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Full Length Research Paper

Comparison of Excitement Methods of Vibrant Wire Sensors

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The vibrating wire sensors are very robust and have a high sensitivity, they are widely used in civil construction for monitoring structures, and hence an accurate measurement of these instruments is highly recommended. However, these sensors must be stimulated before being measure, and then it will transmit a response signal. Thus this study aims to compare the different methods that can be used for excitation to this type of sensor to indicate what their differences and characteristics, consequently proposing one that provides a better response signal.

Keywords: Electromechanical sensors, signal processing, measurement, frequency response, electrical stimulation, vibrating wire.

INTRODUCTION

The measurement using the principle of vibrating wire was developed in France and Germany around 1930, which is a high-sensitivity sensor [Silveira, 2006].

This type of instruments are used in constructions for monitoring civil structures, such as hydroelectric dams, bridges, mines, because of their longevity and robustness.

The excitation method of this sensor consists in bringing the vibration of a string by an electromagnetic field generated by a coil and measuring the frequency that the wire inside the sensor will resonate.

Under these circumstances this study intends to compare the known methods of excitation to determine their main features and differences, in order to discuss its quirks.

As a result, it will be possible to check which method will ensure a better response to the measurementsignal of the sensor response.

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DEVELOPMENT

Sensor's working principle

Inside the vibrating wire sensor, a deflection is caused by extension or compression of the wire that results in a change of the applied tension on the string and this increase or decrease the frequency response according Equation (1), then an electromagnet installed near the wire makes it possible to excite and read the response signal [Pallás-Areny and Webster, 1991].

$$= \frac{1}{2} \cdot \overline{\;-\;} \qquad (1)$$

– Natural frequency
L – Wire length
T – Wire tension
– Linear mass density

In Figure 1 is shown, in detail, the internal construction of

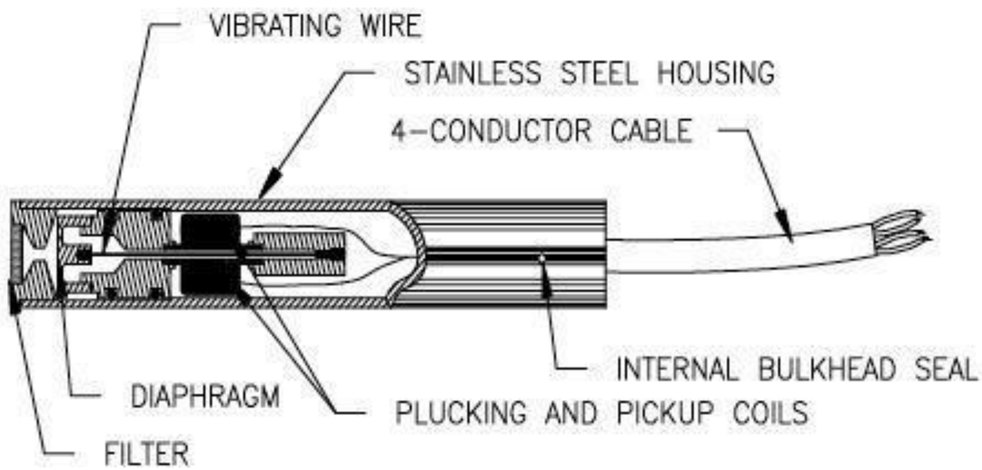

Figure 1. Details of Campbell scientific piezometer [Campbell Scientific Inc., 1992].

a Piezometer manufactured by Campbell Scientific Inc. (1992). In this sensor the pressure-sensitive diaphragm causes the variation of the tension on the wire, the diaphragm is welded to a capsule that is sealed and tightly closed.

Excitation method

The sensors studied have only one inner coil, called single-coil sensors, so the response signal should be measured immediately after the excitation, ie, the time that it is possible to do this measurement is directly related to the damping of the response signal of the sensor.The known methods for stimulating a sensor vibrating string are:

- Impulse;
- Continuous sweep frequency;
- Steps of variable frequency sinusoidal pulse trains;
- Steps of square wave variable frequency pulse trains.

All of them stimulate the wire inside the sensor with enough energy to generate a signal with significant amplitude; therefore the measurement must occur before the signal is fully amortized.

Methodology for achievement tests

For a more satisfactory results, the tests were performed with a single commercial sensor, fixed at its ends so that there was no change in his excursion and in an environment with constant temperature of 23°C, this was made to make sure that the sensor doesn't change it resonance frequency.

Anexcitation signal is sent to the sensor's coil using a function generator and with an oscilloscope, the response signal is checked. An ohmmeter is used to check the sensor's temperature.

