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RESEARCH ON VIBRATION STEERING WHEEL VEHICLE BAJA UNIVATES TEAM

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Abstract. *During Baja Univates design development process, it has been the occurrence of excessive vibration in the steering wheel of the vehicle, particularly, in idle condition idle. In order to get more detailed information about this occurrence, experiments were performed using specific instrumentation for vibration analysis. The natural frequencies of the steering column were obtained in the steering wheel coupling region, relating to the frequency of vibration generated by the vehicle engine. The analysis showed that the 1st, 4th and 10th engine harmonics resonate with the natural frequency of the steering column when the vehicle is idling. With the results, there was a design change on the steering wheel in order to change its stiffness and / or mass avoiding the resonance of engine frequencies.*
Keywords: *Vibrations, Baja, Steering Wheel, Analysis.*

1. INTRODUCTION

Baja is a worldwide competition between higher education institutions, organized by SAE (Society of Automotive Engineers) to put into practice the knowledge acquired in the classroom. During the design of the vehicle, students have the opportunity to simulate the life of an engineering professional having to do not only the manufacturing of the project, but also the whole management costs, acquisitions, human resources, communication to the superiors among others.

With the vehicle completed, the dynamic tests were started where they were validated as choices made by the team at the time of the project and possible improvements appear. During the dynamic tests performed, it was possible to observe an excess of vibration in the steering wheel, causing a discomfort to the pilot and electronic problems in the panel caused by the excessive vibration. In order to understand and minimize the phenomenon, qualitative studies were carried out considering the vibrations of the vehicle steering wheel.

2. BIBLIOGRAPHICAL REVIEW

During the development of a new project, it is of fundamental importance to consider some criteria to reduce the failure rate and improve its performance, as quoted by (Sotelo Jr. and France, 2006, page 05) “Anticipate problems that may cause discomfort or premature failure of the equipment and machines, through vibration analysis, eliminating possible sources of vibration.". All experiments should be done with criteria and caution to avoid the accumulation of errors in the data collected (Rocha, 2004).

When the frequency of external excitation coincides with the natural frequency of vibration of a machine or structure, a phenomenon called resonance occurs, resulting in excessive deflections and faults (Rao, 2009). In the case of component design, such phenomena must be controlled and minimized. In this context, Kaderl and Gomes, 2011 analyzed the degree of the driver’s comfort in relation to vibration transmitted by a vehicle by measurements performed on four vehicles of same category available in Brazil. The authors conclude that according to comfort analysis, it was verified, in a general average, that one of the vehicles presented more comfortable than others. In terms of human exposure to vibration, it is clear that for certain conditions, vibrations may exceed the exposure limits defined by official standard.

Yamagata 2014, describes the process of modeling a vehicle Baja Team using the multibody dynamics simulation software MSC Adams/Car. The parameters used in the model were obtained from design data and test that were previously conducted by the team. The author used the numerical model and simulations were conducted in order to evaluate the lateral and vertical dynamics of the vehicle. Simulation results were compared to the tests measurements in order to evaluate the validity of the model.

3. METHODOLOGY

Two tests were used to investigate the frequencies: Simple Hammer Test and the Coast-Down Test (MILLS, 2010). Both tests are qualitative in the investigation of frequencies. The tests were performed with the vehicle without the wheels and suspended in 4 points through tires, as shown in Figure 1.

Figure 1: Low-hanging vehicle to perform the measurements.

3.1 Simple Hammer Test

With a rubber hammer and a vibration sensor (accelerometer) attached to the steering column, the Baja's body was excited by blows in the region near the engine (bracket).

The data acquisition system was tuned for a frequency response in the range of 0 to 1KHz, with an amplitude in the peak waiting function triggered. With the acquisition time of 4 seconds and the frequency resolution of 0.25 Hz, 10 interactions (averages) were performed by measurement.

