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# Application of Alternative Method for the Detection of Failures in Rotodynamic Systems

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**Abstract:** ***The main cause of an engine failure due to overheating is the increase in current, which, when increased, causes a decrease in speed.This research presents a current and velocity analysis using sensors as an alternative method for detecting faults. A data acquisition board and a development environment for obtaining information is sufficient to achieve the interpretation of graphs. Three studies were carried out in the simulation bank with different loads, which were unloaded, unbalanced and balanced in order to observe the operation of the engine under different operating conditions. With the graphical analysis the reliability of the proposed method was verified, which is offered as an alternative of analysis of rotodynamic systems.***

**Keywords:** Current, Speed, Sensors, Overheating, Graphics

## 1. Introduction

At present the industry is characterized by the enormous need to exploit effective and efficiently the installed machinery and this would not be possible not to correctly apply predictive maintenance. There are a large number of techniques and methods applied within the industry in predictive maintenance. These are used to detect faults in the components of the machinery, is generally applied to all rotodynamic components since from them you can detect any problem that can generate failures in the process or the possible loss of a component of the machinery.

There is a wide range of equipment that has been developed to help the correct application of predictive maintenance which are very efficient and with a high degree of assertiveness, thus, the price of these equipment's is very high and not all the factories manage to acquire equipment for the correct application of the predictive maintenance. For this reason, the objective of this research is to develop a method of predictive maintenance focused on rotodynamic equipment, that is reliable and that is of a low cost using a current sensor, barrier and a data acquisition card Arduino one and for data storage we use the Arduino IDE and Excel platform.

## 2. Methodology

### 2.1 Arduino

Arduino IDE is an open-source electronic prototype platform based on flexible, easy-to-use hardware and software. Arduino can capture the environment by receiving inputs from a variety of sensors and can affect its surroundings by controlling lights, motors and other devices.

Arduino software runs on Windows, Macintosh OSX and GNU / Linux operating systems. Most microcontroller systems are limited to Windows.

For this reason, we chose to enhance a program on the Arduino IDE platform that will facilitate the visualization of the behavior of rotodynamic equipment.

In the Arduino IDE platform were programmed the sensors used in this research, using formulas and functions for data acquisition. Figure 1 shows the function used to acquire data from the current.

**Figure 1:** Function for the acquisition of current data.

In the programming of the speed sensor H2A1, the mustard function was used in figure 2, which counts the interruptions that the encoder performs on the sensor and thus calculate the speed of the system.

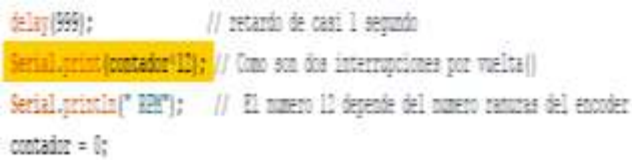

**Figure 2:** Function for the acquisition of speed data.

### 2.2 Current

It is divided into direct current (DC) or continuous and alternating current (AC). The direct current always flows in one direction, that is, from the negative pole to the positive one of the source of electromotive force (EMF) that supplies it.

The difference between the alternating current and the direct current is that the alternating current changes its direction periodically and, therefore, its polarity. Direct current (C.D.) is also called "direct current" (C.C.)

AC is the type of current most used in the industry and is also the one we consume in our homes. For the current detection we used the sensor SCT-013 that to give we data for the visualization of the behavior of rotodynamic equipment.

With the obtained one we can interpret the state in which is the rotodynamic system. As shown in Figure 3.

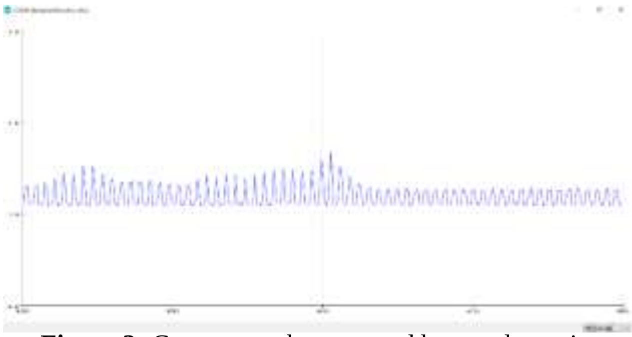

**Figure 3:** Current graph consumed by rotodynamic equipment.

On the figure3 can be visualized the current that gives us the rotodynamic prototype started and we can see that the equipment is in optimal operating conditions so there is no problem whatsoever.

