Application & Installation Guide

Vibration

LEBW4972-03

CAT®

Contents

Foreword

This section of the Application and Installation Guide generally describes Vibration, its causes and suggested corrections for Cat® engines listed on the cover of this section. Additional engine systems, components and dynamics are addressed in other sections of this Application and Installation Guide.

Engine-specific information and data are available from a variety of sources. Refer to the Introduction section of this guide for additional references.

Systems and components described in this guide may not be available or applicable for every engine.

Vibration

All mechanical systems with mass and elasticity are capable of relative motion. If this motion repeats itself over a given time period, it is known as linear vibration. Engines produce linear vibration due to combustion forces, torque reactions and structural mass and stiffness combinations and manufacturing tolerances on rotating components. All these forces may create conditions ranging from unwanted noise to high stress levels, and possible failure of the engine or driven components. Torsional vibration can create similar conditions but is caused by the twisting and untwisting of a shaft.

This guide:

- Reviews the basic theory and nomenclature of linear vibration.
- Identifies causes of engine-related linear vibration.
- Provides instruction for possible corrective action.
- Reviews the basics of torsional vibrations, including an understanding of causes and approaches to addressing them.
- Describes torsional vibration analysis (TVA), its importance, and information required to complete a TVA.

SECTION CONTENTS

Basic Theory

Engine vibrations are produced and maintained by regular, periodic driving forces set up by unbalanced moving masses. These are called forced vibrations.

Free vibrations have no driving force. When set in motion, such vibrations, if undamped, would continue indefinitely with constant amplitude and natural frequency.

If the frequency of a forced vibration is the same as the natural frequency of a free vibration, then excessive vibration will result. This synchronization of forced and free vibration is called resonance.

Resonance stresses can cause serious problems and even reach destructive levels.

The vibration generated by the engine could also result in structural damage if a rigid installation was housed in a building or close to sensitive instruments or equipment, such as computers.

Other factors influencing vibration are foundation design, soil load characteristics, and other machinery operating in close proximity.

Linear Vibration Definitions

Linear vibration occurs as a mass is deflected and returned along the same path. This can be illustrated as a single mass spring system as shown in **Figure 1**. While no external force is imposed on the system, the weight remains at rest and there is no vibration. When the weight is moved or displaced and then released, vibration occurs. The weight travels up and down through its original position until frictional forces cause it to rest.

Mass Spring System

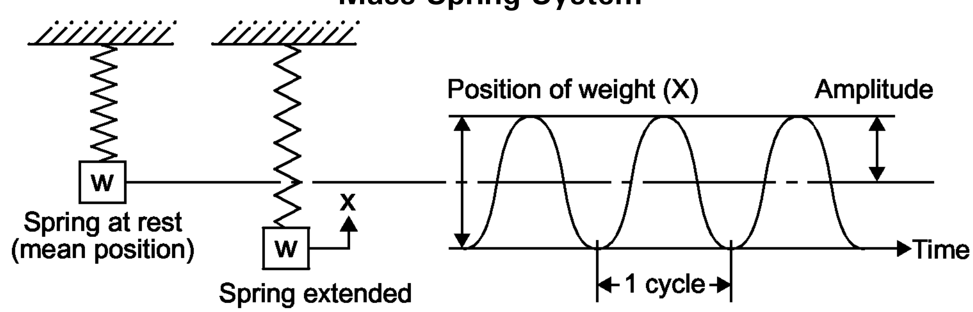


Figure 1

Frequency

Refer to **Figure 2** for an illustration of the following definitions. Maximum displacement from the mean position is called amplitude. The interval in which the motion is repeated is called the cycle. The time required for the weight to complete one cycle is called a period.

If the weight needs one second to complete a cycle, the vibration frequency is one cycle per second.

If one minute, hour or day were required, its frequency would be one cycle per minute, hour or day, respectively. A system completing its full motion 20 times in one minute would have a frequency of 20 cycles per minute, or 20 cpm.

Establishing frequency is necessary when analyzing vibration. It allows identification of the engine component or condition causing the vibration.

Machinery vibration is complex and consists of many frequencies. Displacement, velocity and acceleration are all used to diagnose particular problems. Displacement measurements are better indicators of dynamic stresses and are most commonly used.

Displacement

The total distance traveled by the weight, from one peak to the opposite peak, is peak-to-peak displacement, as shown in **Figure 2**. This measurement is usually expressed in mils, one mil equaling one-thousandth of an inch [0.025 mm (0.001 in.)]. It is a unit of vibration severity.

Average and root-mean-square (rms) are sometimes used to measure vibration (rms = 0.707 times the peak of vibration.) These terms are referred to in theoretical discussions, but are of limited practical value.