3.2 Coast-Down Test

With 2 body-mounted accelerometers, one on the engine mount and the other on the steering wheel column, the engine was accelerated at full speed (approx 4000 rpm) to start data acquisition. Once the acquisition was started, the vehicle was decelerated naturally by releasing the accelerator pedal, stabilizing in idle speed. In the same way, the amplitude was also obtained by the "peak-hold" function. The tests were performed with the vehicle without the wheels and suspended in 4 points through tires, as shown in Figure 1.
The following equipment is used in the experimental analysis:

1) Data Acquisition Module: USB-4431 from National Instruments;
2) Analysis Software: LabView, from National Instruments;
3) Sensors: 2 CTC brand accelerometers with a resolution of 100mV / g, IEPE, mounted on a magnetic base;
4) Computer: Acer Aspire 5536 Notebook;
5) Rubber hammer.

Figure 2 shows the detail of the data acquisition system used during the experimental tests.

Figure 2: Detail of the data acquisition system with the USB-4431 module.

4. RESULTS

Figure 3 shows the result of the frequency response obtained by the accelerometer fixed in the steering column in the radial direction to the impact-type excitations produced by the hammer (Simple Hammer Test, procedure 3.1):

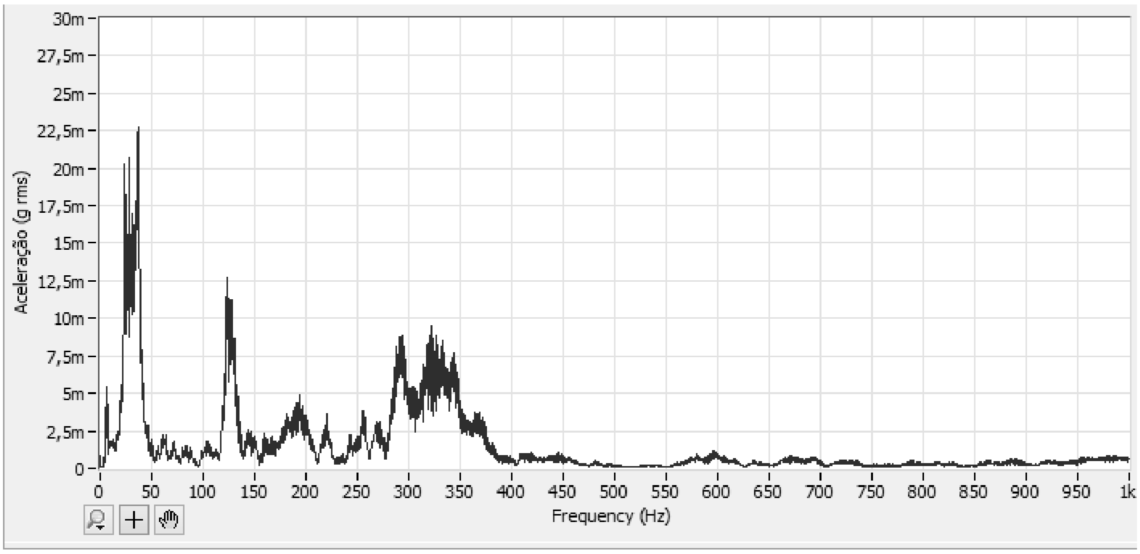

Figure 3: Frequency response obtained on the steering wheel, radial direction.

It is observed that above 400 Hz there are no frequencies with significant amplitudes, therefore, an analysis can be limited to this frequency. Figure 4 shows a response in the range of 0 to 400Hz.