### 2.3 Electromotive force (EMF)

It is called electromotive force (EMF) to the energy coming from any source, means or device that supplies electric current. This requires the existence of a potential difference between two points or poles (negative and positive) of said source, which is capable of pumping or driving electric charges through a closed circuit.

### 2.4Direct or continuous current

Direct current (DC) is one whose electric charges or electrons always flow in the same direction in a closed electric circuit, moving from the negative pole to the positive pole of an electromotive force source (EMF), such as in batteries, dynamos or any other source that generates this type of electric current.

### 2.5 Speed (RPM)

Revolutions per Minute (RPM) is the number of turns a rotating body completes around its axis every sixty seconds. It is usual to use the idea of RPM with reference to the operation of an engine.

#### 2.5.1 Speed

The concept of velocity is associated with the change of position of a body over time. When we need information about the direction and direction of movement, as well as how fast we turn to speed. We can observe the speed that gives us rotodynamic system on the figure 4.

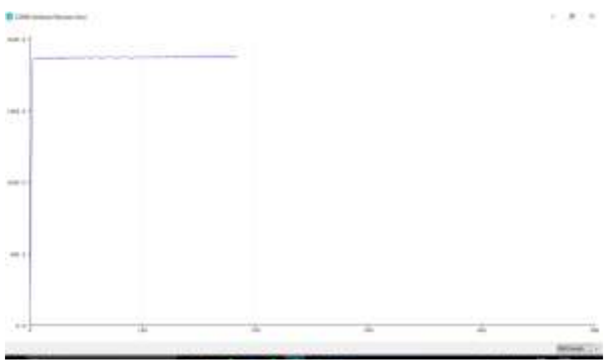

**Figure 4:** Speed Graph of rotodynamic system

As shown in the figure above we can visualize the behavior of the rotodynamic equipment and the equipment speed. We can see that the equipment is in optimal conditions to work and have no problem whatsoever.

### 2.6 Current sensor SCT-013

The sensor of the series SCT-013 as shown in figure 5 is a sensor that works as a transformer, the current that flows through the cable that we want to measure acts as the primary winding (1 loop) and internally has a secondary winding which depending on the model can have up to more than 2000 turns.The number of turns represents the relationship between the current flowing through the cable and the one delivered by the sensor, this ratio or ratio is the difference between the different sensor models SCT-013, in addition they can have a load resistance at the output in this way instead of current is worked with an output voltage.

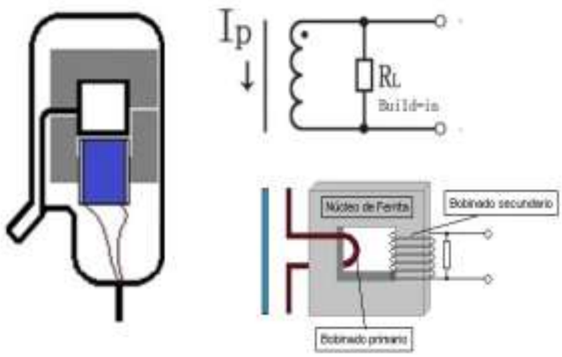


**Figure 5:** Sensor of the series SCT-013

One advantage of the SCT-013 is that we do not need to interrupt (cut or unplug) the cable that we are going to measure, because just like a clamp has the broken core. The current sensor was used to obtain the current consumed during the tests and to obtain the necessary data to structure this alternative method. On the other hand, it is a very commercial sensor and can be acquired with ease.

### 2.7Barrier Optical Sensor H2A1

A photoelectric sensor or photocell is an electronic device that responds to the change in light intensity. These sensors require an emitter component that generates light, and a receiver component that perceives the light generated by the emitter. All the different sensing modes are based on this operating principle. They are specially designed for the detection, classification and positioning of objects; the detection of shapes, colors and surface differences, even under extreme environmental conditions. Light sensors are used to detect the light level and produce a representative output signal with respect to the amount of light detected. A light sensor includes a photoelectric transducer for converting light to an electrical signal and may include electronics for signal conditioning, compensation, and formatting of the output signal.

**Figure 6:** Barrier Optical Sensor H2A1

The H2A1 optical barrier sensor was used to measure the speed at which the rotodynamic system was working and to display the data acquired by the sensor on a screen. We opted for this sensor as it is commercial, very low cost and we can easily acquire it.