Velocity

Another method to analyze vibration is measuring mass velocity. Note that the weight depicted in **Figure 1** and **Figure 2** is not only moving, but changing direction. The speed of the weight is also constantly changing. At its limit, the speed is zero. Its speed or velocity is greatest while passing through the neutral position.

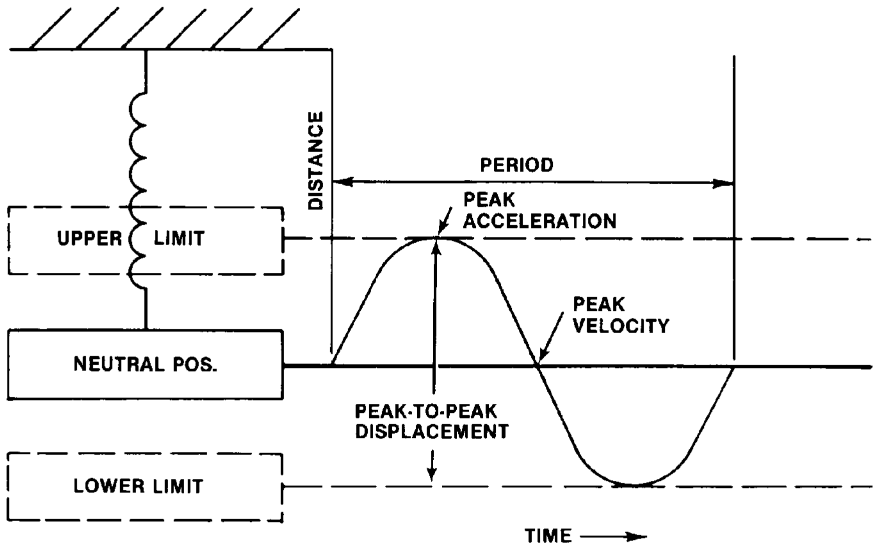


Figure 2

Velocity is an extremely important characteristic of vibration; but because of its changing nature, a single point is commonly chosen for measurement. This is peak velocity and normally expressed in inches per second.

Velocity is a direct measure of vibration and provides the best overall indicator of machinery condition. It does not, however, reflect the effect of vibration on brittle material.

The relationship between peak velocity and peak-to-peak displacement is compared by:

$$V_{peak} = 52.3 \times D \times F \times 10^{-6}$$

Where:

V_{peak} = Vibration velocity in inches per second peak.

D = Peak-to-peak displacement, in mils. 1 mil (0.001 in.).

F = Frequency in cycles-per-minute (cpm).

Acceleration

Acceleration is another characteristic of vibration. It is the rate of velocity change. In **Figure 2**, note that peak acceleration is at the extreme limit of travel where velocity is zero. As velocity increases, acceleration decreases until it reaches zero at the neutral point.

Acceleration is dimensioned in units of "g" (peak), where "g" equals the force of gravity at the earth's surface:

$$(980.665 \text{ cm/s}^2 = 386 \text{ in./s}^2 = 32.3 \text{ ft/s}^2)$$

Acceleration measurements, or "g's", are used where relatively large forces are encountered. At very high frequencies (60,000 cpm), it is perhaps the best indicator of vibration.

Vibration acceleration can be calculated from peak displacement:

$$g_{peak} = 1.42 \times D \times F^2 \times 10^{-8}$$

Note that overall, or total peak-to-peak displacement, shown in **Figure 3**, is approximately the sum of individual vibrations.

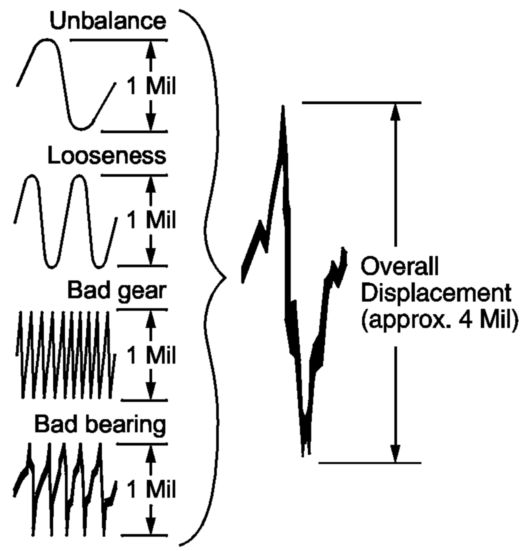


Figure 3

Vibration Identification

If excessive linear vibration motion is present or suspected, an initial inspection should be performed to confirm that:

- Engine, coupling and driven equipment mounting bolts are properly torqued, and that all jacking bolts and set screws are backed off.
- Engine, coupling and driven equipment are properly aligned.
- All external piping is properly isolated from the engine and driven equipment with appropriate flexible couplings.

