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Internal Combustion Engine Vibrations And Vibration Isolation

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Abstract— This paper presents general information of compression injection engine, sources of engine vibration and its solutions. In today's competitive world, the customer expects better products than the existing one. Diesel engine is critical equipment because its failure has high consequences on cost. While designing any equipment it is necessary to consider reliability and maintainability as they are the critical factors that determine equipment performance, running cost and capital cost. Vibrations in an engine are undesired since they can cause increased stresses, added wear, increased sound levels, material fatigue, energy losses and increased bearing loads. This can in time lead to mechanical failure and breakdown. Vibration reduction is important which improves plant availability, as well as reduced breakdown costs of the engine. Vibration isolator is used which reduces the force transmitted from the engine to the support structure. Different methods are used to reduce the engine vibration. Anti-Vibration Mounts (AVMs) are the structures used to absorb the vibrations and dampen the harm causing forces. An anti-vibration mount can be constructed from a number of different materials, rubber has many inherent qualities which make it an ideal solution for this application.

Index Terms—Anti-Vibration Mount, Engine Vibration, Isolator

1 INTRODUCTION

A diesel engine (also known as a compression-ignition engine) is an internal combustion engine that uses the heat of compression to burn the diesel, which is injected into the combustion chamber. Diesel engine is critical equipment because its failure has high cost. Before designing any equipment it is necessary to consider reliability and maintainability as they are the key factors that determine equipment performance, running cost and capital cost.

The diesel engine has the highest thermal efficiency of any regular internal or external combustion engine due to its very high compression ratio. The compression ratio is a measure of how much the engine compresses the gasses in the engine's cylinder. In a diesel engine compression ratio ranging from 14:1 to as high as 24:1 are commonly used. The higher compression ratios are possible because only air is compressed in the cylinder, and then the fuel is injected. A diesel engine is widely used in various applications such as agriculture field, stone crusher, sugar crane crusher, Generators, concrete mixer, firefighting engines etc. Following figure 1 shows the actual model of multi cylinder water cooled engine.

A cyclic motion of a body or a system, due to the elastic deformation under the action of external forces is known as Vibration. Vibration is a magnitude (force, displacement, or acceleration) which oscillates about some specified reference where the magnitude of the force, displacement, or acceleration is alternately smaller and greater than the reference. Vibration is a form of movement of a body or a system around its point of equilibrium. Vibration is commonly expressed in terms of frequency (cycles per second or Hz) and amplitude, which is the magnitude of the force, displacement, or acceleration.

Fig.1 Multi Cylinder Water Cooled Engine

2 ENGINE VIBRATION

Engine vibrations have been one of the serious problems for the engine manufacturers in the world. The internal combustion engine design, itself is a difficult task as it includes multiple parts of various sizes assembled together to form the engine. The internal combustion engine is required to be designed judiciously so that the unbalanced forces generated by the engine parts are reduced. If the design is not optimum it will generate more vibrations and are transmitted to supporting structure where engine is mounted. In the internal combustion engine there are various parts such as piston, piston ring, engine block, connecting rod, engine head, crankshaft, cam shaft, flywheel, valves, pulleys, bell housing

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etc. Among all these parts few parts are taken as vibration generating parts by the industry professionals. There are four major components which generate vibrations by producing unbalanced forces during cycle are piston, crankshaft, engine block and connecting rod. As these components are interconnected with each other, produced unbalancing forces which are transmitted to the engine parts such as building block of engine and to the contacting structure.

Four major causes for overall vibration behavior of IC engine are variation in gas pressure in each cycle, impact forces due to reciprocating parts, unbalanced rotating and reciprocating parts and mount structural characteristics. During working of engine speed, load on the engine is varying depending upon need of customer. Due to which fuel supply and combustion characteristics also changes. The inertial forces changes with respect to compression and combustion variation inside the cylinder of the engine. It is confident that inertial forces give rise to unbalanced forces and they are fluctuating with speed of the engine, fuel supplied and combustion characteristics of the fuel.

IC engine produces mainly two types of vibrations i.e. longitudinal and torsional vibrations. If the part moves up and down along the axis of the shaft, then the vibrations are known as longitudinal vibrations. If the part rotate about the axis of shaft such that the shaft gets twisted and untwisted alternately, then the vibrations are known as torsional vibrations. In which reciprocating behavior of the engine results some torsional vibration continuously. In compression stroke when piston moves towards top dead centre the cylinder pressure increases. As then ignition and combustion of the fuel occurs pressure again increases, and then pressure reduce with piston movement towards bottom dead centre. The pressure generated due to combustion of fuel exerts tangential force on the piston that does required work and crankshaft speed increases. So the crankshaft speed is increases in combustion stroke where as decreases during compression stroke respectively. This changing speed of the crankshaft gives rise to torsional vibrations for crankshaft. Thus the change in combustion pressure during downward motion and changing inertial motion during upward motion of the piston gives rise to unbalanced forces on the engine block. These are considered to be responsible for generating the longitudinal vibrations.

