

Design of Virtual Instrumentation approach for A Multi-Purpose online Mechanical Vibration Experiment Using Labview

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ABSTRACT: The aim of the this paper is to make utilization of web publishing tool provided in the typical signal conditioning software called LabVIEW for the remote accessing of an experimental set up. This set up state an art of experimentation facilities in the selected areas of Engineering and Science education which can be used both through remote access and on site experimental work to give touch and feel about experiments. Hence having access to such an innovative idea of online learning has a great significance and advantage. With this insight NIT, Surathkal has joined hands with government of India with National Mission on Education through Information and Communication Technology to develop a common place called a virtual Laboratory to motivate students to conduct experiment remotely and develop good scientific spirit of experiments have been successfully conducted and demonstrated under the current project.

Keywords: Vibration control, suspension system, single degree freedom system, signal generation, DAQ,

I. INTRODUCTION

Science and engineering education can be made more experimental by having virtual laboratory of basic experiments which are learned by the students a distinct level. In this process students are able to conduct and control the required experiments which allow the student to do at point of time and any place with suitable connectivity to the internet. These experiments help the students in different level with desired practical knowledge. A definition of virtual laboratory could be "An electronic workspace for distance collaboration and experimentation in research or other creative activity, to generate and deliver results using distributed information and communication technologies". Establishment of such a lab would be a highly cost effective method to promote experiential learning in engineering and science education to a wide cross section of students especially in rural and underdeveloped areas in the country.

Web publishing tool in labview

Electronic publishing or ePublishing includes the digital publication of e books and electronic articles and the development of libraries and catalogues. Electronic publishing has become common in scientific publishing. Although distribution via the Internet is nowadays strongly associated with electronic publishing, there are many non network electronic publications such as Encyclopedias as well as technical and reference publications relied on by mobile users and others without reliable and high speed access to a network. After an article is submitted to a journal for consideration, there can be a delay ranging from several months to more than two years before it is published in a journal, rendering journals a less than ideal format for disseminating current research. While the term "electronic publishing" is primarily used today to refer to the current offerings of online and web-based publishers, the term has a history of being used to describe the development of new forms of production, distribution, and user interaction in regard to computer-based production of text and other interactive media A remote laboratory is defined as a computer-controlled laboratory that can be accessed and controlled externally over some communication medium. For this discussion, a remote laboratory is an experiment, demonstration, or process running locally on a LabVIEW platform but with the ability to be monitored and controlled over the Internet from within a Web browser. In the simplest case, the remote laboratory server can be an experiment connected to a computer through a standard interface (DAQ, GPIB, serial, parallel, etc.) and with the host computer connected to the Internet. The client can be any computer connected to the Internet running a simple browser. Once connected, the client will see the same front panel as the local host and also have the same program functionality. LabVIEW was used but extensive programming of Java, CGI, or other third-party software tools was required to bring local laboratory functionality to a browser environment. Now, with LabVIEW Remote Panels, remote execution is just a couple of clicks away. Without any additional programming, a LabVIEW program can be enabled for remote control through a common Web browser. With this new technology, the user simply points the Web browser to the Web page associated

with the application. Then, the user interface for the application shows up in the Web browser and is fully accessible by the remote user.

II. DESIGN OF EXPERIMENTAL SETUP FOR VIBRATIONAL ANALYSIS

Free Vibration Test: The natural frequency of the system is established by its mass and stiffness distribution. Usually there are two cases of vibration. They are free vibration and forced vibration. Free vibration occurs when the system oscillates or vibrates under the action of initial transient forces and thereafter no external agency influencing the oscillation. But forced excitation unlike free vibration is influenced totally by external forces. In free vibration the amplitude of motion will decrease with each cycle at a rate which depends upon the amount of equivalent viscous damping present. The mathematical model is shown in Equation

$$m \frac{d^2x}{dt^2} + c \frac{dx}{dt} + kx = 0$$

Where 'm' is the mass of the system, 'k' is the stiffness of the system and 'c' is the damping coefficient present in the system. 'x' is the displacement measured from the equilibrium position. The transfer function for the second order differential equation can be derived as follows

$$ms^2 + cs + k = 0$$

The characteristic of the natural response of the second order system is determined by the roots of the characteristic equation. The roots of the characteristic equation are

$$s = \frac{-c \pm \sqrt{c^2 - 4mk}}{2m}$$

If the damping coefficient c is small such that $c^2 < 4mk$ roots of the characteristic equation are complex conjugates and the system is said to be underdamped.

