An Overview of Design and Development of Vibration Test Bench to Check the Dynamic Performance of Centrifugal Oil Filter

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ABSTRACT- Components used in automobiles, earthmoving equipment's, marine applications are subjected to vibrations due to mother system as well as motion. The components need to be designed to withstand the vibrations as well as perform in this vibrating environment. The failure of components in vibrating environment can be catastrophic or in the form of deformation causing further assembly problems. Various international standards specify the method to test the components using a "simulation" test bench. The component under development is mounted on the test bench platform and the platform is accelerated in multiple axes to simulate the working condition. The acceleration, amplitude, octave cycle and test duration is specified by the standards. Agencies like ARAI are providing this testing facility for component manufacturing. The need to develop a simple system was felt as outsourcing the test for long duration is very costly and the agencies are mostly providing a static test. This review paper aims at making a simple vibration acceleration test bench. The test bench will have a platform to accelerate the mounted component in x,y,z axis. The excitation shall be in the form of simple harmonic motion. There shall be arrangement to modify the amplitude and frequency of oscillations to finally control the vibration acceleration. The machine will enable the company to check the dynamic performance of the component under test.

Keywords- Vibration, Vibration Analysis, PRO-E, natural frequencies, numerical and modal analysis

Introduction:

Several predictive maintenance techniques are used to monitor and analyze critical machines, equipments, and systems in a typical plant. These include vibration analysis, ultrasonic, thermography, tribology, process monitoring, visual inspection, and other non-destructive analysis techniques of these techniques, vibration analysis is the dominant predictive maintenance technique used with maintenance management programs. Monitoring of vibration characteristics of parts to detect budding problems and to head off catastrophic failure.

Vibration analysis can be used to evaluate fluid flow through pipes or vessels to detect leaks and to perform a variety of non-destructive testing functions that improve the reliability and performance of critical plant systems. Vibration testing machines which are used for developmental, simulation, production, or exploratory vibration tests for the purpose of studying the effects of vibration or evaluating physical properties of materials or structures. A vibration testing machine (sometimes called a shake table or shaker and referred to here as a vibration machine) is distinguished from a vibration exciter. In it, there is complete with a mounting table which includes provisions for bolting the test component directly to it. A vibration exciter, also called a vibration generator, may be part of a vibration machine or it may be a device suitable for transmitting a vibratory force to a structure.

Most conventional shakers excite the test item in one rectilinear direction. Most environments include vibration in several directions (both rectilinear and rotation) simultaneously. In an effort to provide more realistic testing, shaker systems with inputs in several directions at the same time are desirable.

This project mainly concerns the endurance testing of centrifugal filters by vibration analysis. There are two major problems facing by the company during the vibration testing of the filters; Firstly the cost of testing per component: the cost ranged from Rs.2000/- to Rs.3500/-per hour with a fixed number of components in a batch. The required endurance testing hours being extensive ranging from 300-500 hours, thus it is practically uneconomical to send the components for vibration analysis. Secondly, the conventional vibration testing methods are restricted to the motion in one direction only (1 DOF). But from the utility point of view, better simulation conditions and according to the requirements of the company, the component should withstand forces and stresses from various directions.

Relevance/Motivation:

Components used in automobiles, earthmoving equipment's, marine applications are subject to vibrations due to mother system as well as motion. Components need to be designed to withstand the vibrations as well as perform in this vibrating environment. The failure of components in vibrating environment can be catastrophic or in the form of deformation causing further assembly problems.

Various international standards specify the method to test the components using a "simulation" test bench. The component under development is mounted on the test bench platform and the platform is accelerated in multiple axes to simulate the working condition. The acceleration, amplitude, octave cycle and test duration is specified by the standards. This testing facility is provided by ARAI, Pune. Hence, it needs to develop such type of system

Literature Review:

There has been lot of work carried out related to vibration analysis for various applications like centrifugal oil filters etc. but it is not possible to include all work here. Only most relevant work is mentioned here. The research from developing theories related to vibration test bench and is now moving optimizing various parameters according to applications.

