

Application Guidance Notes: Technical Information from Cummins Generator Technologies

# AGN 233 – Generating Set Assembly – Mounting Arrangements

## **INTRODUCTION**

This Applications Guidance Note is the first in a series of four AGNs that look at assembling an alternator to a prime mover:

- AGN232 – Generating Set Assembly – Coupling Arrangements
- AGN233 – Generating Set Assembly – Mounting Arrangements
- AGN234 – Generating Set Assembly – Alignment
- AGN235 – Generating Set Assembly – Torsional Vibration Analysis

## **OVERVIEW**

A complete Generating Set, as shown in Figure 1 on the next page, is a complex machine made up of many stationary and moving parts; the main assemblies being the alternator, the prime mover (engine) and the cooling system (radiator).

When integrating an alternator into a Generating Set, the system engineer must carefully plan the system layout, to ensure satisfactory operation for the installation and application. The system engineer must ensure that the complete system functions as intended by specifying, designing, manufacturing and testing according to the relevant engineering standards. Key standards used in the design of Generating Sets are included in Table 1, on the next page.

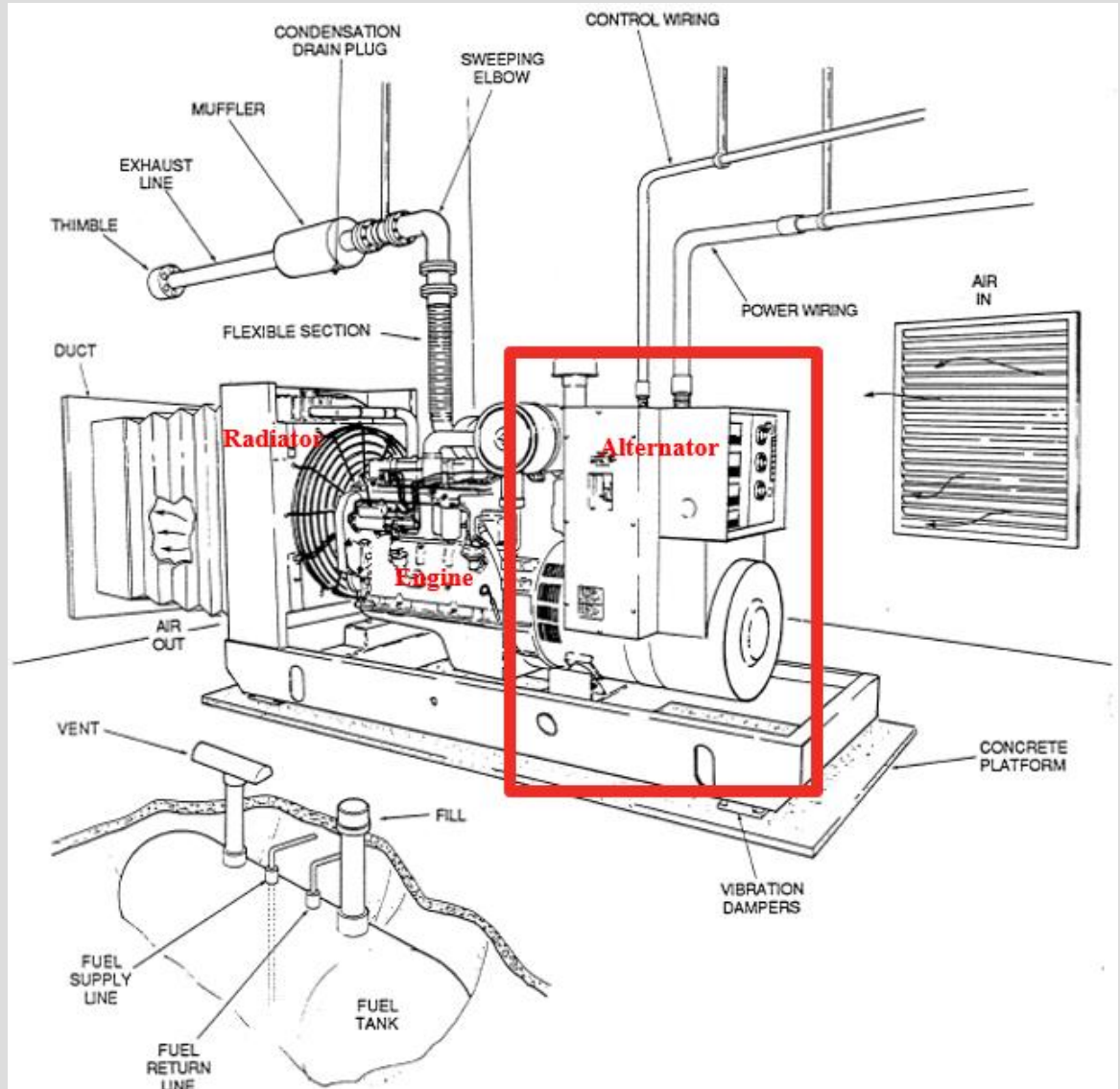


Figure 1: Typical location of an alternator in a complete Generating Set installation

