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Design and Realization of a Test Bench for Balancing and Diagnosis of Faults

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Abstract: *A test bench makes it possible to put a product in conditions of use. Under laboratory conditions, making changes is safe, because final users are not involved.*
The test bench is a functional physical system, intended to verify and/or validate the properties and functionalities of the product, throughout the manufacturing process until its final form.
In our case, the Test system that we are going to build is for balancing testing and diagnosis, it contains two different parts, and the first one could test only the upper parts shaft and the two discs, for the second one also
The aim of this paper is the study and realization of a balancing test bench. This wheel balancer is modular with interchangeable parts. The latter helps to take measurements and analyze vibrations to find better solutions. For example, engines, motors, discs, and turbines develop characteristic inertia effects that can be analyzed to improve the design and decrease the possibility of failure.
.In this paper, the processes of mechanical design, 3D designs, and the realization of the test bench are tackled.

Keywords: *Imbalance, Vibration, reducing vibration, rotating machines, test bench, technological system.*

1. Introduction

An unbalanced rotor will tend to vibrate while it is spinning. We measure the unbalance by measuring this vibration. However, not all vibration is caused by rotor unbalance. From this we must realize that to understand balancing we first need to have some knowledge of vibration.

High levels of vibration caused by unbalance can cause increased high consumption of energy and reduced system service life.

Unbalance is the most common source of vibration in rotating equipment. Vibration due to unbalance occurs at a frequency of 1 × rpm of the unbalanced element, and its amplitude is proportional to the amount of unbalance.

A test bench makes it possible to put a product in conditions of use, it's an isolated, controlled environment, very similar to the production environment but only for engineers or students for study cases, therefore making changes is safe, because final users are not involved.

The test bench is a functional physical system, intended to verify and/or validate the properties and functionalities of the product, throughout the manufacturing process until its final form.

The aim of this paper is the study and realization of a balancing test bench. This wheel balancer is modular with interchangeable parts.

In our case, the Test system that we are going to build is for balancing testing, it contained two different parts, the first one could test only the upper parts shaft and the two discs, for the second one includes also the transmission via belts, the reducer and it may contain other systems like chain transmission in output [2].

2. Conception and realization

In this step, we had to brainstorm the most suitable solutions for our project based on our needs a. In this part we went through many processes starting from sketching, CAD designing, production, and assembling, we faced some obstacles that sometimes lead us to look for other solutions.

In the end, to reach out our goal and finishing the test bench we used manufacturing machines and different materials.

We will try to give you a general idea of the whole project.

CAD software: Solidworks is the used software, SOLIDWORKS is an industry-leading CAD (Computer-Aided Design) and CAE (Computer-Aided Engineering), Known for its range of features and high functionality. SOLIDWORKS uses parametric design; it's an effective tool for designers and engineers. This means that the designer can see how changes will affect neighboring components or even the overall solution [3].

As resources we used these two known websites where you can find some ready pieces and modify them based on what you need: McMaster-Carr [4] and Grabcad [5].

2.1 Conception

For the conception, we obtain after applications:

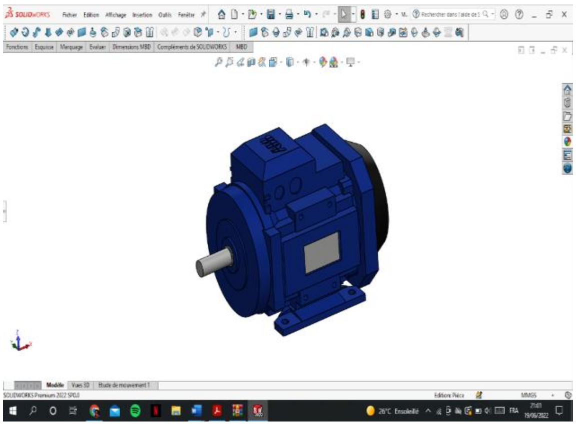


Fig.1: 3D design of the motor

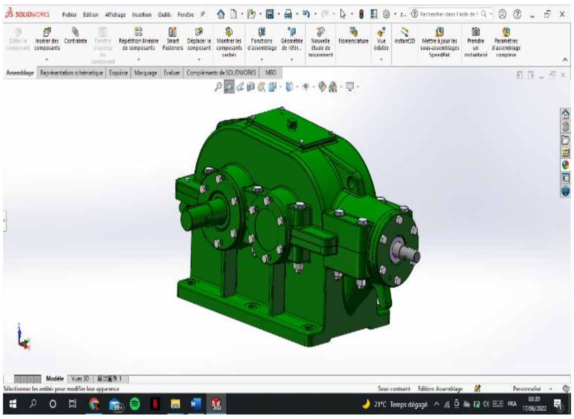


Fig.2: 3D design of the reducer

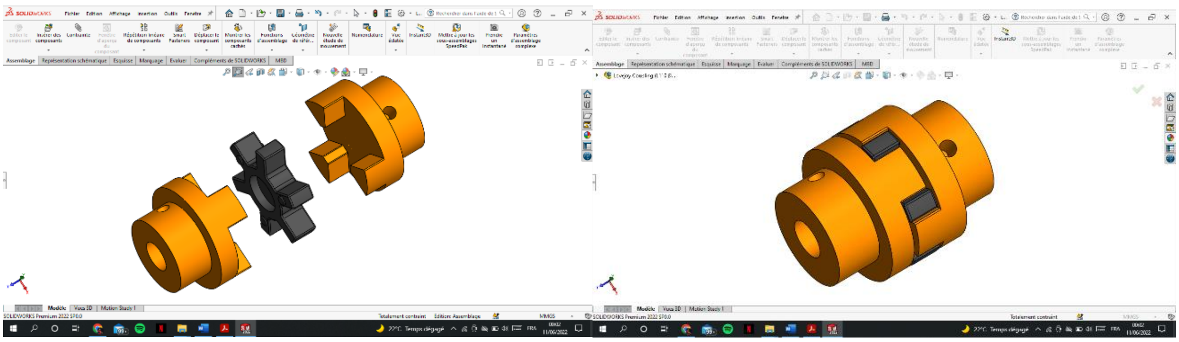


Fig.3: 3D design of the JAW coupling & (exploded view)