S. Ricci, et al, [1] studied on "Virtual Shaker Testing for Predicting and improving Vibration Test Performance. "In this paper, virtual shaker testing approach is developed, which include a coupled electro-dynamic exciter lumped parameter model and vibration controller. Because of the importance of the shaker model and the fact that the specified shaker information isn't always effortlessly to be had from the manufacturers, a device identity technique to extract shaker version parameters from measurements was supplied. A coupled electro-mechanical lumped parameter shaker model turned into created first, and model parameters were tuned by some dedicated experiments. A vibration controller model then implemented. Primarily based on present algorithms, measurements have been confirmed through hardware-in-the-loop (HIL) simulation. At that degree, The motion of virtual shaker Test is obtained by coupling shaker and control loop models in a co-simulation routine. Finally, a satellite effective mass model was introduced to the virtual shaker platform and confirmed the high degree of realism that may be received within the virtual shaker technique.

Daniel M.Harris, et al.[2], studied on "Generating Uniaxial Vibration with an Electro dynamic Shaker and External Air Bearing. "They had verified the efficacy of introducing a linear air bearing to rectify the non-axial motions of flexure-based electro dynamic shakers. Additionally examined a standard shaker and discovered a distinct mechanical resonance of the armature's suspension leading to non-axial motion of the pay load, also tested that the performance of the unmodified shaker is very sensitive to the detail of the pay load, including its mass. They offered the information of an advanced improved design that in corporate an external air bearing eliminates torsional movement and greater effectively constrain the vibration to single axis. They provided preferred standards for choice of a drive rod that couples the shaker to the air bearing slider and presented test results, which confirmed a enormous improvement of the vibration quality of the payload for their whole frequency range of interest (20–150Hz). Specifically, their design decreased the most in homogeneity of the vertical vibration amplitude from about 10 % to 0.1 % additionally established that just under the Faraday threshold, the dynamical and statistical behavior of the droplets is extremely sensitive to the driving amplitude.

Lei You, et al, [3] worked on "Fault Diagnosis System of Rotating Machinery Vibration Signal. "In this paper, a new fault diagnosis system of rotating machinery vibration signal, which can improve the precision of testing vibration signal, was proposed. they used the advanced PXI test platform, adopting 16bit resolution A/D device and FPGA technology in the design. The conditions for further realization of detail analysis of time-frequency domain were also provided. The system monitored vibration acceleration and velocity signal, made accurate judgment on mechanical fault. Compared with the existed fault diagnosis systems, the system mentioned in that paper achieved higher accuracy, and improved accurate diagnostic capability and dramatically increased interaction. Experimental results demonstrated that the system had met the design requirements.

Soukup J, et al. [4] published paper on "Vertical Vibration of The Vehicle Model with Higher Degree of Freedom." New method of solution of the motion equation of the mechanical system with higher degree of freedom is applied on the investigation of the vertical vibration of the vehicle. Mechanical model is composed from three spatially elastically supported and bounded bodies. Model represents the chassis of railroad vehicle with elastic and dissipative elements. Proposed method enables to determine the vertical displacement of the arbitrary point of the system also allows solving various vibration tasks for model of vehicle with higher degree of freedom. It allows analyzing the effect of the input values, e.g. body geometry and its support, properties of springs and dumping, mass distribution, track imperfection; it is simplified analysis of the resulting motion, included frequency analysis. The unicity of the solution is implemented into the standard commercial software (Mathematica, Matlab,) to solve wide range of the similar described problems.