### 2.8Encoder

Opto-switches are simple sensors.One end contains an infrared emitting diode, while the other contains a phototransistor that receives the signal. When an object passes through the slot it interrupts the beam of infrared light, which is detected by the phototransistor.

Opto-switches are widely used as a string to detect the speed of rotation and position of a motor shaft. For this purpose, a disc with grooves coupled to the shaft is used as shown in figure 7.

It is also possible to use a transparent sheet on which black stripes are printed, something that is frequently found in printers.

**Figure 7:** Disk with slots (encoder).

In addition to being used as encoder, an opto-switch can be used to detect any type of object that interrupts the beam, for example, to detect the closing of a door, or as an optical limit switch in the movement of a machine.

A string with dimensions determined for the optical sensor of barrier H2A1 and to the measurement of the arrow of the rotodynamic prototype was designed. As shown in Figure 8.

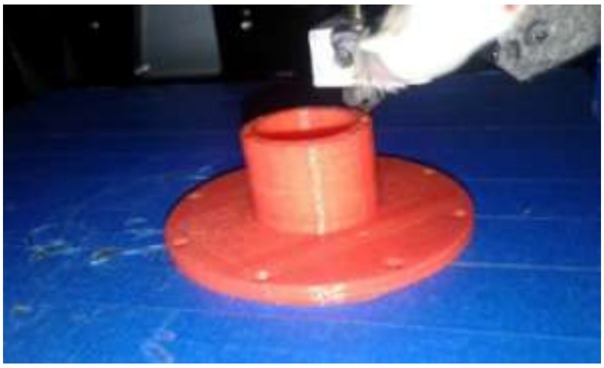

**Figure 8:** Encoder designed to measure speed.

### 2.9 Solid Works

SolidWorks is a 3D mechanical design program, with which you can create 3D parts using parametric solids, the program is focused on the design of mechanical parts, assemblies, and workshop drawings. SolidWorks has a design form in which it leaves a history of operations so you can refer to them at any time.

SolidWorks has solutions for the plastics, thin film, electrical, simulation and finite element analysis industries, the program includes an intelligent design error detection module and modules for sustainable design.

As a 3D design tool it is easy to use, it accompanies the mechanical engineer and the industrial designer in their daily performance.

With SolidWorks you can design mechanical parts in 3D, evaluate assemblies of various parts and produce drawings for the manufacture of parts for the workshop, in addition you can handle the design data in your PDM management system and take control of drawings versions.

SolidWorks was used for the design of the encoder (as shown in figure 9) with dimensions determined for the optical sensor of barrier H2A1.

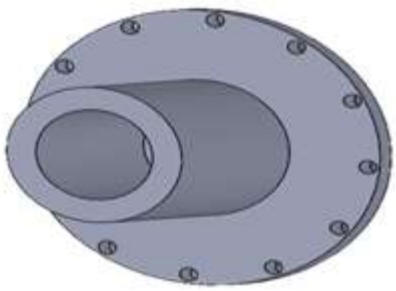

**Figure 9:** Design of the encoder in SolidWorks

In order to implement the method of fault detection in rotodynamic equipment, the above mentioned sensors were placed on the support of this equipment and in the power cable.

Based on this they were programmed in the platform of Arduino IDE each with certain programming. The circuit was performed on a test board (protoboard) which had electrical devices connected according to the diagram of each sensor as shown in figure 10.

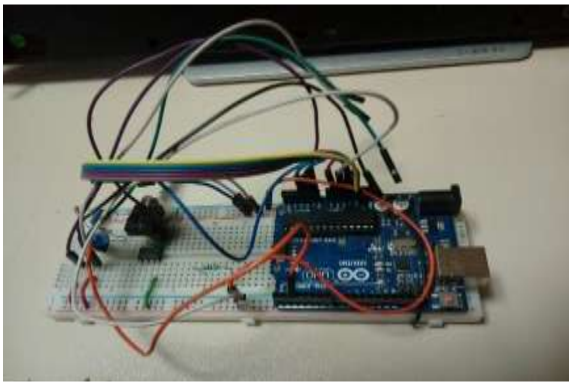

**Figure 10:** Connecting the sensors to the test board.

After several attempts it was possible to obtain a programming in which it was able to store the necessary data, which through graphs showed the behavior of the rotodynamic system in progress. The results shown were the first reading and, failing that, the basis that indicated the current state of the rotodynamic system.
The speed sensor (barrier optic H2A1) was mounted on the base of the system, as shown in figure 14, and with it we performed 3 speed tests in different working conditions of the system; the first test was focused on measuring the rotodynamic system in vacuum (without any load), the second was performed with unbalanced load and the third was performed with balanced load.