If the initial inspection results do not identify the problem, then vibration measurements should be made to determine the source prior to starting corrective action. The Vibration Measurement Data Sheet, at the end of this guide, is provided for convenient recording of raw data at various engine speed and load conditions. This form can be used for the basic engine as well as any packaged unit, including one or two bearing generator sets, marine propulsion engine/reduction gear sets, and pump or compressor packages.

Vibration Measurement

Vibration should be measured in both vertical and horizontal directions at each bearing location, and in an axial direction at the rear face of each major piece of equipment. For example, an engine driving a two bearing generator set will require measurements at ten points, two at each bearing and two in an axial direction, as illustrated in **Figure 4**.

Engine only applications and other types of packaged units may require fewer measurement points, but the following descriptions and graphic in **Figure 4** still apply.

Marine propulsion applications will also require a measurement in the vertical direction at the right rear engine mounting foot. This is required to check for rolling of the engine. The measurement is taken at the point where the engine is anchored by means of a fitted bolt.

Vibration measurements must be made at the advertised driven equipment rating (100% load). If additional data is desired, it is recommended that measurements be made at 0% load, 50% load, 75% load and, depending on the rating, 110% load.

For generator set applications, if measurements are taken while a generator is loaded, the magnetic field of the generator leads must be avoided. In addition, two sets of measurements should be made at the 0% load condition for generator set applications; one with the exciter turned “on” and one with the exciter turned “off.”

Vibration Measurement Points

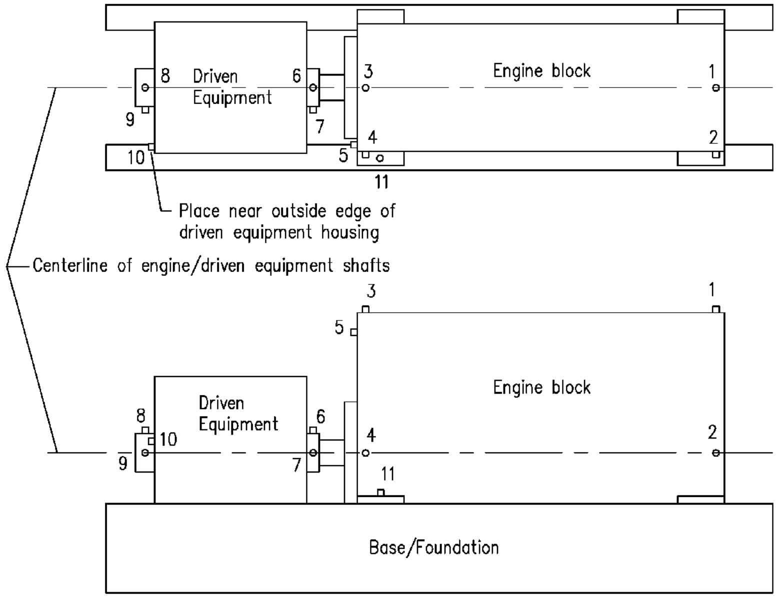


Figure 4

Point 1 – EFV (Engine Front Vert.)
Vertical direction at the front of the engine; locate the probe on the block top deck in the plane of the crankshaft centerline.

Point 2 – EFH (Engine Front Hor.)
Horizontal direction at the front of the engine; locate the probe on the side of the block at the crankshaft centerline.

Point 3 – ERV (Engine Rear Vert.)
Vertical direction at the rear of the engine; locate the probe on the block top deck (or rear housing) in the plane of the crankshaft centerline.

Point 4 – ERH (Engine Rear Hor.)
Horizontal direction at the rear of the engine; locate the probe on the side of the block at the crankshaft centerline.

Point 5 – ERA (Engine Rear Axial)
Axial direction at the rear of the engine; locate the probe on the right rear outside edge of the block at the crankshaft centerline.

Point 6 – XFV (Driven Front Vert.)
Vertical direction at the driven equipment front bearing; locate the probe on the bearing housing at the shaft centerline.

Point 7 – XFH (Driven Front Hor.)
Horizontal direction at the driven equipment front bearing; locate the probe on the side of the bearing housing at the shaft centerline.

Point 8 – XRV (Driven Rear Vert.)
Vertical direction at the driven equipment rear bearing; locate the probe on the bearing housing at the shaft centerline.

Point 9 – XRH (Driven Rear Hor.)

Horizontal direction at the driven equipment rear bearing; locate the probe on the side of the bearing housing at the shaft centerline.