IEC 60034	Rotating Electrical Machines
IEC 60085	Thermal Evaluation and Classification of Electrical Insulation
IEC 60529	Degrees of Protection provided by Enclosures (IP Code)
ISO 10816	Specification for Mechanical Performance: Vibration
ISO 3046	Specification for Reciprocating Internal Combustion Engines
ISO 8528	Standard for reciprocating internal combustion engine driven alternating current generator sets.
SI 426	European Commission (dangerous substances): Classification, packing, labelling, and Notification of Regulations 1992).
CIMAC	Congress International des Machines a Combustion Recommendations for Diesel Engine Acceptance Tests
ISO 9000	Quality assurance

Table 1: Engineering standards used in the Generating Set industry

## MOUNTING ARRANGEMENT

A mounting arrangement is a technique used in the Generating Set industry to mount (or assemble) an alternator onto a Generating Set base frame. The number of mounting holes and type of base frame to be used will depend upon the installation conditions and the type of the application. The base frame must provide a supporting structure for the Generating Set assemblies, to maintain structural integrity and alignment, whilst allowing for thermal growth. It must maintain acceptable vibration levels resulting from excitation forces and external sources.

Alternator mounting arrangements should be designed to ensure that the alternator can withstand the high sudden torque loads developed during transient events. Examples of transient event that develop high torque are: short circuit conditions, under/over voltage ride through events and engine fuel management issues. The torque exerted into the alternator's feet arrangement and connecting housings will be dependent on the type of transient events and the associated connected inertias. An appropriate Generating Set assembly design will be selected with the following considerations: direct coupled to engine, connection type to base frame, type of rotating shaft connection (rigid or soft coupling), alternator frame type, application loads and speeds.

An example of an alternator mounting feet arrangement with hole positions can be seen in general arrangement drawing in Figure 2 (encircled area).

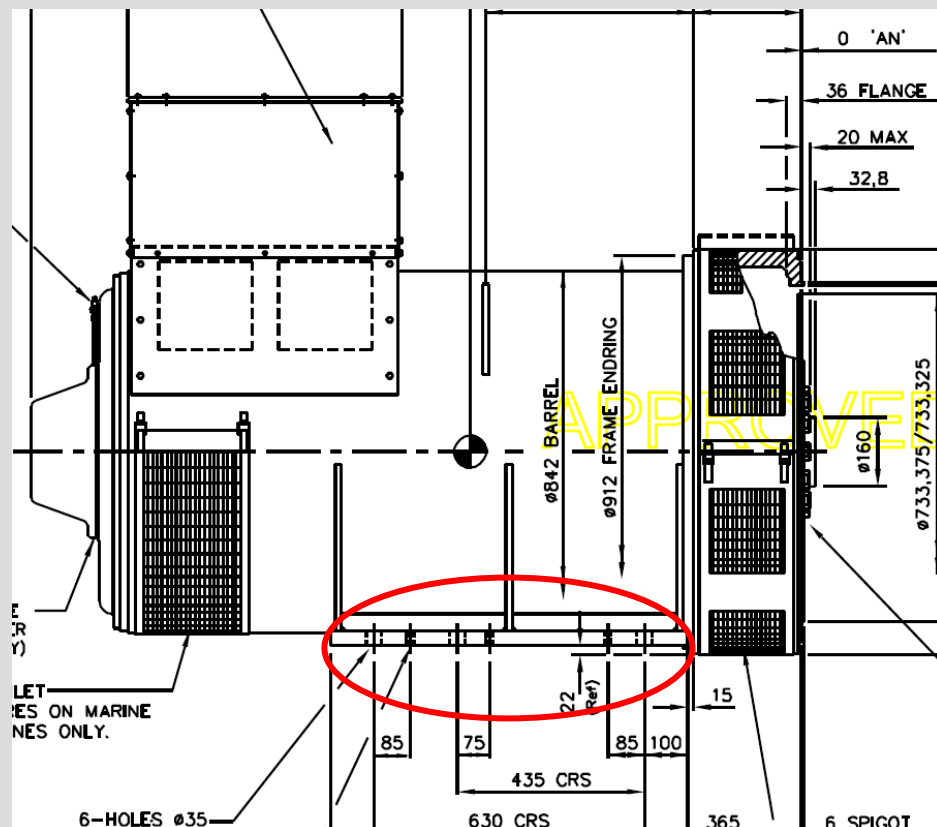


Figure 2: Location of the jacking and mounting holes

## Bending Moment

The alternator's feet arrangement is designed with mounting holes that provide flexibility in mounting location and type, to ensure that the required bending moment at the cylinder block/flywheel housing interface, X-X as shown in

Figure 3, is within limits that are acceptable to the engine/alternator manufacturers. Typically, the bending moment calculation can be determined using a finite element analysis simulation tool. It is also important that the static deflection at each of the flexible mounts in the system, is the same. If the static deflection is not the same, a rocking motion or pitching motion may be induced, leading to natural frequencies higher than the simple vertical modes. Preferably, mounts should be symmetrically arranged about the combined centre of gravity of the engine and alternator so that each carries the same weight.