The first method evaluated was the stimulation with impulses, which in theory is a Dirac delta function, that is, a rectangular pulse tall and narrows [Lathi, 2004]; in practice is a signal very small duration with high voltage amplitude.

Using the function generator and power amplifier, was applied on the sensor a voltage of 50 V for 1 min, and the sensor response was a sinusoidal signal with frequency 1769 Hz and 10 mV peak and lasting about 4 min to be alleviated to a voltage less than 2.5 mV (Figure 2).

During the second test, the method used was continuous sweep frequency, which consists of a sinusoidal frequency increased steadily starting from the lowest to the highest frequency. For the sensor under study, we used the range of operating frequency from 1200 to 2800 Hz, according to specification in the manual. The period of stimulation was determined to 500 min, and will sweep all the frequencies within this time.

With this test, it was not possible to obtain a satisfactory result, the resonance frequency measured was very close to the previous test, ranging in mean ± 4 Hz in all tests, but the amplitude varied widely. In some tests showed values above 20 mV and other less than 10mV.

The next test performed was the steps of variable frequency sinusoidal pulse train [Kovacs et al., 2012]. The operating principle of this method consists in applying on the vibrating wire steps of approximately 10ms, a sinusoidal signal of constant frequency, and then applies another step with 10 Hz frequency higher than the previous one and so on until all of them are applied. In the interval, pacing of each step is measured resonant frequency of the sensor.

The last method tested was using square wave signals with variable frequency [Nabeyama et al., 2012]. This method is similar to the previous one but, using a sequence

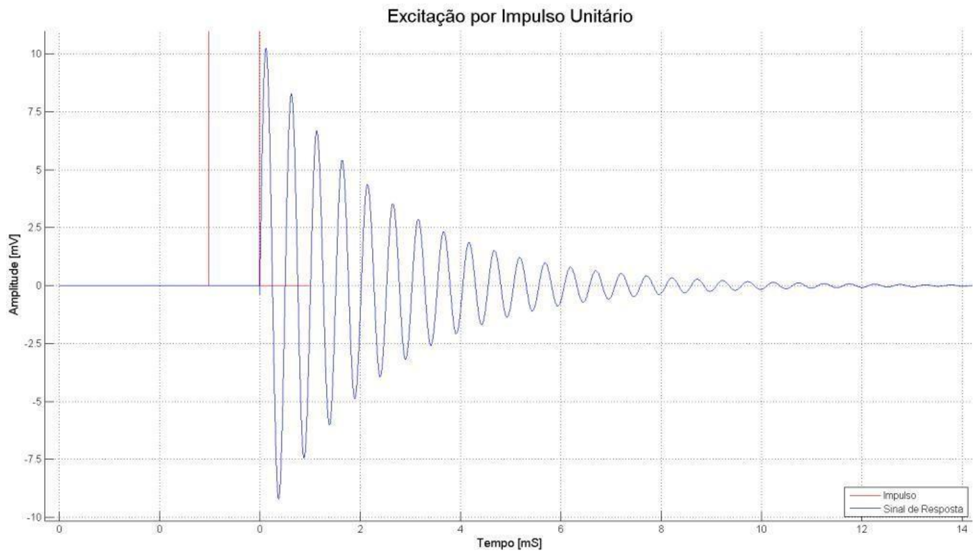

Figure 2. Impulse response.

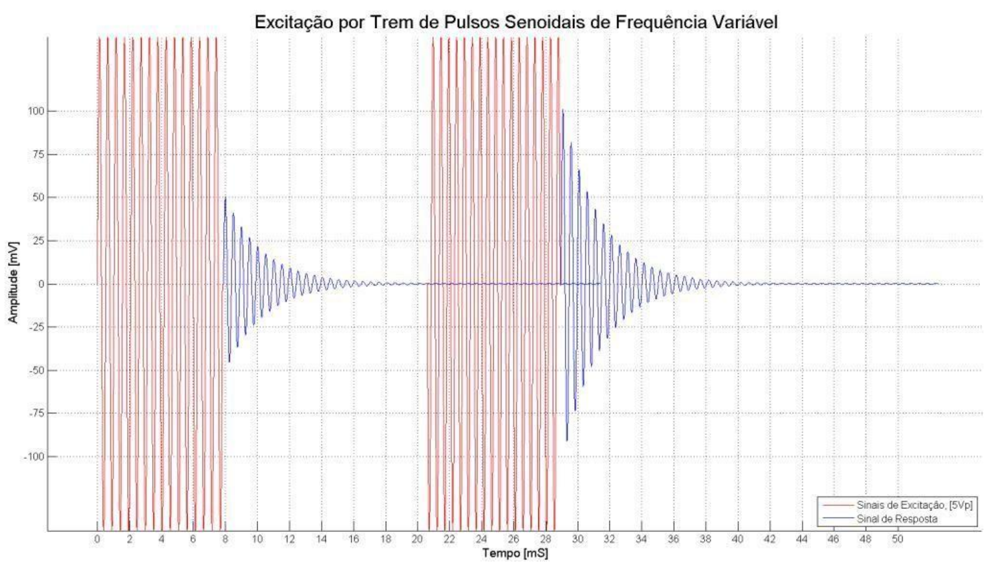

Figure 3. Steps of variable frequency sinusoidal pulse trains response.