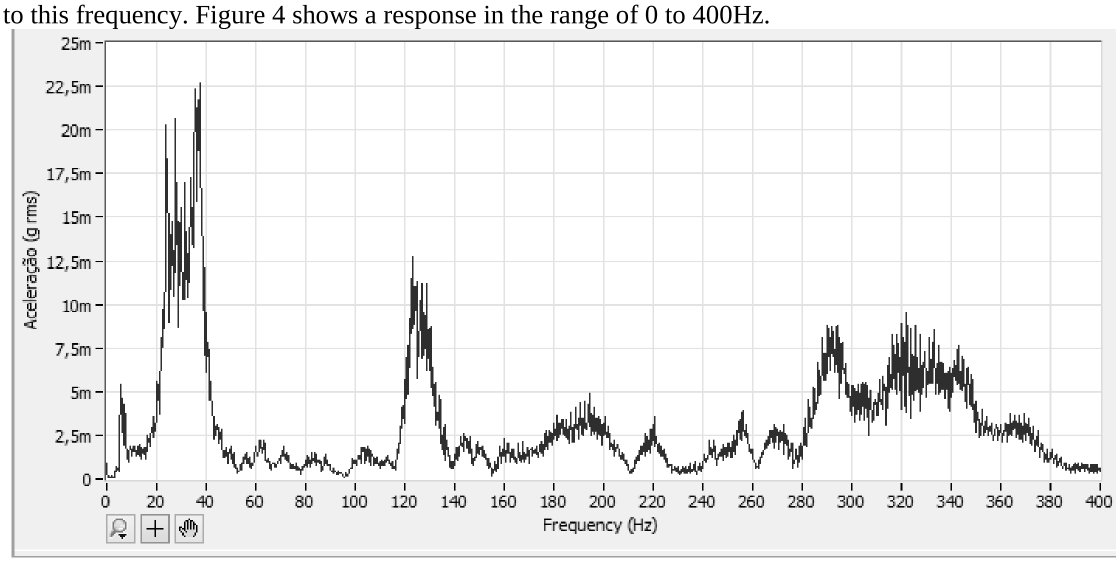

Figure 4: Frequency response obtained from the steering wheel from 0 to 400 Hz.

A large amplitude is observed in the bands between 20Hz and 40Hz, 120Hz and 140Hz and between 280Hz and 360Hz. The large amplitude of acceleration in these three bands indicates the frequencies where the steering column vibrates freely, that is, they indicate the fundamental frequencies of the structure in this region.

Since the motor of the Baja when idling, has a rotational speed of approximately 2000 RPM and, considering the motor of a cylinder, it can be stated that the frequency of vibration of the motor is given by Equation 1:

$$Freq.motor \approx \frac{2000\ RPM}{60} i \approx 34i \ \ (Hz) \tag{1}$$

Where: i = 1, 2, 3, .., representing the harmonics produced by the motor.

Thus, when operating in idle, the first, fourth and tenth harmonics of the motor coincided with the natural frequencies of the steering column, resonating.

The steering column frequency response in the axial direction was also obtained. Figure 5, as soon as applied by the Coast-Down Test 3.2 procedure, shows the region between 100 Hz and 140 Hz is a more significant range where excessive vibration may also occur in this direction.

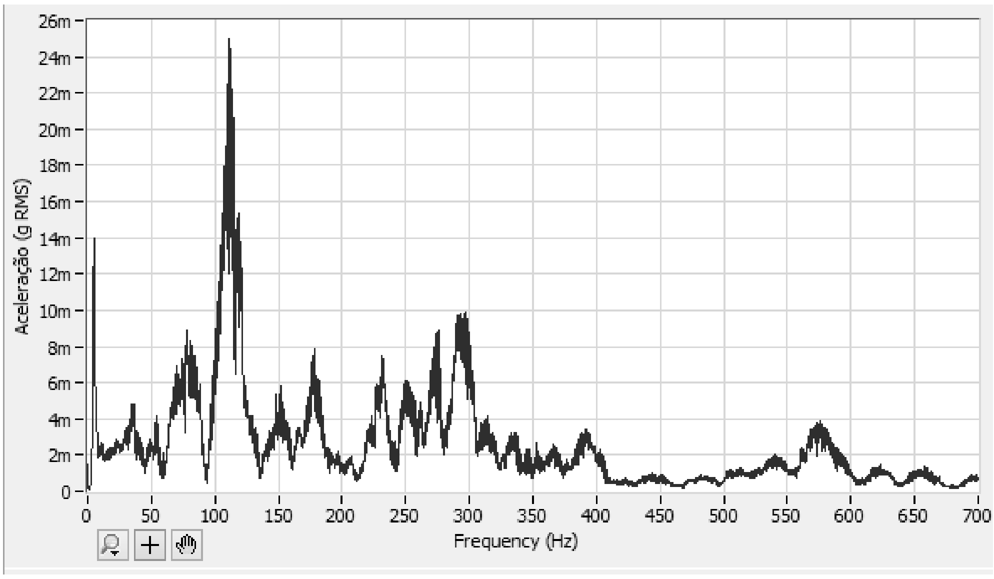

Figure 5: Frequency response of the flywheel in the axial direction.