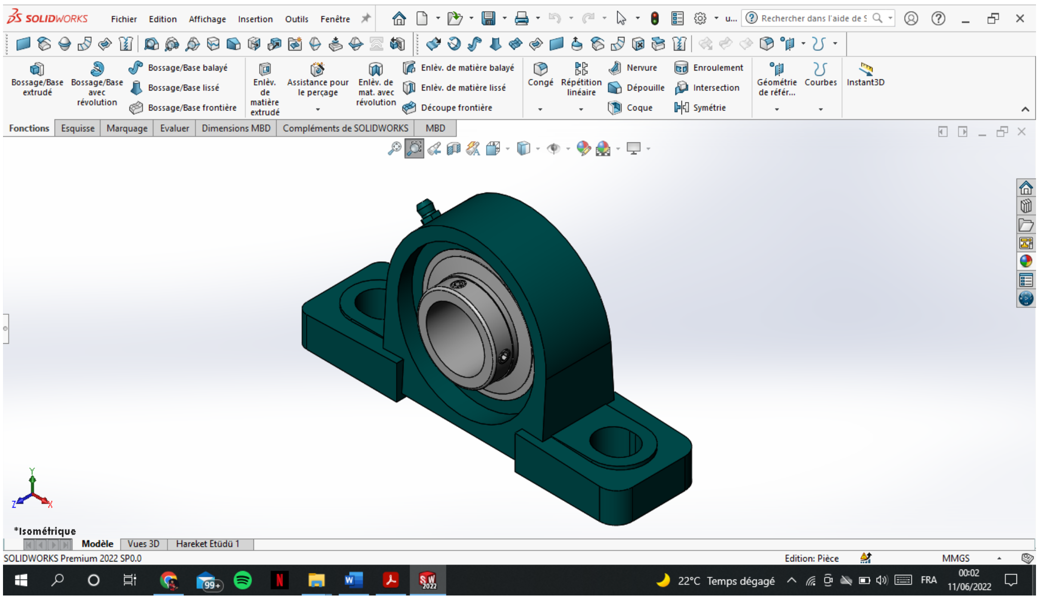


Fig.4: 3D design of the block bearing

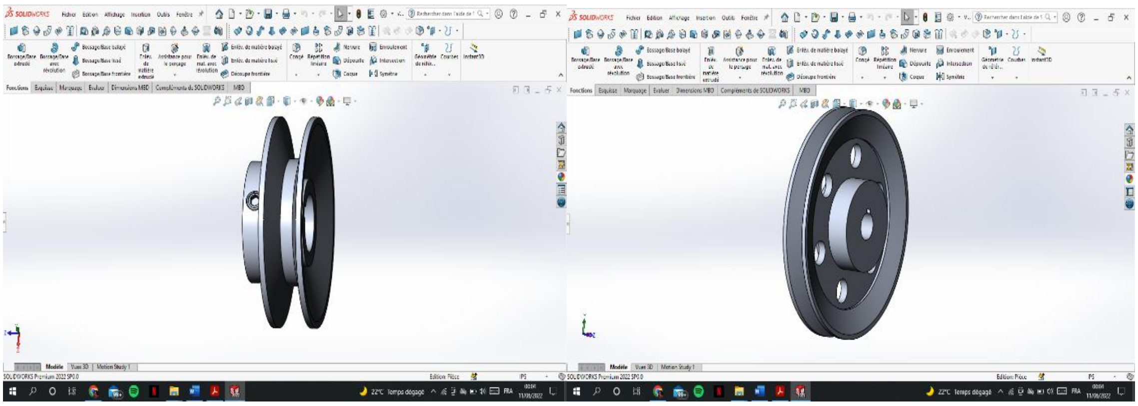


Fig.5: 3D design of the driving and driven pully (80mm) & (160mm)

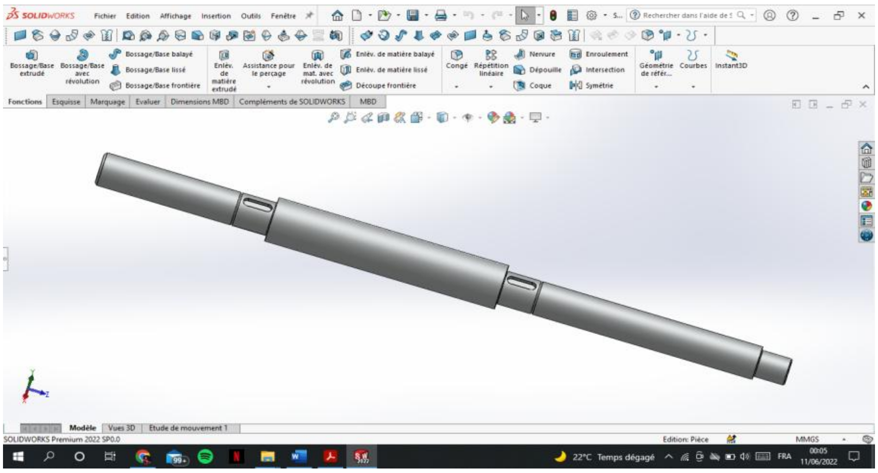


Fig.6: 3D design of the shaft

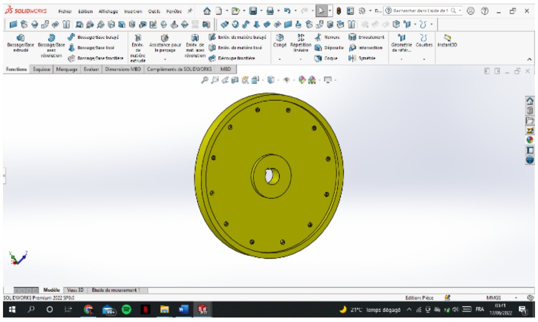


Fig.7: 3D design of the disc

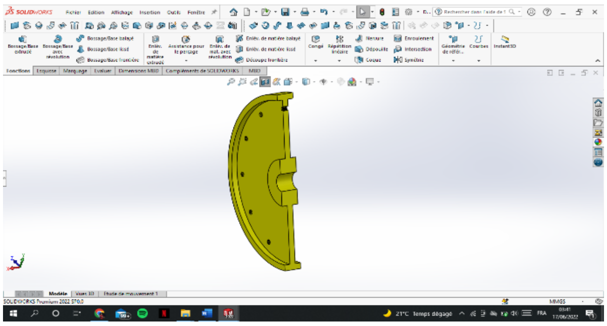


Fig.8: 3D design of the disc (sectional view)