Point 10 – XRA (Driven Rear Axial)

Axial direction at the driven equipment rear; locate the probe on the right rear outside edge of the driven equipment structure (not sheet metal) at the shaft centerline.

Point 11* - ERR (Engine Rear Rot.)

Vertical direction at the right rear engine mounting foot.

* - marine applications only, when engine is anchored with fitted bolt.

Order of Vibration

In discussions of vibration, the frequency of the motion is commonly referred to in terms of order of vibration. In an engine, the order of vibration is the number of vibratory cycles exhibited by a component during one revolution of the crankshaft.

One-Half Order is one occurrence every two crankshaft revolutions.

First Order is one occurrence per crankshaft revolution.

Second Order is two occurrences per crankshaft revolution.

Higher Order describes occurrences at 1½, 2½ or more crankshaft revolutions.

$$\text{Order} = \frac{\text{Vibration Frequency (cpm)}}{\text{Engine Speed (rpm)}}$$

Overall vibration motion is the vector sum of the motion of all the orders. In other words, individual order motions will add or subtract to produce the overall. This measurement is not used to identify problems or establish limits, but rather as an indication of the total linear vibration motion.

Data should be reported in terms of peak-to-peak displacement (mils) at half order frequency, first order frequency, overall velocity level (in/s) and overall displacement (mils) for each of the measuring locations. The data sheet at the end of this guide can be used to record and report the measured vibration data.

All measurements must be made on the main rigid structural members of the engine and driven equipment. The instrument pickups must be positioned on the crankshaft centerline at the previously defined locations.

Vibration measurements on large engine units should be taken using a Cat Vibration Analyzer, part number 9U5831. This tool may be ordered through the Caterpillar Tool & Shop Product Guide, Media Number NENG2500. If Caterpillar measuring equipment is not available, an equivalent device capable of measuring peak-to-peak displacement at selected frequencies, overall velocity, and overall displacement should be used.

Vibration Level Guidelines

The following vibration level guidelines are used for assessing the vibration severity of the core engine or package installation.

Attachments to the engine or package installation typically raise vibration values and are not included in these guidelines.

The vibration levels for any load condition, at any of the measuring locations, must not exceed the following guidelines:

- Peak-to-peak displacement at half order frequency = 0.13 mm (5 mils)
- Peak-to-peak displacement at first order frequency = 0.13 mm (5 mils)
- Overall displacement = 0.22 mm (8.5 mils)
- Overall velocity = 34.3 mm/s (1.35 in/s)

These guidelines apply to both gas and diesel engine packages installed with or without isolation mounts. If linear vibration is higher than these guidelines, refer to the Vibration Causes and Corrective Actions section in this guide.

Consult the manufacturer of the driven equipment for any such vibration guidelines.

A vibration worksheet is provided at the end of this guide.

WARNING: It is not an acceptable practice to lower the package vibration levels when operating at stable conditions by tightening the snubber bolts on the Cat vibration isolators. This practice will only hide vibration problems.

Vibration Causes and Corrective Actions

Causes

Experience has shown that linear vibration motion problems can be attributed to:

- Misalignment of engine and driven equipment.
- Unbalance of rotating parts.
- Resonance from structural mass (weight) and stiffness (rigidity) combinations.
- Torque reaction.
- Cylinder misfiring.
- Combustion forces.
- Unbalance of reciprocating parts.

The following table correlates vibration characteristics to these possible causes:

Vibration Characteristic	Correctable Causes
1 component	Mounting of component
1/2 x engine rpm (one-half order)	Misfiring of one or more cylinders
1 x engine rpm (first order)	Unbalance, misalignment, out-of-time balance weights, crankcase overfill
2 x engine rpm (second order)	Unbalance, out-of-time balance weights
1 1/2, 2 1/2, third higher orders	Normal cylinder and combustion (not correctable)
Large vibration motion	Resonance
Motion increases as load is applied	Torque reaction – insecure mounting or inadequate base

Corrective Actions

One Component

If one component is the only item with excessive motion, the component mounting will have to be altered until the motion is reduced to an acceptable level at operating rpm.

1/2 Order Vibration

When the vibration motion measurements show that 1/2 order is causing the problem, the engine fuel and governing system should be serviced to eliminate engine misfiring. No other work should be attempted until engine misfiring is eliminated.

1st Order Vibration

Refer to the Balance Procedure in this guide.

2nd Order Vibration

When excessive second order vibration occurs on 4-cylinder and vee 8 engines, the timing of the second order force balancers should be checked.

Higher Order Vibration

Other high order vibration levels cannot be corrected with flywheel balance weights or balancer timing. Usually these orders involve the structural characteristics of the generator and base which will need to be altered.