The internal combustion engine looks simple but it is highly complicated machine containing hundreds of components which have to perform its functions satisfactorily to produce required power output. In such a complicated Internal combustion engine while it is running components have relative motion with respect to each other producing internal vibrations. The collective effects of these relative motions are also responsible for external vibrations of the internal combustion engine.

3 LITERATURE REVIEW

Vibrations in an engine are undesired since they can cause increased stresses, added wear, increased sound levels, material fatigue, energy losses and increased bearing loads. This can in time lead to mechanical failure and breakdown.

T. Ramachandran et al. [1] have studied on the vibration that reduces the engine performance and it need to be controlled to some extent so that the engine performance will be improved. The IC engine is made up of reciprocating and rotating parts and they produce unbalanced forces during their operation and produce the vibratory output at the vehicle supporting members. The vibration reduction will be possible by minimizing unbalanced forces and by providing the anti-vibration mounts at the engine and vehicle interface.

Dr.S.S.Gawade et al. [2] explained about internal combustion engine and measurement of vibration. This internal combustion engine is a heat engine that converts chemical energy of fuel into mechanical energy. This mechanical energy is utilize to drive the various application such as agriculture, Automobile, concrete mixer, etc. In every diesel engine there is vibration due to reciprocal component, rotational component, unidirectional combustion forces, structural resonance etc.As per standard it is necessary to analyze the vibration. Researcher explained about vibration testing of single cylinder diesel engine by using FFT (Fast Fourier Transform) & Accelerometer.

Amit V. Chavan et al. [3] described on Finite Element Analysis of Base Frame for Rigidity. For typical base frame, the stiffness is measured by means of rigidity test (actual measurement) for different load cases. These modified cases are simulated using FEA techniques for stiffness qualification. ANSYS is used for simulation of these cases including that of existing design, for bench marking and comparison purpose. Based on these results, best feasible design solution is proposed and validated experimentally.

V.S.Chavan et al. [4] have been proposed about Engine vibrations which have been one of the major problems for the engine manufacturers in the world. The engine excitation forces, arising from the gas pressure and unbalance forces are the sources of vibrations. Anti- Vibration Mounts (AVMs) are the structures used to absorb the vibrations and dampen the harm causing forces. The engine is bolted freely on mount which dampens the vibrations going to the base frame/canopy. Comparative study of AVM to suggest which material is to be selected for AVMs. A single AVM is analyzed for modal and frequency response.

A.R.Jadhav et al. [5] have been studied on vibration of diesel electric generator which influences building cost, efficiency, performance and effectiveness. This paper review the theoretical and practical aspect associated with one particular vibration control technology, namely passive vibration isolation. It discusses the selection of elastomeric isolator for single degree freedom of diesel electric generator assembly.

Namdev A. Patil et al. [6] have been examined on the vibrations generated in the IC engine that affects the performance of the vehicle. Reciprocating as well as rotating parts of the engine are producing vibrations continuously in the internal combustion engine. The inertial forces are

produced by these reciprocating and rotating parts. The vibrations produced by the engine can be minimized by reducing those unbalanced forces generated during its functioning, otherwise anti-vibration mounts are placed in between engine and its base. The experimental work performed on a single cylinder diesel engine to measure vibrations using FFT spectrum analyzer.

Nader Vahdati et al. [7] have been analyzed that Rubber and fluid-filled rubber engine mounts are commonly used in automotive and aerospace applications to reduce the cabin noise and vibration, in certain applications, the rubber mount may operate at frequencies as high as 5000 Hz. The dynamic stiffness of the mount needs to be known in the above frequency range.

T Ramachandran et al. [8] have been investigated, modelled and analyzed the rubber engine mount. The performance of the automobile engine is affected due to the vibration. The engines are the major source of the vibrations and are caused because of the unbalanced forces from the engine. Engine mounts are identified as one of the vibration controller unit. The mount consists of the two mild steel plates and rubber isolator in between the plates.

C. Nataraj et al. [9] have been examined the forced response of an airplane engine supported by an elastic foundation. It is assumed that the vibrations of the engine and the foundation are small enough such that the equations of motion are linear. The engine is modeled as a rigid body connected to the foundation by standard industrial rubber mounts which act as three-dimensional springs with a significant amount of hysteresis damping. In all cases, the mass, stiffness, and damping matrices of the engine-mount system are constructed and the frequency response to the rotating unbalance is determined. It is shown that the foundation elasticity may have a significant effect on the engine vibration and the mounting forces transmitted from the engine to the structure.