Nangolo N.F,et al. [5] Studied on "A Combined Numerical and Modal Analysis on Vertical Vibration Response of Railway Vehicle."In this paper, The 9 degrees-of-freedom (DOF) 4-axle freight wagon were modeled as a multi-body system. Mathematical model was developed to describe the vertical vibration of the system. The motion equations were assembled using Lagrange's equation. Modal analysis was applied to differential equations and the convolution integrals were solved by numerical integration using piecewise constants as interpolation function. Ten Experiments were carried out with system to obtain data for comparison. The data were treated by CEM method to obtain input parameters for numerical solution. Two cases of carried out experiments are presented here. Mode A had symmetrical distribution of sprung mass and mode E had asymmetrical distribution of the sprung mass. Developed mathematical model allows simulating the system with symmetrical distribution and arbitrary asymmetrical distribution of sprung mass as well. The experimental data were compared with model prediction for both cases respectively. From results, it is obvious the excellent agreement of measured data and model prediction for both presented cases of vertical vibration of the 9 degrees-of-freedom (DOF) 4-axle freight wagon. The developed mathematical model has potential to describe specified investigated system.

Ashwani Kumar, et al [6], published a paper on "Free Vibration Analysis of Truck Transmission Housing Based on FEA."In This paper, The analysis outcomes showed that transmission housing was subjected to Axial bending vibration, Torsional vibration and Axial bending with torsional vibration. The transmission housing motion was constrained by using constraining the displacement of bolt holes. ANSYS14.5 software has powerful evaluation abilities and SOLIDEDGE software has a powerful function of stable modeling. They have been desirable for Finite detail evaluation of complicated shapes. The3D solid version turned into prepared via making use of SOLIDEDGE software program and transferred to ANSYS 14.zero. In this research work, they had been taken into consideration the vibration problem of the transmission housing using FEA technique. Finite Element analysis provided satisfactory results. First 20 Vibration mode form has been calculated. The experimental and analytical analysis was not available in literature for the transmission housing. So it is a new simulation analysis for transmission housing.

From the literature survey it can be seen the Design and Development of Vibration Test Bench Centrifugal Oil Filter to Check the Dynamic Performance has been a hot research topic for many researchers, due to its important role in Dynamic performance checking. The researchers started from developing theories related to general behavior of vibration exciter and further moving to implementing the optimizing various parameters according to their application.

Scope

Well definition of the problem.
Learning and use of the PRO-E and AUTOCAD Software.
Development of equations of free vibration with damping, free vibrations without damping.Spring design under fluctuating load.
Development and analysis of centrifugal oil filter vibration test bench.
Experimental analysis of oil filter vibration exciter system mounted on test rig.
Validation of all the results.

Objectives

To reduce Cost of Testing per Component effectively.
To reduce the required Endurance Testing Hours.
To obtain better simulation conditions.

Methodology

Initially theoretical study of Centrifugal oil filter Vibration test bench will be done. After making strong theoretical background, Vibrational analysis of centrifugal oil filter attached to working table will be done by using FFT. After this, actual experimentation will be carried out by using FFT Analyzer. Then validation of all the results will be done.

Facilities available and requirements:

1. Central and Departmental Library.
2. Computer Lab and Internet lab equipped with High speed Broadband and Lease Line
3. Central Workshop.
4. PG Research Lab equipped with FFT Analyzer.
5.CAD/CAM lab equipped with PRO-E and AUTOCAD Software.

