for the training of future engineering students.

## ACKNOWLEDGEMENTS

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