Non-Engine Vibration

If the vibration motion involves non-engine mounted structures and the engine vibration motion is acceptable, either the off-engine components must have their mounting altered or proper vibration isolators must be installed between the engine or generator set and the structure.

Excessive Engine Motion

If the engine unit has excessive motion, it will generally be due to misalignment/unbalance, resonance or torque reaction. However, if the vibration motion for the first and second order still remain excessive after examination and correction, the engine should be removed from the set and placed on suitable isolators.

Another condition that causes excessive engine motion is rigid body mode. Due to sizing and selection of engine or package mounts, the engine and package will move as a rigid body. This can only be corrected by changing the package mounts.

If vibration is present, but the engine is within limits, a vibration specialist should be consulted. If the bare engine exceeds the limits, engine components rotating at engine speed (first order) or twice engine speed (second order) should be inspected.

Misalignment/Unbalance

Most linear vibrations of generator sets or other packaged units are caused by misalignment or unbalance of the rotating members. This typically results in first order vibration which can be corrected in the field.

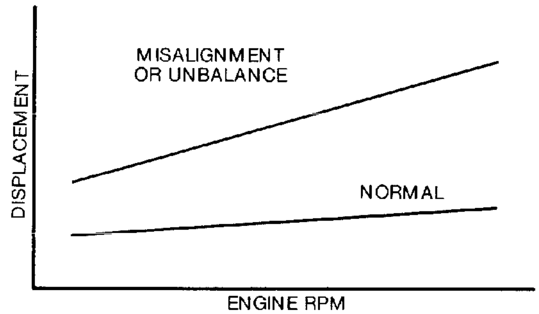


Figure 5

Misalignment/unbalanced vibration motion is relatively constant over the speed range, as shown in **Figure 5**, but exceeds accepted limits. For generator set applications, this may be determined by operating between 45 Hz and 65 Hz. Misalignment/unbalanced vibration motion is not changed by load.

If misalignment or unbalance is identified:

- Check the alignment of the unit. Refer to Caterpillar Special Instructions listed under Reference Material at the end of this section.
- If vibration is still excessive, refer to the Balance Procedure at the end of this section.
- If vibration is still present after the balance procedure, mount the unit on isolators and repeat the balance procedure until a satisfactory level of vibration is obtained.

Resonance

Resonance occurs when a large vibration motion (amplitude) takes place within a narrow speed range, as shown in **Figure 6**.

The vibration can occur on the generator set and/or the attached equipment, such as piping and air cleaners. When vibrations peak out in a narrow speed range, the vibrating component is in resonance.

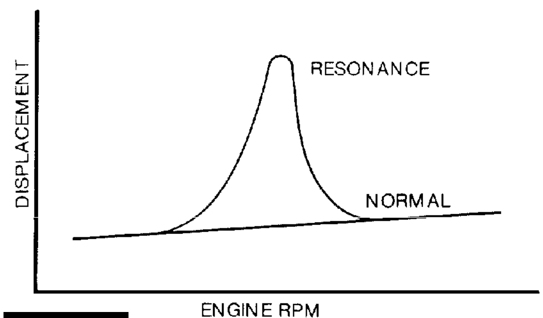


Figure 6

There are two methods of reducing resonance vibration levels. These are:

- Changing the natural frequency of the part that is resonant.
- Reduction of the exciting force.

If the following checks show that the cause of the problem is the structure that the engine, generator set, or other packaged unit is mounted on, a vibration specialist or mounting system specialist should be consulted.

- Check the alignment of the unit. Refer to Caterpillar Special Instructions listed under Reference Material at the end of this section.
- If vibration is still excessive, refer to the Balance Procedure at the end of this section.
- If vibration is still present after the balance procedure, mount the unit on isolators and recheck. If the unit is satisfactory, the problem is an improper mounting system which requires changing. Consult the proper specialist.
- Should the balance procedure fail and the set has excessive linear vibration motion when installed on the proper isolators, repeat the balance procedure until the linear vibration motion level is satisfactory.

Torque Reaction

When the vibration motion increases as load is applied, as shown in **Figure 7**, torque reaction is the likely problem. With a two-bearing generator, it can be caused by insecure mounting of the engine or generator to its base and/or by a base not sufficiently rigid to withstand the associated forces.

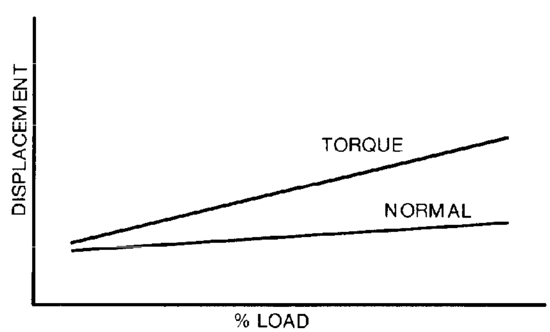


Figure 7

Torque reaction problems are not found with close-coupled generators. The rigid joint between the flywheel housing and the generator body is generally adequate to withstand torque.