Further studies were performed in the region of the backrest of the motorcycle seat, near the neck. Figure 6 shows in detail the location of the sensor while in Figure 7 shows the result of the frequency response.

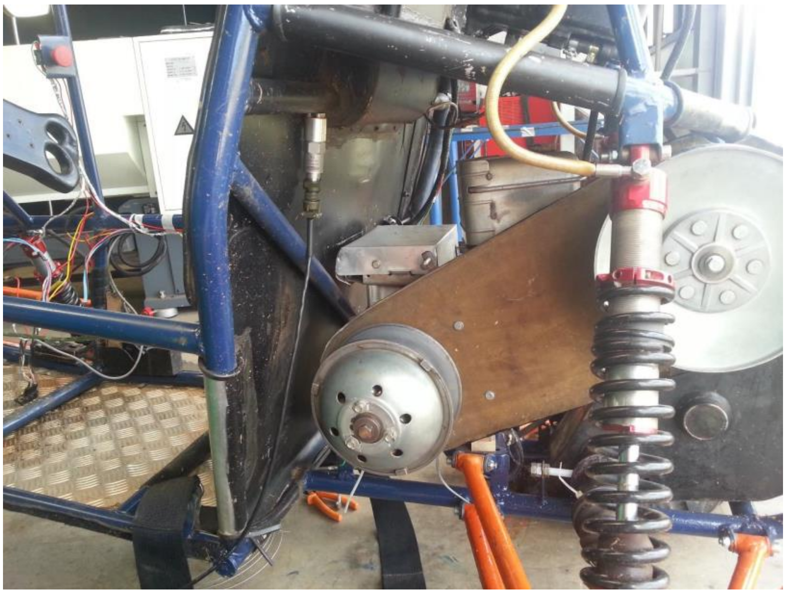

Figure 6: Detail of the location of the accelerometer as measured from the seat back.