At a point when $c^2 = 4mk$ the roots of the equation become real and equal the system is said to be critically damped. If the damping coefficient is increased further such that $c^2 > 4mk$ then the system is said to be overdamped. A term damping ratio is defined in this context such that

$$\xi = \frac{c}{c_c}$$

Where c is damping coefficient and c_c is critical damping coefficient.

$$c_c = 2\sqrt{mk}$$

The natural frequency of the system is defined as

$$\omega_n = \sqrt{\frac{k}{m}}$$

Where 'k' is the system stiffness and 'm' is system mass. Due to presence of damping a term called damped natural frequency ω_d is defined

$$\omega_d = \omega_n \sqrt{1 - \xi^2}$$

The typical response for an underdamped case is as shown in Figure. 1

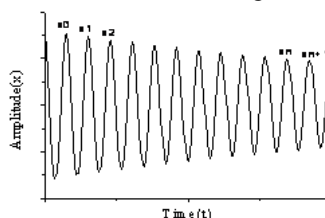


Fig. 1 Underdamped response in Time domain

The logarithm of the ratio of succeeding amplitudes is termed as logarithmic decrement

Thus logarithmic decrement is

$$\delta = \ln \frac{x_1}{x_2} = \frac{1}{(n-1) \left(\ln \left[\frac{x_1}{x_{n+1}} \right] \right)} = \xi \omega_n T$$

$$\delta = \xi \omega_n \frac{2\pi}{\omega_d} = \frac{2\pi\xi}{\sqrt{1 - \xi^2}}$$

Equating the above equations damping ratio (ξ) can be calculated as

$$\xi = \frac{\delta}{\sqrt{4\pi^2 + \delta^2}}$$

This type of analysis based on free vibration response is termed as time domain analysis.

To compute Natural frequency of the cantilever beam, study the decay pattern and damping, compute the reaction forces developed at the clamped end, to study the initial displacement and strain at a point in the beam. The application of transducers, data acquisition systems and graphical programming can also be studied. A&D Accelerometer, Kistler Force Transducer, Banner Laser Displacement pickup, Strain Gauge, Agilent DC Power Supply, Electromagnetic Exciter, NI PXI 1050 with NI PXI 4472 Sound & Vibration measurement module, NI LabVIEW 8.5 software.

A cantilever beam is held in its fixing condition along with an external excitation system to set the initial displacement. An external electromagnetic exciter is used to set this initial displacement. Thereafter the beam is allowed to respond to this external excitation. The beam stiffness and mass decides its natural frequency. The material damping decides decay pattern. An accelerometer mounted on the beam measures its acceleration with time and a Time vs. Acceleration plot is obtained. But it does not contain any frequency based information. To simplify the measurement process LabVIEW software makes use of an algorithm known as 'Fast Fourier Transforms (FFT)' which extracts Frequency information from a time domain signal. The process is irreversible, Hence using FFT one can easily determine the natural frequency of the beam. Laser displacement pickup is a non contact type of sensor and it measures the response of the beam in terms of displacement. Dynamic forces will also be developed and will be maximum at the fixed end. The beam is rigidly fixed to the force transducer. The reaction forces developed in the transducer will be dynamic in nature. Similarly strain gauge measures the strain at the point.

A data acquisition system usually consists of Signal acquisition, Signal conditioning & Analog to Digital converter. NI modules are all in one combined Data Acquisition System. Transducers are instruments which convert any energy form to electrical energy. Graphical programming interface like LabVIEW reduces the burden of high end complicated codes which have to be written otherwise in case of primitive programming languages. The front panel which will be visible to the student who performs online experiment is shown in the Figure 4.