Jordan Cheer et al. [10] have been investigated on the applications of an active noise control system to the control of generator noise in the master cabin of a luxury yacht. Active noise control has been applied to a variety of systems in order to improve performance without the increases in size and weight of the engine. It is shown that, due to the high number of engine orders produced by the generator, in order to achieve significantly perceptible levels of noise.

3 VIBRATION ISOLATION

Vibrations in an engine are never good but it cannot be avoided still it can be reduced to certain level. In discussing vibration protection, it is useful to identify the three basic elements of dynamic systems:

- The equipment (component, engine, instrument, etc.)
- The support structure (floor, base plate, concrete foundation, etc.)
- The resilient member referred to as an isolator or mount (rubber pad, air column, spring, etc.) which is interposed between the equipment and the support structure.

If the equipment is the source of the vibration the purpose of the isolator is to reduce the force transmitted from the equipment to the support structure. The direction of force transmission is from the equipment to the support structure. Vibration isolation is the process of isolating an object, such as a piece of equipment, from the source of vibrations.

Passive isolation: "Passive vibration isolation" refers to vibration isolation or mitigation of vibrations by passive techniques such as rubber pads or mechanical springs,

Common passive isolation systems:

A. Mechanical springs and spring-dampers- Helical coil springs are available in many different sizes and load carrying capabilities. These are heavy-duty isolators used for building systems and industry. Sometimes they serve as mounts for a concrete block, which provides further isolation.

B. Pads or sheets of flexible materials such as elastomers, rubber, cork, dense foam and laminate materials- Elastomer pads and laminate materials are often used under heavy machinery, under common household items, in vehicles and even under higher performing audio systems.

C. Molded and bonded rubber and elastomeric isolators and mounts- These are often used as machinery mounts in vehicles. They absorb shock and attenuate some vibration. Isolation mounts reduce the transmission of energy from one body to another by providing a resilient connection between them. Damping reduces the amplitude of vibration by converting a portion of the energy into low grade heat. Anti-vibration Mounts (AVM) are the structures used to absorb the vibrations and dampen the harm causing forces. Mount result in a system which is modeled as mass/spring/damper. AVM consist of the rubber or elastomer sandwiched between the two metal cover plates. The ability of an elastomer to convert energy of motion allows it to absorb vibration. Anti-vibration mounts are designed to isolate undesirable vibration which is generated in engine, industrial, consumer and scientific equipment. An anti-vibration mount achieves these aims by balancing out the system frequency with the disturbing frequency. In actual anti-vibration mount can absorb over half of the energy produced by the vibration.

D. Tuned mass dampers- Tuned mass dampers reduce the effects of harmonic vibration in buildings or other structures. A relatively small mass is attached in such a way that it can dampen out a very narrow band of vibration of the structure.

The performance of an isolation system is determined by the transmissibility of the system i.e the ratio of the energy going into the system to the energy coming from the system.

Active isolation: Active vibration isolation systems contain, along with the spring, a feedback circuit which consists of a sensor, a controller and an actuator.

4 SUMMARY

It can be summarized that vibrations in a machine or an engine are the undesired part since they can cause increased stresses, added wear, increased sound levels, material fatigue, energy losses and increased bearing loads. These can in-time lead to mechanical failure and breakdown. Vibration reduction clearly improved engine efficiency, as well as reduced breakdown costs is the greatest benefits. The best solution to a vibration problem is to avoid it in the first stage that is at the time of design. Therefore it is important to design the engine such that none of these vibrations are close

to the natural frequency of the engine. If the vibrations of the running engine are close to its natural frequency, they will amplify each other and generates higher forces and causes early breakdown of the bell housing or other engine components.

Based on the literatures from the various research articles for the engine vibration testing and measurement techniques used and the various mountings used to reduce the vibration and recent technologies invented and adopted. The dominant frequency of engine is proportion to fundamental frequency of engine and reciprocating balancing and rotary balancing is necessary to reduce the vibration.However, when you are choosing the material for the mounts, it is a good idea to choose the material that's going to last and provide you with the best solution. Most of will agree that high quality rubber is going to be the best possible solution. Rubber is an ideal material for anti-vibration mount because rubber is extremely durable, rubber offers increased flexibility and versatility, rubber components offer a cost-effective alternative. Ant vibration mount plays a key role in absorption of engine vibrations towards the base structure.

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