Review on Design and Development of Vibration Test Rig

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ABSTRACT

In industry leading companies doing NVH testing require a standard test bench for reference data acquisition and research purpose. Testing and consultancy incorporates the Design, Development, Measurement, Data acquisition, Analysis, Report generation aimed at product improvement. This review paper is intended at extracting relevant information and study of various concepts aimed at designing, fabrication and testing of a multipurpose test rig used by company for corporate presentation. This test rig will be capable of performing tests like vibrational analysis, torsional vibration testing, rotational balancing, force transmissibility and noise testing. The various tests capable to be performed on this test rig serve the purpose of presenting the company's profile to its clients. The papers reviewed provide useful information on design and testing of systems like damped vibration in a shock absorber used in automobiles, test rigs utilised for estimating vibration characteristics of a beam, rigs for vibration loosening of bolts and easy interchangeability as well as its study, research work done on modelling and fabrication of crankshaft is also considered.
Keywords: Test Rig, FFT Analysis, Order Analysis, Octave Analysis etc.

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1. INTRODUCTION

The knowledge of the physical nature of vibration phenomena has always been important for engineers in industry, as models are becoming lighter and more flexible due to increased demands for efficiency, speed, safety and comfort. A model or machine in motion presents several issues like high vibration, performance limitations and failure in the model. Two ways could be considered to solve the vibration problem: first, prevent via proper design, and secondly, cure it, by changing model that serves as a design to control vibration. In any case, a full proof knowledge of vibration of the model is essential. Hence, accurate mathematical models are required to describe the vibration characteristics of the model.

For simple models, like beams and plates, good analytical predictions using closed form solutions can be easily found in various reference books and tables (Like Blevins) or lumped parameter systems can be used to model the dynamic behaviour of the model. However, for more complex models more powerful tools are needed. Today, two separate tools are used to model the dynamic behaviour of the models, namely analytical tools and experimental ones. The most widely used analytical tool is the Finite Element (FE) method, while the experimental counterparts are largely based on modal testing and analysis. As a result of different built-in limitations, assumptions and choices, each approach has its own advantages and disadvantages.

Structural vibration testing and analysis contributes to progress in many industries, including aerospace, auto-making, manufacturing, wood and paper production, power generation, defence, consumer electronics, telecommunications and transportation. The widely used application is identification and suppression of unwanted vibration to improve product quality. This application note provides an introduction to the basic concepts of structural vibration. It presents the fundamentals and definitions in terms of the basic concept. It also emphasizes practical applications and real world examples.

The tests for vibration are conducted by introducing a forcing function into a model, usually with some type of shaker. Alternately, a DUT (device under test) is attached to the "table" of a shaker. Vibration testing is performed to examine the response of a device under test (DUT) to a defined vibration environment. The measured response may be fatigue life, resonant frequencies or squeak and rattle sound output (NVH). Squeak and rattle tests are done with a special type of quiet shaker that produces very low sound levels while under operation. The most common types of vibration testing services conducted by vibration test labs are Sinusoidal and Random. Devices focussed at tracing or recording vibrations are called vibroscopes.

Vibration Analysis (VA), applied in an industrial or maintenance environment aims to reduce maintenance costs and equipment downtime by detecting equipment faults.VA is a key component of a Condition Monitoring (CM) program, and is usually called as Predictive Maintenance (PdM). Most commonly VA is used to detect faults in rotating equipment (Fans, Motors, Pumps, and Gearboxes etc.) like Unbalance, Misalignment, rolling element bearing faults and resonance conditions. Vibration Analysis utilises the units of Displacement, Velocity and Acceleration displayed as a Time Waveform (TWF), but most commonly the spectrum is used, derived from a Fast Fourier Transform of the TWF. The vibration spectrum provides important frequency information that can pinpoint the faulty component. The basics of vibration analysis can be learned by studying the simple mass–spring–damper model.

Noise Analysis is a small signal analysis which is carried out at discrete frequencies using a linearized version of the circuit. The mechanics are quite similar to that of an AC analysis. Noise analysis can be done by using various instruments and parameters. Mainly used SLM, ISLM, DOSIMETER, etc.

The SLM includes a microphone, electronic circuits and a readout display. The microphone detects the small air pressure variations associated with sound and changes them into electrical signals. The signals are then processed by the electronic circuits of the instrument. The readout displays the sound level in decibels. The SLM takes the sound pressure level at one instant in a particular location. Noise dosimeter is a tiny, light device which rests on a person's belt with a small microphone that fastens to the person's collar, close to an ear. The dosimeter stores the noise level information and carries out an averaging process. It is useful in industry where noise usually varies in duration and intensity, and where the person changes locations.