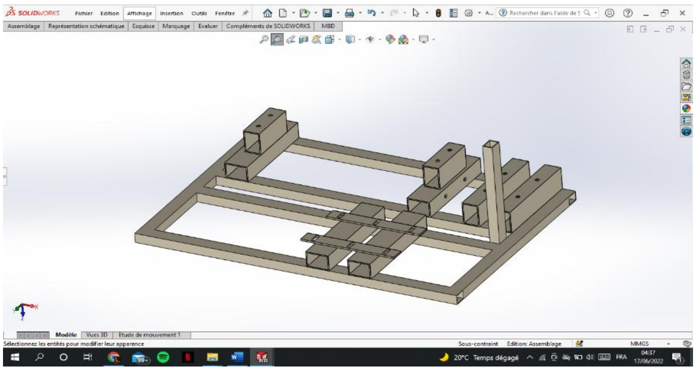


Fig.9: 3D design of the platform

2.2 Realization

a) The discs: we have 2 discs in our project with a 300 mm diameter, 30mm thickness and 7, 4 kg from black sheet metal **(**Photo 3)

Photo 1: Some of the disc manufacturing process

The used machine is the lathe as we can see in the photo 4

Photo 2 : The used mechanical lathe in the workshop

In the design we made 12 holes M8 to add bolts, in this prosses we used the drill machine for the holes and the tapping for the thread (Photo 3).

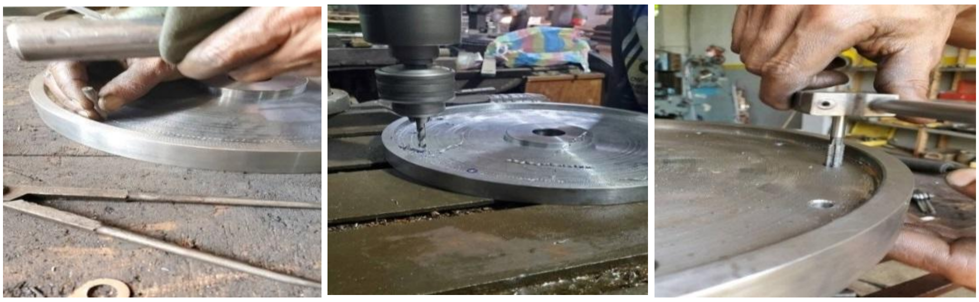


Photo 4: Process of the M8 holes

Also, the keyways were made by the keyways machine shown in the photos (the pictures that follow).

Photo 6: Keyways machine in the workshop

Photo 7: The final Wight of discs

b) Shaft : Our shaft is 600mm length and different diameters, we have 40mm,30mm and 25mm in the end where the coupling is mounted, for the shaft manufacturing we used 2 Machines, lathe for straight turning, shoulder and spring ring way, also the milling machine for the keyways as is shown in the photos 8 and 9.

Photo8: The shaft on the milling machine

Photo 9: Manufactured shaft

c) Coupling: We bought this piece half ready, so we just had to do the center drilling, you will see the first state and the final one in the photos 10 and 11.

We used the lathe for manufacturing; we did a center drilling of 25mm diameter in the shaft side and 24mm in the motor side.

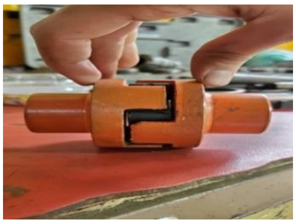


Photo 10: The first state of our coupling (without the mounting holes) photo 5 the final state of our coupling (ready for the mounting)

Pulleys: The pulleys were also bought and we just needed to modify them based on our design, the smaller one is the driving pulley with a 80mm diameter and a 24mm bore, the bigger one is the driven pulley with a 160mm diameter and 19mm bore. Both of them are made from aluminum Photo12 and Photo13.