Proposed Experimental Setup

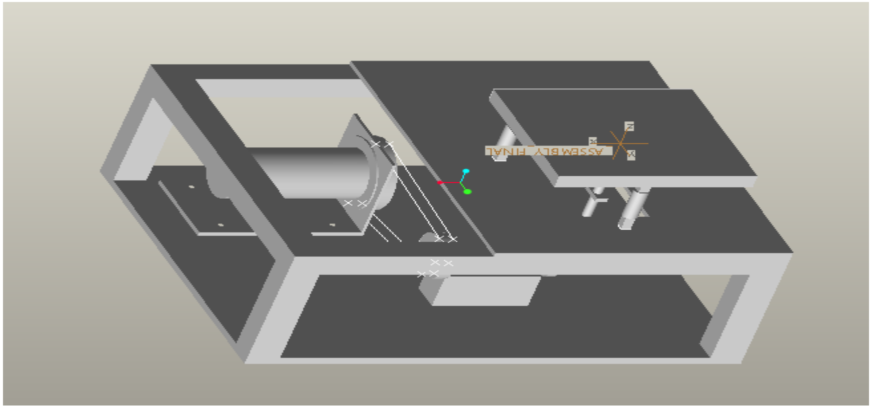

Fig: Proposed Experimental Setup for Vibration Testing Bench

Applications

This vibrating table having multiple degrees of freedom is mainly designed for fatigue testing or endurance testing of the centrifugal oil-filter which are used mainly in the vehicles. Other engine parts can also be tested on this mechanism given their natural frequencies and weight the deflection and vibration frequency and amplitude has to be calculated. The centrifugal oil filter is described as given in fig.

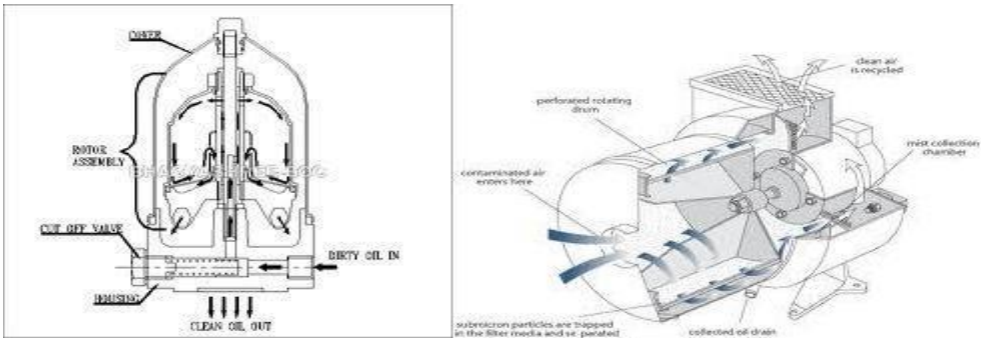

Fig: centrifugal oil filter

An oil filter is a filter designed to remove contaminants from engine oil, transmission oil, lubricating oil, or hydraulic oil. Oil filters are used in many different types of hydraulic machinery. A chief use of the oil filter is in internal-combustion engines in on- and off- vehicles, light aircraft and various naval vessels. such as those in automatic transmissions and power steering, are often equipped with an oil filter. Gas turbine engines, such as those on jet aircraft, require the use of oil filters. Aside from these uses, oil production, transport, and recycling facilities also employ filters in the manufacturing process.

A centrifugal oil cleaner is a rotary sedimentation device using centrifugal force rather than gravity to separate contaminants from the oil, in the same manner as any other centrifuge. Pressurized oil enters the center of the housing and passes into a drum rotor free to spin on a bearing and seal. The rotor has two jet nozzles arranged to direct a stream of oil at the inner housing to rotate the drum. The oil then slides to the bottom of the housing wall, leaving Particulate oil contaminants stuck to the housing walls.

The housing must periodically be cleaned, or the particles will accumulate to such a thickness as to stop the drum rotating. In this condition, unfiltered oil will be re-circulated.

Vibration Fixtures

The scope of testing of this mechanism is not restricted to only one component. Hence there would be requirement for fixtures to clamp these test items to the table. The mechanical design of systems with more than two degrees of freedom is more difficult. The shaker providing the input can usually move in only one direction. If the test item is to move in more than one direction and/or rotate, the mechanical design of the system must isolate all the motion except in one direction from the shakers. It is also difficult to restrain other degrees-of-freedom, for example, rotations. Restraint of unwanted motion is usually accomplished with passive restraints (for example, hydrostatic bearings) or with active restraints using the exciters and the control system. Undesired motion, compromising the test, will result if the uncontrolled degrees of freedom are not restrained. These fixtures are usually designed to be rigid in the frequency band of interest and lightweight. Rigidity is required because the vibration test is typically controlled at a single point. The assumption is that the motion of the control point is representative of the input to the test item. If the fixture is not rigid, this assumption is obviously not true.

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