Assuming that a free standing two-bearing generator is mounted on a weak base, first order motion and orders related to the number of cylinders firing with one crankshaft revolution are due to torque reaction which, in turn, causes misalignment. In this case, the first order motion would be most prevalent.

This condition is generally encountered when the engine is driving a conventional two-bearing generator which is not close-coupled. Check the alignment of the unit.

If the two-bearing generator set utilizes a structural steel base which is point-mounted, for example, pads and isolators, torque reaction can deflect the weak base. This deflection can cause severe misalignment and resulting vibration.

If the unit continues to exhibit vibration after alignment, the base is likely not strong enough to hold the torque reaction and needs strengthening.

One method of strengthening is to weld plates on top and bottom of the base across the width of the base from 6 in. forward of the rear engine supports to 6 in. behind the generator feet closest to the engine.

Balance Procedure

The following correction procedure can be applied to first order vibration motion:

- The crankshaft must assume the same position each time a balance adjustment is made. To assure this identical location is assumed, position flywheel to top dead center (TDC) of number 1 cylinder. A chalk mark or scribe across flywheel and coupling plates will provide an easy reference during the balancing operation.
- Remove bolts holding generator coupling plates to flywheel. Rotate generator rotor with plates attached 90° clockwise while flywheel remains at number 1 TDC. Replace coupling plate bolts and retest for vibration.
- If vibration remains, again position flywheel at TDC number 1 cylinder, index generator rotor another 90° clockwise (total 180°), and retest.
- If necessary, repeat the previous step by rotating another 90° clockwise.
- Position coupling assembly relative to flywheel where least amount of vibration occurred. If magnitude of vibration remains unacceptable, add weight of 56.70 g (2 oz) under any single coupling plate to flywheel bolt. Flat washers

can be used for this purpose. Bolt must be sufficiently long to maintain at least 1 1/4 times the bolt diameter of thread engagement.

- Observe vibration level and relocate weight 90° quadrant to identify where minimum vibration occurs.
- Add additional weight at point of minimum vibration identified in the previous step until vibration level is no longer diminished. In no case should more than 141.75 g (5 oz) be added under any one bolt.

If vibration levels are still unacceptable, a vibration control specialist should be consulted.

Torsional Vibration

Torsional vibration refers to irregularities in the speed of rotation in a shafting system. In the context of engine-driven systems, the shafting system is referred to as the "driveline" and formally includes all of the sub-systems directly connected to the crankshaft, both internal to the engine and external. Torsional vibrations appear in the driveline as a result of engine combustion impulses, reciprocating motion of the pistons and connecting rods, and from the operating characteristics of the driven equipment, such as a generator, propeller, pump, or compressor. Even gear-driven equipment such as coolant pumps or other auxiliary components can contribute to the overall dynamic behavior of the driveline.

Torsional vibrations may be understood as the rotational equivalent of linear vibrations, and in a similar manner many of the dynamic concerns that we must address for linear vibration apply for torsional vibrations. A driveline is designed for transmitting the torque that the engine delivers to the driven equipment, but it must also be capable of withstanding the oscillating energies of torsional vibrations without damage. The dimensional design of each of the components in the driveline contributes torsional characteristics to the driveline, which functions as a dynamic system with its own fundamental characteristics and natural frequencies. If the frequency of the excitations contributed by the torsional vibration sources match the natural frequency any of the components in the system, a resonance will occur.

Any shaft rotating with a mass attached at each end may experience torsional vibration. The simplified drive train in Figure 32 illustrates the torsional system formed by the piston, connecting rod, and crankshaft within a reciprocating engine. Even without combustion impulses, the forces generated by inertia as the piston and connecting rod change direction at each end of the stroke are enough to cause variations in the torque measured in the crankshaft.

Simplified Drive Train

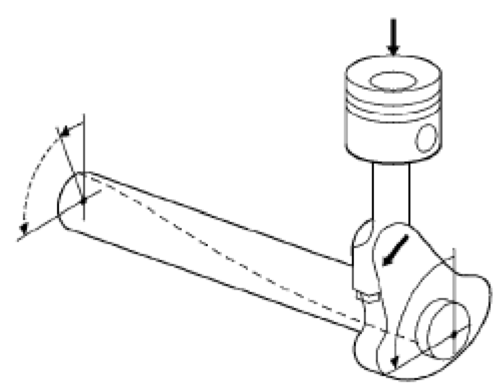


Figure 32

A systematic study of the entire system is required to determine if resonances are present in a given driveline design, and whether those resonances pose a risk of causing failure of a particular driveline component. This study is called a torsional vibration analysis or TVA.