Modal analysis is the study of the dynamic properties of models under vibrational excitation. Modal analysis is the field of measuring and analysing the dynamic response of models and or fluids during excitation. Examples would include measuring the vibration of a car's body when it is attached to an electromagnetic shaker, or the noise pattern in a room when excited by a loudspeaker. Currently used modal analysis systems are comprised of 1)transducers (typically accelerometers, load cells), or non-contact via a Laser vibro-meter, or stereo photogrammetric cameras 2) data acquisition system and an analogue to digital converter frontend (to digitize analogue instrumentation signals) and 3) host PC (personal computer) to view the data and analyse it.

The analysis of the signals usually relies on Fast Fourier analysis. The resulting transfer function will show one or more resonances, whose characteristic mass, frequency and damping can be estimated from the measurements. The graphic representation of the mode shape is very useful to NVH (noise, vibration, and harshness) engineers. The results can also be used to correlate with finite element analysis normal mode solutions

2. DESIGN & FABRICATION

In design and fabrication, we learned from all papers we have referred that they made it as per the simplicity of testing and not by the aesthetic purpose. Nikhil T et al. [1] made a simply supporting beam structure so that the beam testing can be simple and quick. Similarly Sarika M. Aware who have done her work on test rig for threaded fastener made a simple construction as shown below.

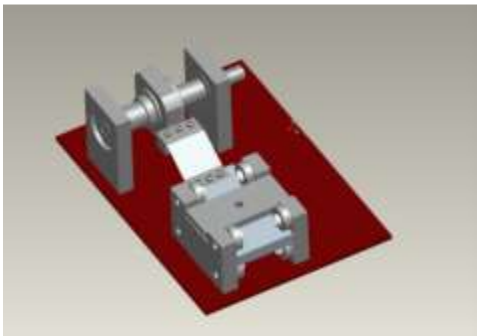

Fig.1 3D Test Rig Model Prepared by Sarika M. Aware [2]

2.1Design

Designing of test rig incorporates several factors regarding the application of the rig as well as feasibility for the required tests to be done on it. Several attempts done by various researchers were considered ranging from test rig design for characteristics for vibration of a beam. Such rigs had salient features like variation in cross section of the beam achieved through detachable ends, variable length through guide assembly as well as use of various materials. The test rig used also had arrangements for providing different end conditions like cantilever, simply supported and fixed ends. The location for excitement given could be varied as per requirement and excitation is provided through an eccentric mass mounted to a disc run by variable speed motor that produces a sinusoidal unidirectional force.

The location of this excitation source can be varied (through Motor Assembly),and its magnitude can be varied by changing any one of the parameters like eccentric mass (m) or distance of eccentric mass from center of the disc (e) or by changing RPM of DC motor (ω) using speed controller. Eccentric weights are adjustable from zero to full eccentricity so as to allow a wide range of forces to be covered with approximately same frequency. The test-rig was designed for aluminium beam with cantilever condition. Dimensions of beam were calculated by considering both static load due to weight of motor assembly and beam. Stresses developed were calculated analytically by drawing SFD, BMD for each case and found to be lesser than allowable stresses calculated using endurance limit of material. The test rig developed enables to perform a wide range of transverse vibration experiments with the minimum amount of assembly time and the maximum adaptability.

2.2 Fabrication

As A.P Arun et al. [7] created a concrete base for main frame placement we are planning to incorporate 6 AVMs to mount our baseplate on it. Also, they used a 3 phase induction motor along with a separate RPM controller to control motor RPM from 0 to 3000. Similarly, we are planning to use a servo motor which will get its power from AC-DC converter ranging from 0 to 4000 RPM. Flange coupling was used by A.P Arun et al. [7] to connect gearbox and motor shaft. Similarly, we will use love joy coupling to connect motor output shaft and main shaft of the test rig. As the shaft will be long enough in length it will need some support to avoid deflection at center, we will add two supports with bearing inside whose ID will be similar to the OD of shaft. Here on the bearing supports we will be able to take FFT readings by mounting an accelerometer on it. The shaft will be having a keyway where a small disc or flywheel will be mounted. This flywheel will do the work of measuring revolutions using tacho probe mounted on fixture or on second bearing support. Before the love joy coupling two fixtures will be designed to mount a motor by which shaft will be rotated. One will be mounted rigidly on baseplate and it will bear the load of motor and another fixture. Another fixture will be consisting of a stepped plate which will go inside the first fixture and have motor mounted on it. Below shown is the fabrication and arrangement done by Nikhil T. et al [1]. We are also planning to do the same arrangement for our test rig.