Forced vibration Test

The solution of the vibration problem can be viewed as an input/output relation where the force ($F(\omega)$) is the input and vibration amplitude ($X(\omega)$) is the output. If force and vibration are represented in the frequency domain, then the transfer function can be written as

$$X(\omega) = H(\omega) * F(\omega)$$

Or

$$H(\omega) = \frac{X(\omega)}{F(\omega)}$$

Where $H(\omega)$ is called the Frequency Response Function (FRF). It has both phase and magnitude component. The magnitude of FRF for the current model can be derived as

$$H(\omega) = \frac{\omega_n^2}{\sqrt{(\omega_n^2 - \omega^2)^2 + 4\xi^2\omega_n^2\omega^2}}$$

$$H(\omega) = \tan^{-1} \left(\frac{2\xi\eta}{\sqrt{1 - \xi^2}} \right)$$

Phase of

$$\eta = \frac{\omega}{\omega_n}$$

Where

The frequency response function can be measured experimentally. If we apply a known force at a given frequency and sweep the frequency of excitation and then measure the resulting vibration then one can then calculate the frequency response function, and hence characterize the system. This technique is used in the field of experimental modal analysis to determine the vibration characteristics of a structure. Some of the popular experimentation methods in the frequency domain analysis are

Impulse excitation Test

Sweep Sine Test

By applying a constant excitation force and sweeping the frequency of excitation one can measure the resulting vibration and calculate the frequency response function, and hence characterize the system. The name

sweep sine arises due to the fact that the system is allowed to respond between 2 frequency limits, chosen in such a way that the suspected natural frequency may lie between these two frequency limits. At a particular instance of time, the input frequency becomes equal to the natural frequency of the system and the amplitude level increases significantly. This is the resonance peak and can be clearly distinguished in the response curve. As soon as the input frequency crosses the resonant frequency, system amplitude keeps on reducing. From analysis point of view, resonant frequency amplitude is very important. Here unlike impulse excitation technique, the structure is excited by a pure sine wave of fixed amplitude but varying frequency and the system response to this varying frequency is studied.

A cantilever beam is fixed to an Electrodynamics shaker. The theoretical natural frequency of the beam is calculated and a band of frequency sweep is decided such that the theoretical natural frequency is between the sweeping frequency bands. At resonance the amplitude of vibration will be maximum and this will be the domain of interest. The amplitude is fixed and the frequency is slowly increased until resonance occurs. As soon as the first natural frequency is crossed vibration amplitude will come down drastically. At some instance of time, again the amplitude level will increase as the system approaches its second natural frequency. Second natural frequency is characterised by second mode shape. Each experiment has a video streaming feature also where student will actually see the experiment setup and also the experiment being conducted and controlled by him.

III. CONCLUSION

The performance of personal computers has been continuously increasing and the cost has been decreasing. This has facilitated the development PC based signal acquisition and analysis systems. These systems can replace costly stand-alone systems that are currently in use. The components necessary for a LabVIEW based acquisition and analysis system are inexpensive, and readily available. Here, the initial requirements of a PC based bio signal acquisition and processing systems have been studied and reviewed. Developing PC based systems using LabVIEW is an efficient alternative to stand alone systems. A virtual laboratory featuring experiments on vibration is illustrated and demonstrated successfully using the national instruments web publishing wizard. Hence the concept of using a versatile virtual instrumentation laboratory is justified where students who do not have access to such facilities can make use of the feature. This will give them better insight of theory and also confidence to conduct and setup experiment themselves. With the rapid development of PCs, Virtual Instrument will be applied in all kinds of measurement areas. Especially in seismographic observation, the users can acquire and analyze the seismographic vibration signals accurately. As a result, the seismographic observation will be realized more effectively.

The response of an aluminum cantilever beam under harmonic excitation is simultaneously measured using a strain gage, a linear variable differential transformer and an accelerometer, and compared with the real time theoretical response. All data acquisition and analysis is done using a custom built Labview virtual instrument.

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