Torsional Vibration Analysis

The starting point for a torsional vibration analysis (TVA) is a thorough accounting of the driveline system and its torsional inputs during normal operation. The analysis requires consideration of both the physical dimensions of the driveline components and the characteristics of the torsional inputs at the expected operating conditions in terms of rotational speed and torque.

To understand this, consider inside the engine how combustion interacts with the piston and crankshaft. Just as the pressure exerted on the piston by the burning fuel and air becomes torque in the crankshaft, the impulse of the burning air/fuel charge on the piston is translated into a rotational irregularity at the crankshaft. Both the steady torque and the rotational irregularity contributed by the burning fuel/air charge are affected by changes in the rotational speed and the resistance to motion the driven equipment (torque load). That change in burning characteristics is experienced by the crankshaft as a change in the torsional input from the cylinders. Changes in the operation of the driven equipment also alter the torsional input experienced by the crankshaft, making each driveline unique. One driveline design may produce very different TVA results when evaluated at different loads and/or speeds.

The goal of a TVA is to determine whether a driveline design is at risk of a resonance when at the intended operating speed and load points. If the operating speed matches the resonant speed, portions of the driveline can become excited, with torque amplitudes reaching many times their levels in the non-excited state. Because the resonant torques are cyclic, they result in rotational flexing of the system that, if left unchecked, can result in a fatigue-related failure.

A torsional-related failure of a major component, such as the engine’s crankshaft, can be very costly, both in terms of cost to repair and revenue lost while the unit is out of service. By comparison, the cost of completing a TVA in the design phase is much less. As a best practice, Caterpillar requires the completion of a TVA for new driveline designs and for applications using an existing driveline layout under new load/speed conditions. As stated above, the goal of the TVA is to ensure the resonant points do not occur at the expected operating conditions.

Since compatibility of the installation is the system designer’s responsibility, it is also their responsibility to obtain the TVA. Caterpillar offers TVA services in many engine price lists, and our TVA experience is tied to the computational methods used by our TVA provider. TVA services are also available through many third party firms. However, our unfamiliarity with the methods used by those other firms makes it difficult for Caterpillar to clearly assess the acceptability of a given driveline-and-application design from their results.

For challenging driveline configurations, Caterpillar reserves the right to require a TVA completed by our provider to ensure a consistent interpretation of the results. If you have any questions about the acceptability of a proposed driveline design, please contact Caterpillar to determine how best to evaluate the risks involved.

Required Data

Because the TVA seeks to model the dynamic behavior of the entire driveline, the data required to complete the analysis is extensive, touching on virtually all the driveline-connected components. The specific data required will vary with the driveline design and application, but in general certain details are common to all TVAs:

- A general arrangement drawing or sketch. This provides an understanding of the relative location of each piece of equipment and type of connection between them.
- A detailed listing of the rotational characteristics of each of the driveline components. This describes in detail the mass-elastic characteristics of the rotational portion of the component. Mass-elastic characteristics are details such as the rotational inertia and torsional rigidity of the component. Major components (such as engines and compressors) are comprised of many internal parts that must be represented individually and in the proper physical location relative to one another to fully describe their mass-elastic systems.
- A description of the harmonic inputs contributed by the component. In the case of an engine or reciprocating compressor the relative timing ("phase angles") of the torsional inputs from each individual cylinder must also be provided.
- For driven equipment that can vary in load demand on the engine, a load demand curve is required.

Each TVA provider should be able to provide a detailed listing of the information they will need to complete their analysis. Providing all of the required information up front is the first step toward receiving the completed analysis in a timely manner.

Consult the manufacturer for their torsional information on each major component. Caterpillar offers documentation summarizing the mass-elastic and combustion impulse harmonic information for each of their engine models. Data on the driven equipment should be evaluated for the speed-load points at which the driveline is expected to operate. Manufacturers of complex driven equipment (such as reciprocating compressors) may offer software tools to assist in compiling this application-specific data.

Driveline Design

Changes in the design of the components in the driveline can have a significant impact on the torsional performance of the system. Even if resonance concerns are revealed in a TVA, it is often possible to tune frequency response of the driveline by changing a key component. Here are a few of the key components that are often manipulated to improve the torsional response of a driveline system.