Photo12: Driven pulley 160mm

Photo 13: Driving pulley 80 mm

d) Motor: ABB motor with a 1,5 KW power, 2895 rpm with a 380 voltage , you can also see the characteristic table in photos14 and 15

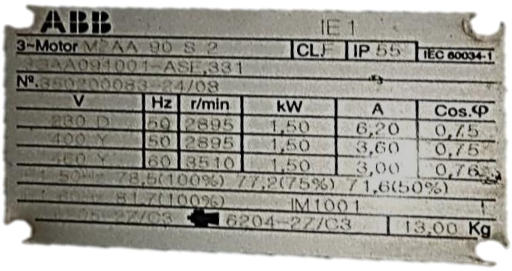


Photo14: Motor characteristics table

Photo15: ABB motor 1,5KW

e) Reducer and belt: in this part we will add his characteristic ticket.

Photo16: Reducer characteristic ticket

Photo17: V-belt 12.5X1150 La

Photo18: platform building

f) Platform: Our platform is made from different types of rectangular tubes, 25x30mm and 70x40mm, the assembly was by welding and the structural design was well studied **(**photo 6 platform building).

g) Supplies: In our system we used some supplies for mounting and setting items, in the next photos you will see all the used items: keys, spring ring, socket Head bolts M8, *HEX* head bolt M10 **(**Photo19).

Photo19:   Supplies

h) Cover: We made a Plexiglas of a 3mm thickness as a protection cover for our test bench; we used plastic bars of 90° for the assembly (Photo20).

Photo20: Plexiglas assembly

2.3 Assembly

The assembly of our elements was a strict step, we had to calculate everything to know where to do the mounting and how to avoid misalignment our plat form was ready, we used HEX head bolt M10 for the assembly

Photos 21, 22, 23: respectively final elements assembly, bolts-way on the reducer support and Applying mastic and painting

In the Photo 22, we are making bolts-way on the reducer support in purpose of stretching the V-belt

a) Painting: After finishing all the mounting and setting everything in it place, it comes the turn of last touches, painting help us also differencing between elements and it’s also good for the appearance of our test bench.

Photo24: Discs painting

Photo25: Reducer painting

We face some challenging situations, from the beginning of the realization until the last of it. It takes a lot of time for us to achieve our goal.

For the conception websites like grabcad and MC Master-carr helped us a lot by finding elements from the market in specific dimensions we just had to personalize them based on our need, for other elements like discs, shaft, platform...etc. wasn’t difficult to concept them.

And for the realization, it went as we wanted, we manufactured the discs, shaft and platform and we personalized the coupling and the pulleys.

One of the obstacles that we faced is not respecting the timeline, and that affected us.

3. Experimental study

3.1. Vibratory analysis of the balancing test bench

Conditional preventive maintenance, uses several surveillance techniques, the most used one is the method of vibratory analysis, which allows early detection of failures and tracking their evolutions over time. Monitoring of mechanical defects at an early stage offers the possibility of planning corrective interventions on production equipment during technical stops scheduled in particular for production requirements.

We propose to study the vibratory behavior of a test bench, composed of several organs that can be found in the industry in general .One of the constructive elements of the machine has a mechanical fault which is fault of balance. We will study the consequences of this defect on the vibratory behavior of the other organs like pillow blocks, bearings and reducer.

The spectral interpretation of the vibration measures taken is delicate, when possible mechanical defects of these bodies will be associated and generate the same spectral images.

Technical data of the test bench:

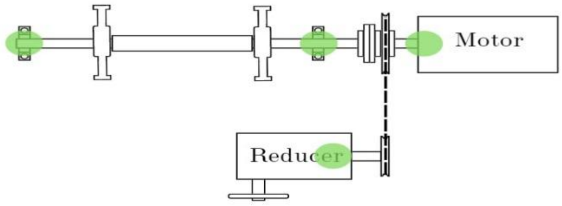


Fig.10. Cinematic diagram and vibration measurement points

Nomenclature: TABLE I to TABLE VII.