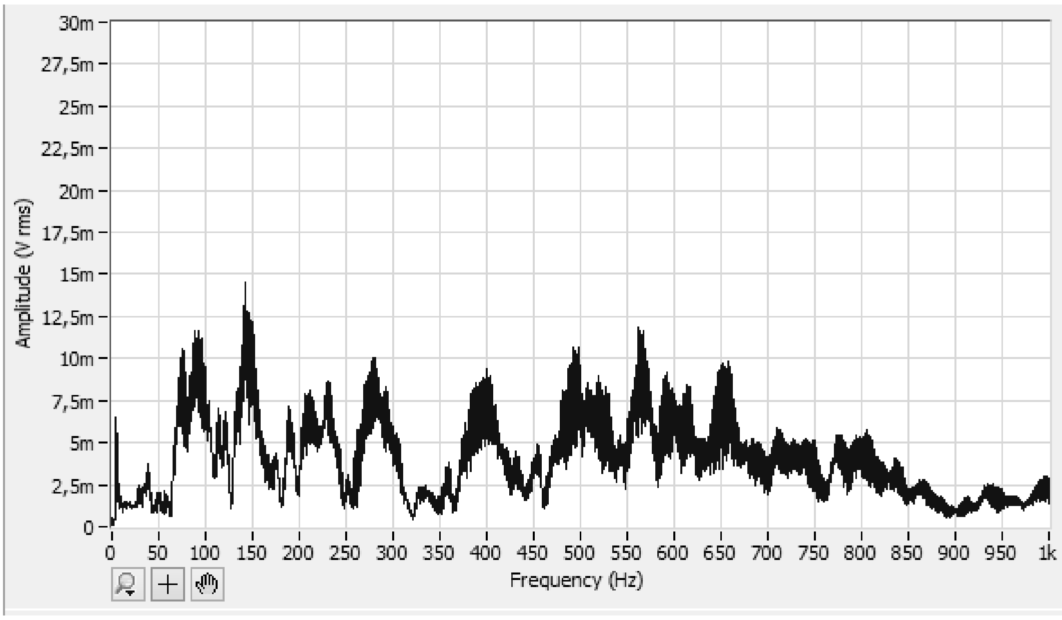

Figure 7: Frequency response in the seat backrest region.

In this graph, a particular frequency (or frequency range) is not highlighted. On the other hand, it is a less critical vibration condition with respect to the frequencies generated by the idling engine that went into resonance.

Figure 8 shows a frequency response of two sensors, one fixed without motor support (blue line) and one in the steering column (red line). The signals were acquired considering the idle vehicle.

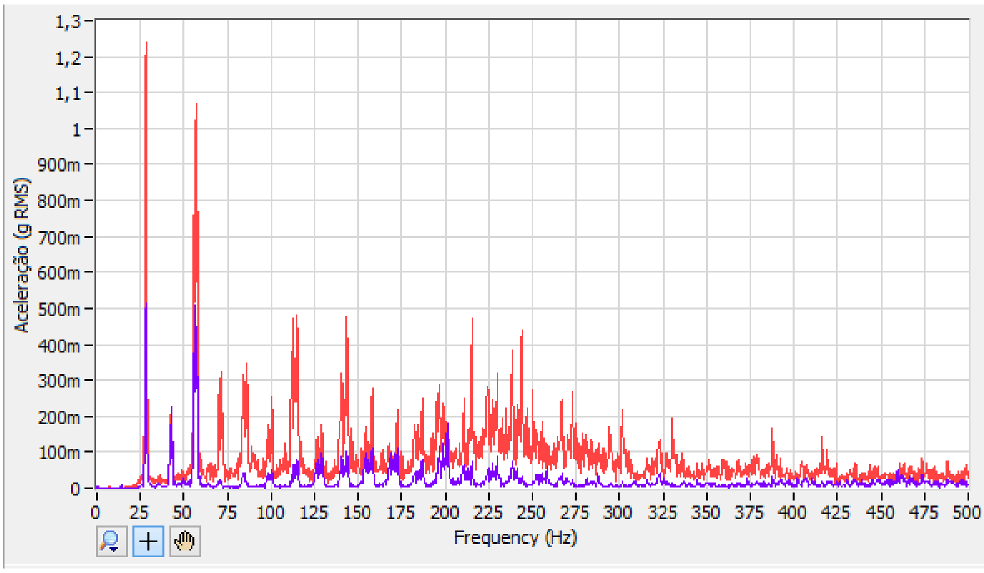

Figure 8: Frequency response of the engine (blue line) and steering wheel (red line). Vehicle idle.

In this experiment, the motor rotation stabilized around 1680 RPM (28Hz), represented in the graph by the maximum amplitude (blue line) at this frequency, as well as the other peaks relative to its harmonics.

By reducing the observed frequency range (0 to 150Hz), the effect of engine vibration on the steering wheel vibration is shown, as shown in Figure 9. At the frequency close to 27 Hz, the steering vibration amplitude is approximately 2.1 times that of the engine. Figure 10 shows the amplitude gain due to the resonance between the engine and flywheel frequencies, when the vehicle is idle, across the spectrum.