Flywheel – The flywheel is a rotating mass that contributes inertia to the system. Simply put, rotational inertia is a resistance to changes in rotating speed. The engine incorporates a flywheel to help smooth out the rotational variations that occur from one cylinder firing to the next. The engine's flywheel is typically located at the rear, which usually places it between the engine and the driven equipment. This location is strategic, as the flywheel's inertia help to isolate the engine's internal torsional variations from those originating outside the engine.

Torsional Damper – Torsional dampers may be viewed as rotational shock absorbers. Inside the typical torsional damper is a system designed to dissipate torsional vibration energy as heat. By accomplishing this, they represent a critical tool in manipulating the torsional response of a driveline system. One critical finding of a TVA is whether the torsional damper can dissipate all of the energy it absorbs from the driveline during operation. If the input energy level exceeds the dissipation capability of the damper, it may fail leaving the driveline susceptible to further damage if it is not addressed quickly.

Coupling – While often considered a simple "connector" between the engine and driven equipment, the coupling forms a critical part of the driveline torsional solution. Coupling designs vary depending on the requirements of the application. Generator sets often use compliant couplings that place elastomeric material between the engine and driven equipment. This provides an internal damping that is well matched to the low torsional operating characteristics of a generator. A reciprocating compressor contributes much higher torsional energies into the driveline, typically in excess of the limits of an elastomeric coupling. Engine driven recip compressors typically use torsionally rigid couplings, using metal flex plates to limit the torsional compliance of the coupling. The higher rotating mass of this arrangement does, however, interact with the system as a small flywheel, helping to manage torsional energy by resisting the variations in rotational speed.

As stated above, the engine is designed with components intended to help keep the natural frequency of the system away from the designed operating speed. The engine's rear-mounted flywheel and front-mounted torsional dampers are located for best performance with a rear-driven load. If it becomes necessary to drive the load from the front of the engine, the damper and flywheel become poorly located to help manage torsional energies from that load. A large front-driven load is an important case where seeking expert advice is critical to achieving an acceptable outcome. As stated earlier, if you have any questions about the acceptability of a proposed driveline design, please contact Caterpillar to determine how best to evaluate the risks involved.

Reference Material

Media List

The following information is provided as an additional reference to subjects discussed in this manual.

SEHS7654: Special Instruction – Alignment – General Instructions

REHS0423: Special Instruction – Alignment of Two-Bearing Generators

REHS0177: Special Instruction – Alignment of Close Coupled Two-Bearing Generators

NENG2500: Tool and Shop Product Guide

Engine/Driven Equipment Vibration Measurement Data Sheet

Engine/Driven Equipment Description:

____

____

____

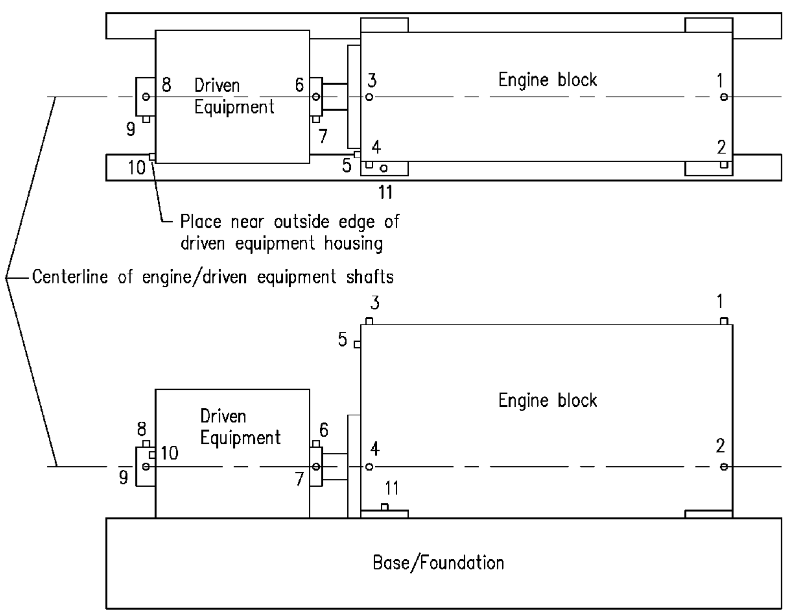
Rating: ________________________________

Rated Speed: ________________________________

Load Condition: ________________________________

Location	1/2 Order Displacement (mils)	1st Order Displacement (mils)	Overall Displacement (mils)	Overall Velocity mm/sec (in/sec)
Point 1 - EFV				
Point 2 - EFH				
Point 3 - ERV				
Point 4 - ERH				
Point 5 - ERA				
Point 6 - XFV				
Point 7 - XFH				
Point 8 - XRV				
Point 9 - XRH				
Point 10 - XRA				
Point 11 – ERR*				

* Marine Applications Only, when engine is anchored with fitted bolt.



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