TABLE I: Electric motor Characteristic

Electrical motor	brand	Type	power	Speed of rotation	Intensity
	ABB	D - 91056	1.5 KW	2985 Tr/min	3,6 A

TABLE II: Feature of the motor pulley and Feature of the receiving pulley

Driving pulley	Diameter 80mm	Width 19mm	Number of grooves 01
Receiving pulley	Diameter 160mm	width19mm	Number of grooves 01

TABLE III: Feature of the receiving pulley and bearings

Pillow block and bearin	Type of the block	reference	Bearing reference	Type of lubrification
	Applied	UPC206	/	/

TABLE IV: Feature of the turbine

Discs	Diameter	width	Number of holes	Rotation speed
	300mm	30mm	12	50 Hz (3000 Tr/min)

TABLE V: Feature of the reducer

Reducer	Brand	Number of stages	Bearing reference	Ratio
	S.I.T.I	2	7304 = 580n20 6208 A – FAG	1 : 8

TABLE VI: Feature of the coupling

Coupling	Jaw coupling	Type: Semi-elastic

TABLE VII: Feature of the speed controller

Inverter	Brand chint	Power 1.5 KW	Type NVF5-1.5/TS4-B	Power supply 380V

Photos 26, 27, 28 respectively: test bench, Test bench working and test bench under vibration testing under 25Hz

We propose to study the vibratory of a balancing test bench.

3.1. Balancing test bench machine

3.1.1. Machine description:

The machine is composed of an electric motor of 01.5KW, rotating at 2985 rpm linked with an inverter, driving in one side a horizontal shaft line caring two (02) discs of 300mm diameter and supported by two (02) block bearing on the vertical side of the motor we have a two (02) stages reducer driven by a V-belt, using a 80 mm pulley as a driving pulley, and the driven pulley is 160 mm diameter.

3.1.2. Choice of vibration measurements:

The vibration points are chosen to accurately obtain the information we need. Our goal in this case is to know the general condition of the machine. It is therefore necessary to know the state of the system bearings, is the behavior of the horizontal shaft line carrying unbalanced discs and their consequence on the other organs. The figure 10 makes it possible to study the machine and choose the vibration measuring points on the bearings that will be used to detect all the failings that can arise on the machine during its operation. The programming of the measurement points is established in a manner that allows to capture all the frequencies of interest and to follow their evolutions in the three (03) horizontal, vertical, and axial directions.

3.2. Vibratory diagnosis and analysis of the results of June 18, 2022

The spectral interpretation of the measures taken on the entire cinematic chain of the machine reveals the presence of the following anomalies:

- Detection of a misalignment between the motor shaft and that of the two (02) discs shaft, as indicated the two preponderant components at 25 Hz and 50 Hz shown in the spectrum .
  - Presence of an unbalance on the shaft line carrying the two (02) discs generating high level vibrations on all the kinematic chain of the test bench as indicated by the 50 Hz dominant frequency component represented in the specters of figures .This failure generates vibrations of high level of 24.37 mm/s on the bearing N°03, based on the criteria of the vibration judgment, following the international standards VDI 2056 this vibration is danger. Global vibration levels on both of the bearings are shown in table VIII.

Figure 11 gives a window regarding vibration measurement points programming.