In order to carry out the second and third tests, a stability disc was placed that contained eight holes correctly distributed by its radius, which was assembled to the arrow of the rotodynamic system, this stability disk was added screws with a number of nuts according to the test performed, this in order to simulate a load X to generate the balance and unbalance of the system.

**Figure 11:** Disc with balanced load

**Figure 12:** Disc with unbalanced load.

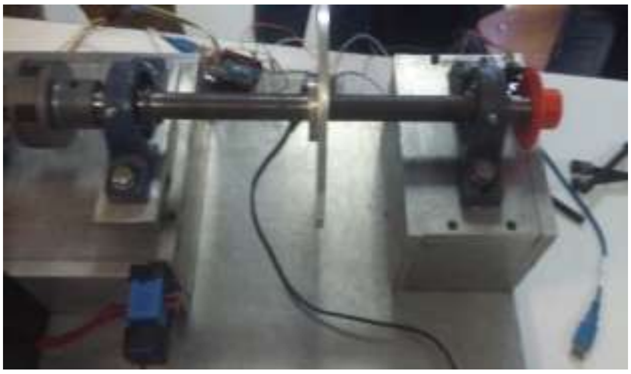

**Figure 13:** Stability disc and arrow of the rotodynamic system

Each one that added a certain amount of load was verified the behavior of the rotodynamic System in the generated graph.

**Figure 14:** Positioning of the optical barrier sensor

The current sensor (SCT-013) as previously mentioned,was mounted on the power cable as shown in Figure 15. With the current sensor, the same tests were carried out to observe the behavior of the current transmitted by the prototype when it was started without load (in vacuum), unbalanced and balanced.

**Figure 15:** Position of the current sensor.

In the same way in the Arduino IDE platform we had to realize a program based on the connections of the current sensor, with the programming was able to collect data and interpret them in graphs in the screen of Arduino IDE as it was realized with the speed sensor, these data collected in Arduino IDE we used to re-graph in Excel, this in order to make our analysis more accurate.

Thanks to the graphs obtained from the two sensors, we made our proposed method more reliable.

## 3. Results

To validate the alternative method of fault detection in rotodynamic systems, we generated graphs with the data obtained from the program, to compare the behavior of the rotodynamic system in the different working conditions to which it was exposed, and to give a verdict on how to identify the faults in these systems with the help of the current sensor SCT-35 and of barrier H2A1.

In the following graphs, we can observe the behavior of the rotodynamic system that was subjected to different tests:

### 3.1 First empty test (no load)

Figure 16 and 17 show the current and velocity graphs, which were constant during the first test. By observing these graphs we can deliberate that: Because there is no excessive consumption of current and have a constant speed, the rotodynamic system finds optimal working conditions.

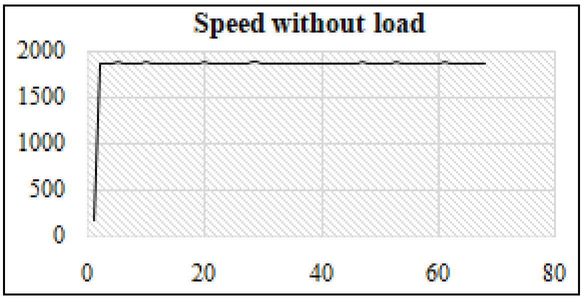


**Figure 16:** speed of the rotodynamic system without load

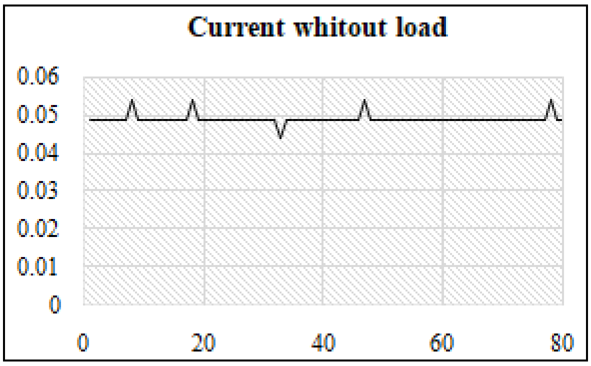


**Figure 17:** Current (mA) in the rotodynamic system.

### 3.2 Second test with unbalanced load

In Figure 18 and 19, the graphical behavior of the rotodynamic system is observed during the second test, which was unbalanced. In the graph of velocity they show us how tends to have variations during the test, and in the graph of current shows us an increase of the consumption along with a variation.