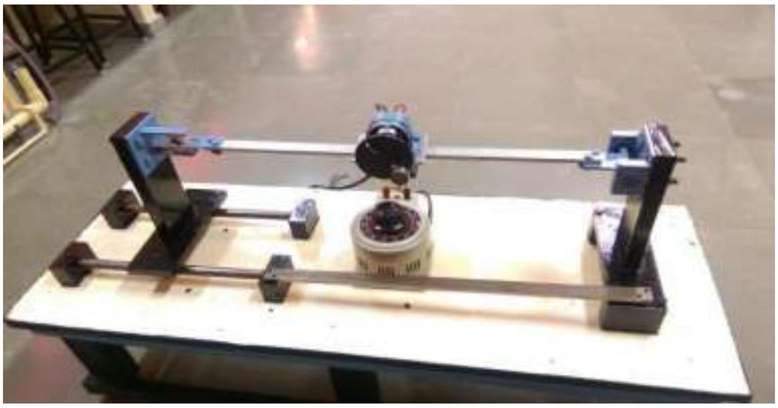

Fig.2 Vibration Test Rig Prepared by Nikhil T. et al [1]

3. TESTING

3.1 Octave Analysis

An octave is the difference between a frequency and its double or its half. There is one octave band between frequencies 1 000 Hz and 2 000 Hz. Like there is an octave band between 1000 Hz and 500 Hz. In application for engineers, sound spectrums are data presented in octave or one-third octave frequency bands and not in narrow frequency bands. This frequency representation is linked to the perception of sound by a human ear and it allows a compression of the amount of information. Still major part of this information is lost while conversions of signals from narrow frequency to one-third frequency band.Narrow frequency refers to band that has a constant frequency increment in step much smaller than the frequency spectrum. Measurements carried out with spectrum in the 200 to 4000 Hz having a frequency step of 20 Hz is called narrow frequency band results.

3.2 Octave Bands

In cases where further information is needed we split the spectrum in 10 bands called as the Octave Bands since there is one octave between the bottom and top of each band.The centre frequencies for these bands are usually:

31.5Hz , 63Hz , 125Hz , 250Hz , 500Hz , 1kHz , 2kHz , 4kHz , 8kHz and 16kHz

Sound level meter measures the noise for each of the bands in the octave, either all at the same time that is parallel or switching to one band at a time that is serial filter.The graph shows a typical octave band spectrum. In this case, you can clearly see that the 1kHz and 2kHz bands are showing much higher levels than the others. If you were trying to reduce the noise then based on this measurement you can see where all the effort needs to go, especially when you consider that these bands intersect or overlap with the frequencies where a human ear is most sensitive.

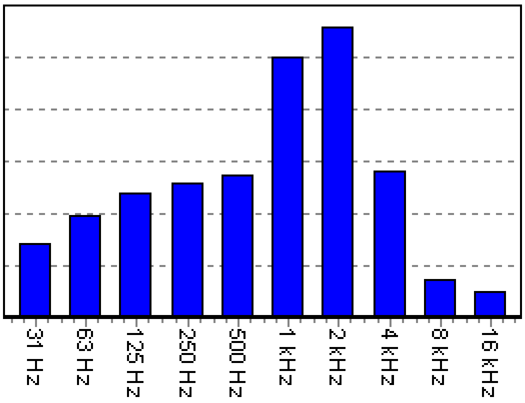

Fig.3 Octave Band Spectrum

3.3 FFT Analysis

Human ear creates a transform by changing sound—the waves with respect to pressure traveling over time and through the atmosphere—into a spectrum, a data of sound as a series of volumes at distinct pitch values. The brain further converts that information into audible sound.

Such conversion is also possible by the use of a mathematical method on the same sound waves or virtually any other fluctuating signal that varies with respect to time. Fourier transform is used for that specific mathematical conversion. In few words, the Fourier transforms changes waveform data in the time domain into the frequency domain. The way this is done is that Fourier transform breaks these series of time based signals into sinusoidal terms, each with a unique magnitude, frequency, and phase. Such process, as an effect, changes a waveform in the time domain which is difficult to understand mathematically into a more simplified series of sinusoidal functions that when added together, exactly reproduce the original waveform

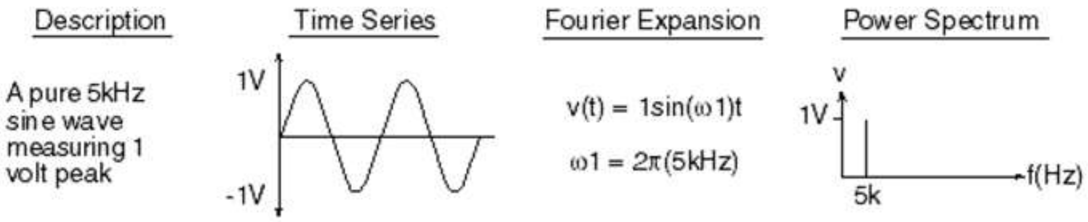

Fig.4 Transformation from Time Domain to Frequency Domain

3. CONCLUSION

By reviewing some of the papers which were based on the design and development of the test rig, we get to know that mainly test rig is developed on the basis of ease of operation and analysis. Also we learned some scientific phenomenon like cantilever condition of the bean can be very sensitive to the change in the characteristic conditions while on the other and fixed beam is less sensitive. From the paper of Sarika M. Aware [2] we reviewed that while developing a test model Ansys plays an important role for determining the safety of the test rig. We are planning to make a test rig in CADmainly in Creosoftware first then for the analysis of model, we are aimed to use Ansys and the model will be designed towards simplicity.

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