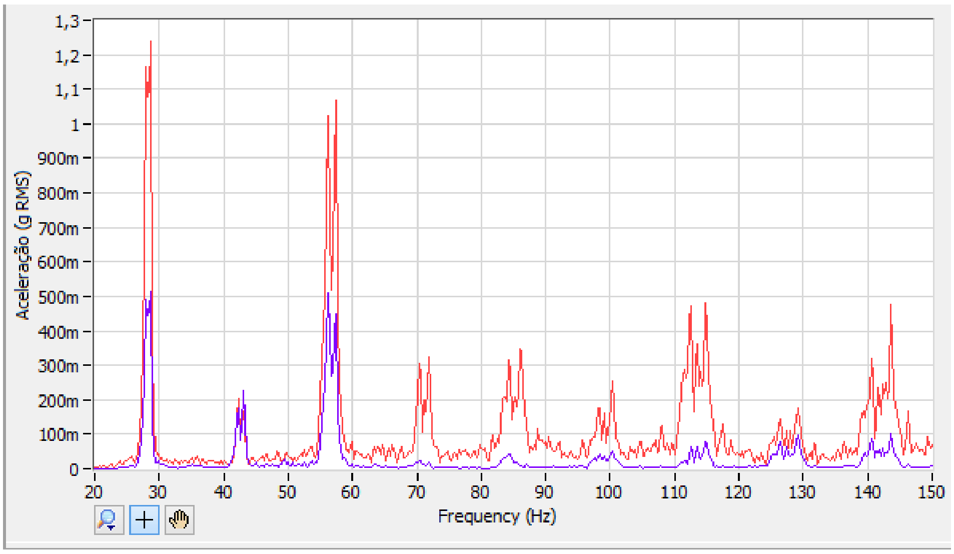

Figure 9: Comparison between amplitudes. Steering wheel (red) X Engine (blue).

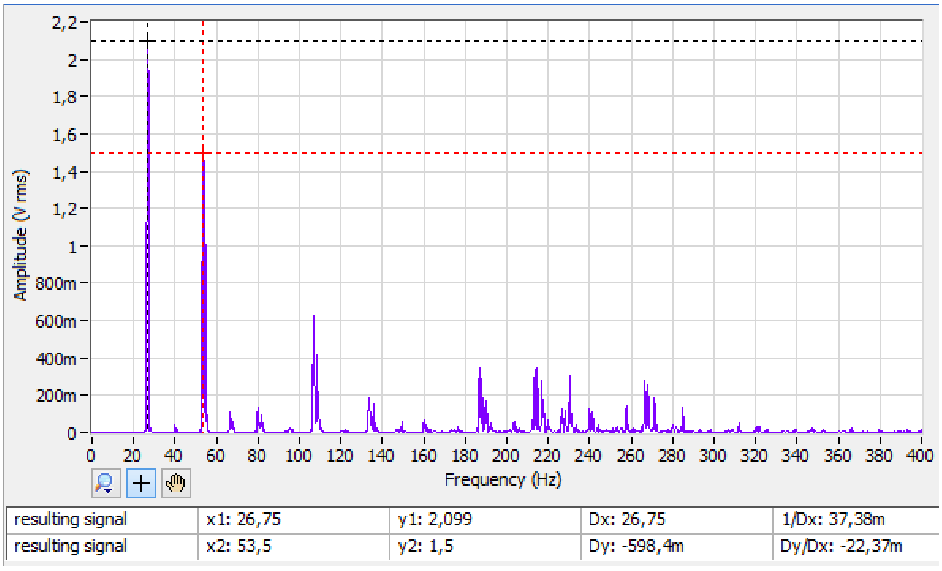

Figure 10: Gain amplitude graph of the flywheel. Vehicle idle.

The Coast-Down Test was also carried out. In this test, a new steering wheel with smaller mass was mounted in the steering column (880 grams and the previous one had 1200 grams). For this experiment, the same assembling configuration of the previous analysis was used, that is, two accelerometers; one fixed to the engine mount and one to the steering column.

The results of Figure 11 shows the frequency response of the accelerometer signal set in the engine (blue) and the fixed on the steering wheel (red), using the Coast-Down method, as previously described.