With these results, we deliberate that: When placing an unbalanced load, the system had a behavior outside the parameters of operation established by the first test performed.

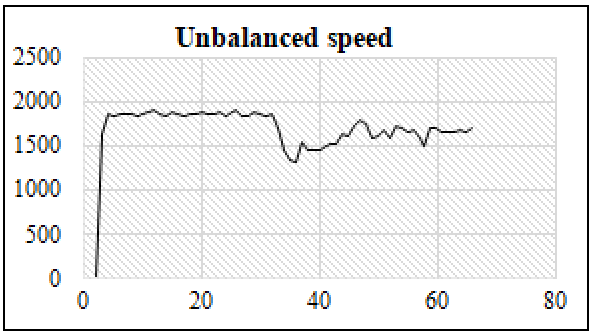


**Figure 18:** Rotodynamic system velocity with unbalanced load.

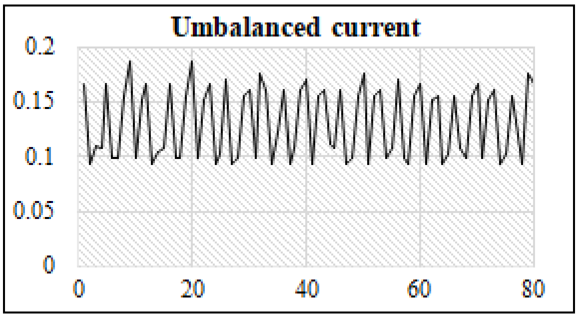


**Figure 19:** Rotodynamic system current with unbalanced load

### 3.3 Third test with balanced load

Figure 20 and 21 show the velocity and current graphs, respectively, which resulted from the third test performed in the rotodynamic system with balanced load, and it can be seen that the behavior of this, as in the second test, that the system slowed to reach the operating speed but was more constant during the time it was in operation, while the current was elevated, but not as it happened during the second test, and it remained more constant during the time of which was in operation.

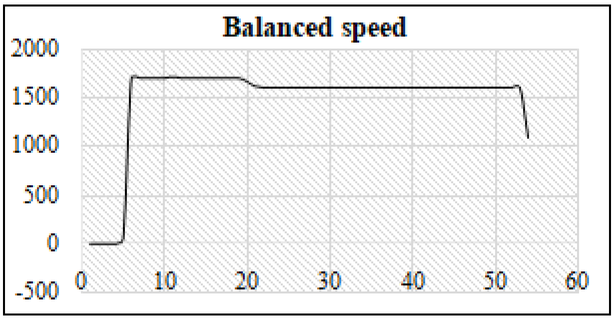


**Figure 20:** Rotodynamic system velocity with balanced load.

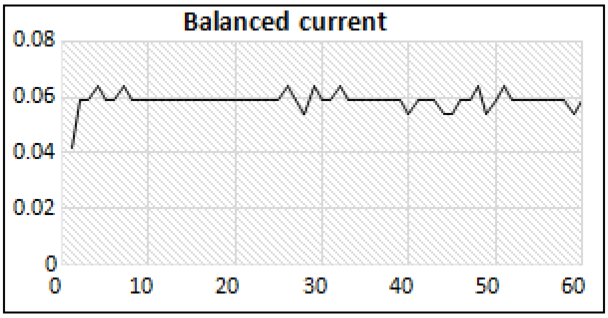


**Figure 21:** Rotodynamic system current with balanced load.

## 4. Conclusion

In this research, an alternative method was proposed to identify rotodynamic system faults through current and velocity sensors. With the results obtained by performing three tests in the simulation bank with different loads, the operation of the system was observed under different operating conditions. With the graphical analysis the reliability of the proposed method was verified, since they are notary the changes and very significant in the behavior of the system, as they are, increase and variation of the consumption of current, a ramp in increase of speed of greater length and the variation of the same variable, during the second test.

## 5. Future Scope

Since our method is an alternative new for detection of failures, in future you can add different sensors for the analysis of other variables, such as vibration and temperature, which affect the behavior of rotodynamic systems. The analysis of these variables additional method would be more accurate in the detection of failures.

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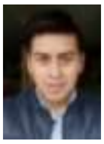

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