of discrete amplitude pulses for excitation of the vibrating wire (Figure 3).

Method's comparison

All methods return a value of frequency withamaximum error of 20 Hz, which may be related to measurement; however this will not compromise the focus of this work.

The use of an impulse is very problematic for the system, as it applies a high voltage, even for a short period, it can damage the equipment in a long term. In addition, the response signal has amplitude and damping time low, when compared with the other methods.

In the second method evaluated was not possible to reach a satisfactory result, because the variation of the parameters of the response does not guarantee accurate measurement and thus several measurements that would be needed to acquire a reliable conclusion. For this method, it is interesting to apply a different experimental methodology using, for example, a spectrum analyzer.

Tests have worked better in the pulse train sine and square wave with variable frequency. For sinusoidal input, the output was a response with maximum amplitude

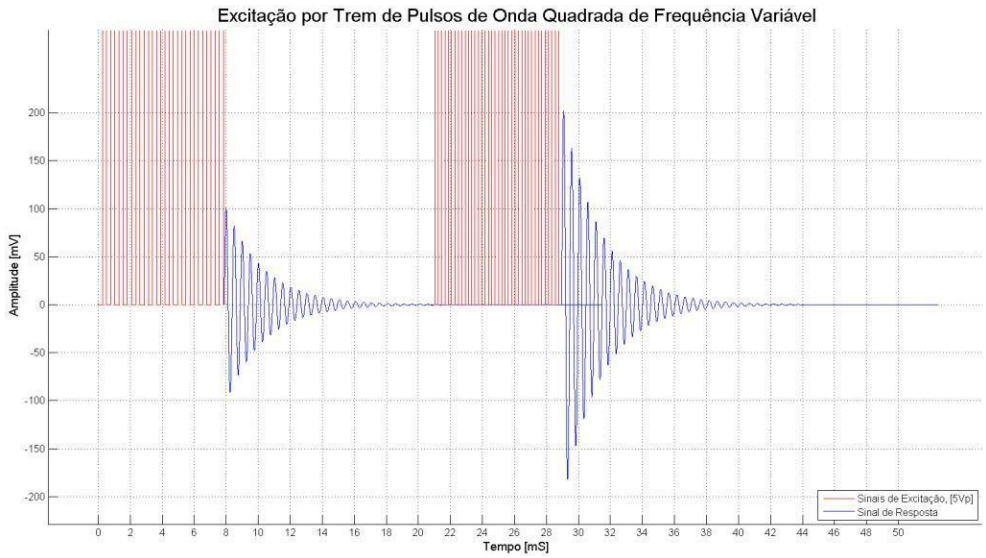

Figure 4. Steps of variable frequency square wave pulse trains response.

of 100 mV and damping time of around 10 min. To test the square wave the voltage peak was nearly the double, and hence the damping time is greater than the previous one.

The use of pulse trains with variable frequency, regardless of being a sinusoid or a square wave leads to an amplitude response and damping time acceptable to perform the measurements.

The main difference between these two methods is that the use of a square wave is simpler, since it is a signal generated more easily and could be easily implemented in a digital on-off controller (Figure 4).

Conclusion

From this study, it's possible to see that all of the methods tested weretechnically plausible, it is possible to implement them and all return a response signal with the desired frequency. However someof them return a signal with higher amplitude and with thatthe damping time is larger, ie, with more time it's viable to acquire more data from a single excitation, increase it measure accuracy and ensure greater reliability.

A better result were see in the steps of square wave with variable frequency pulse trains, which provides higher amplitude from the response signal, but the best feature of this method is its simplicity, it can be implemented by a simple on-off controller that only changes the frequency between turning on and turning off the controller.

Another advantage is that the square waves have the characteristic of carry all the harmonics, Gibbs phenomena, which implies that the square wave has more energy, to make the wire vibrate, then a sine wave.

However each excitation method also depends on the type of signal response of the sensor, ie, how the output frequency will be measure. Therefore, isnecessary to evaluate which method is more suitable for the desire application, to improve a better measurement.

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