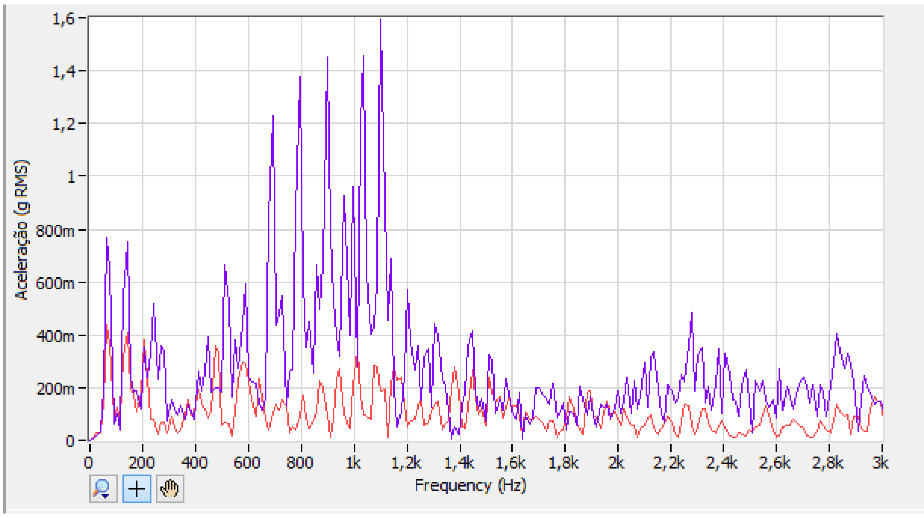

Figure 11: Frequency response of accelerometers with rotation ranging from 4000 RPM to 1650 RPM.

A reduction in the amplitude of acceleration of the flywheel is observed when compared with the previous experiments, that is to say, with larger flywheel (old flywheel). For a better observation, Figure 12 shows the result of the subtraction of these 2 signals. Note that in frequencies below 200 Hz, there was a reduction of two (reduced by 50%).

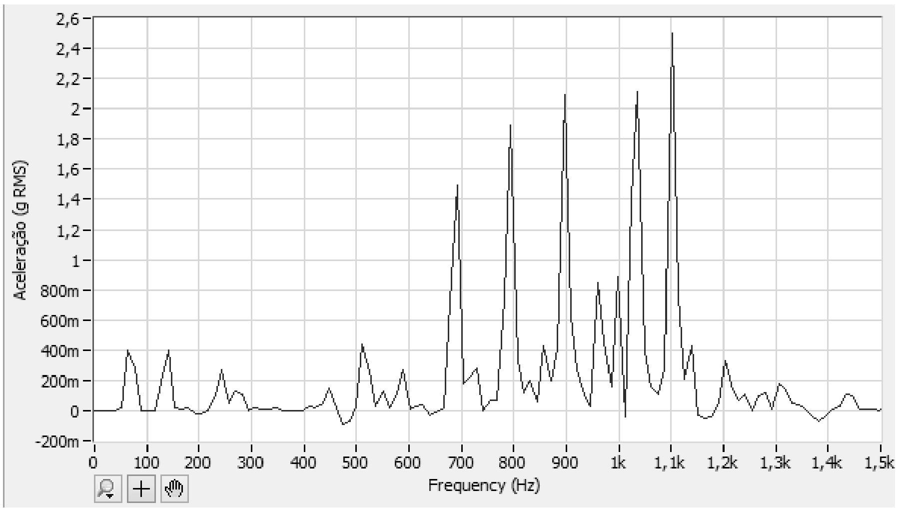

Figure 12: Subtraction of the signals from the motor and steering responses.

The solution found was to use a flywheel with lower mass (880 grams), according to Figure 13.

Figure 13: Steering wheel with mass 880 grams.

5. CONCLUSION

In this study, perform a survey on a steering column vibration of a Low-Vehicle. The resonant frequencies were determined and how they are excited by the vibration of the engine when idling. From experimental tests, the mechanical designer of the vehicle has obtained information to guide a future there is a structural design of the Baja, aiming at a better fixation to the steering wheel. In order to improve in the future it is suggested to develop shims to attenuate like vibrations originating from the engine, solving or attenuating the problem of previous excessive vibration.

6. REFERENCES

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7. RESPONSIBILITY NOTICE

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