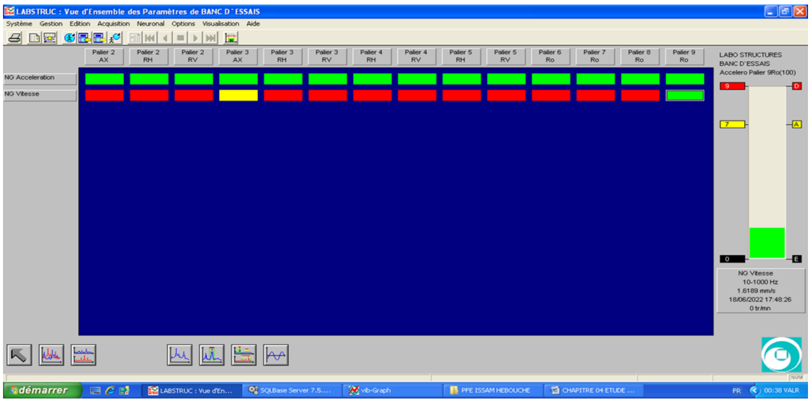


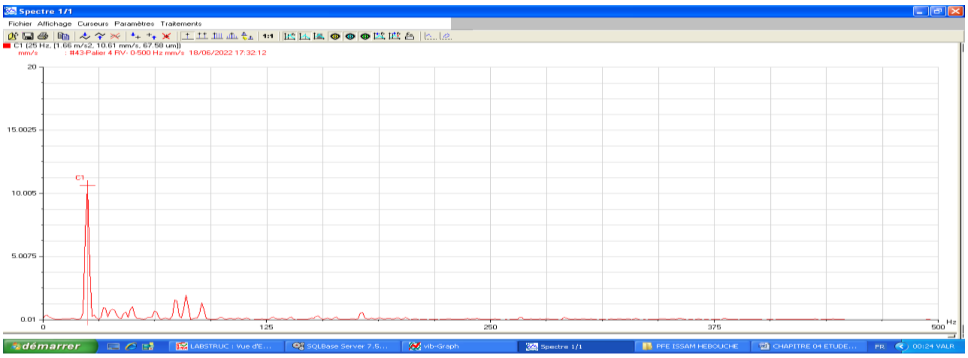
Fig.11. Presentation of the vibratory tracking window on the entire kinematic chain of the test bench

Fig.12: Spectrums taken on bearing N°04 in the vertical direction on: June 18th 2022, indicating the presence of an Unbalance on the rotor carrying the discs of 10.61mm/s at 25Hz.

After experimentation and measurements, we obtain various spectra. As an indication, we give:

Interpretation

- Spectrum taken on the motor bearing in the horizontal direction on: June 18th 2022, indicating the presence of a misalignment on the motor rotor C1=05.59mm/s at 25 Hz and C2=05.86mm/s at 50.
- specter taken on bearing N°03 in the vertical direction on: June 18th 2022, indicating the presence of an Unbalance on the rotor carrying the discs of 24.37mm/s at 25 Hz
- Spectrum on bearing N°04 in the vertical direction on: June 18th 2022, indicating the presence of an Unbalance on the rotor carrying the discs of 10.61mm/s at 25Hz. 18th 2022, indicating the presence of an Unbalance on the rotor carrying the discs of 11.91mm/s at 25Hz



- Spectrum taken on bearing N°06 in the vertical direction on: June 18th 2022, indicating the imbalance on the rotor carrying the discs of 16.71mm/s at 25Hz.
- Spectrum taken on bearing N°07 in the vertical direction on: June 18th 2022, indicating the presence of an unbalance on the rotor carrying the discs of 14.20mm/s at 25.

TABLE VIII- Taken measures of Global vibration level

Measures taken on the Kinematic chain of discs		Measures taken on the driver's Kinematic chain	
Bearing	Global vibration level in mm/s	Bearing	Global vibration level in mm/s
Moteur N°02	24,64	Moteur N°02	24,64
N°03	26,39	N°05	13,12
N°04	11,91	N°06	16,87
		N°07	14,92
		N°08	19,08
		N°09	01,62

4. Conclusion

This Test bench is an isolated, controlled environment, very similar to the rotating machines, it helped us to focus and consider all the vibratory aspects by analyzing them and studying them.

After this analyzing we discovered two mechanical defects in our test bench, they are: unbalance and misalignment. The last one can be corrected by balancing the two discs and the alignment of the two shafts (the shaft carrying the discs et motor's shaft). It should be noted that the correction of the misalignment to a positive consequence, it may be possible and implicitly correcting the unbalance consequence.

Being able to start the designing from the beginning helped us to customize our kinematic chain based on our need, therefor; going through the whole process of sizing our elements left an impact on our work.

About mechanical design, we took all the characteristics of our elements into consideration, starting from the shaft who can resists the loads, type of motor, reducer ratio, coupling and v-belt sizing.

The e test bench is realized in the workshop.

After finishing our test bench, we reached experimental study .We studied the vibratory behavior of this test bench, because it's composed of several organs.

5. References

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