Figure 3 is an example of a basic equations used for calculating loads on mounts at stated locations, and the bending moment across the engine flywheel housing.

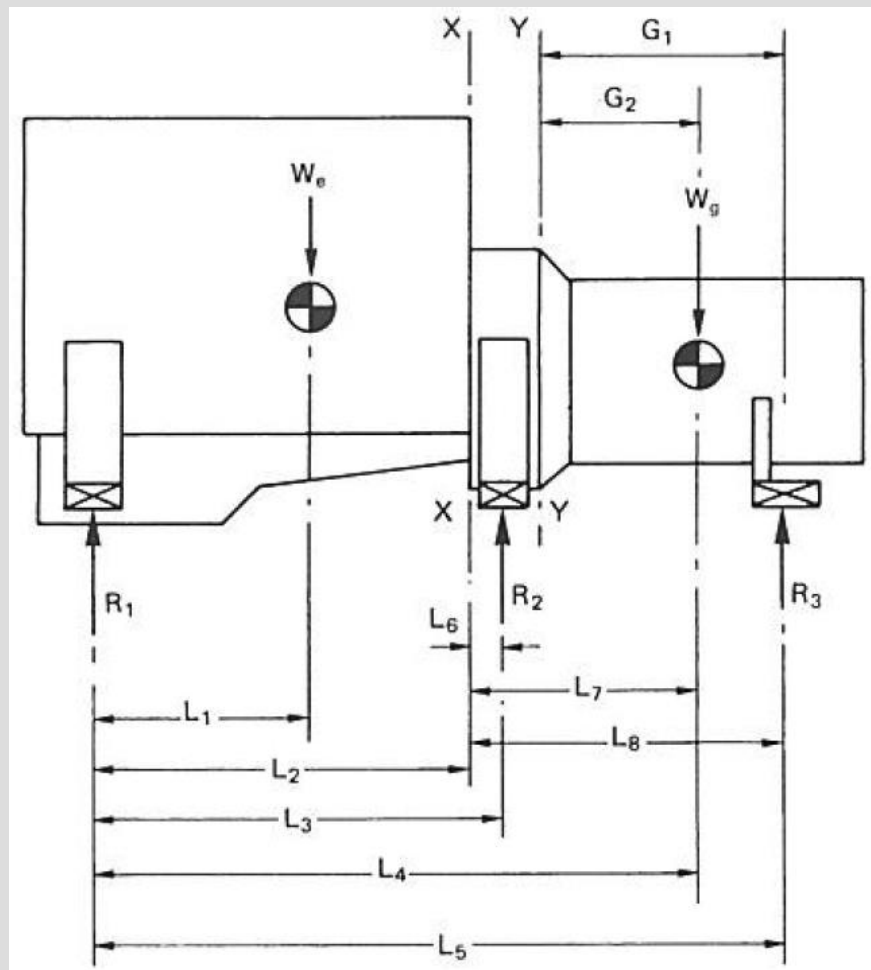


Figure 3: Factors for calculating loads on mounts at stated locations and the bending moment across the engine flywheel housing.

Since standard engine and alternator mounting location points are fixed, it is necessary to find the static load to be carried by each mounts at the given locations.

$W_e$  in Figure 3 is for the total weight of the engine and  $W_g$  is for the total weight of alternator; acting through their respective centres of gravity.  
The reaction at  $R_3$  will have a predetermined value obtained by taking moments at the flanged interface between the alternator stator frame and the flywheel housing (face Y-Y).

That is:

$$R_3 * G_1 = W_g * G_2 \quad \text{Equation 1}$$

By making  $R_3$  subject of the formula;

$$R_3 = \frac{W_g * G_2}{G_1} \quad \text{Equation 2}$$

To find  $R_2$ , take moment about  $R_1$ ;

$$R_2 = \frac{W_e * L_1 + W_g * L_4 - R_3 * L_5}{L_3} \quad \text{Equation 3}$$

To find  $R_1$ , take moment about  $R_2$ ;

$$R_1 = \frac{W_e * (L_3 - L_1) - W_g * (L_4 - L_3) + R_3 * (L_5 - L_3)}{L_3} \quad \text{Equation 4}$$

The bending moment ( $M_x$ ) between the cylinder block and flywheel housing interface (X-X) is given by;

$$M_x = R_2 * L_6 + R_3 * L_8 - W_g * L_7 \quad \text{Equation 5}$$

or

$$M_x = R_1 * L_2 + W_e * (L_2 - L_1) \quad \text{Equation 6}$$

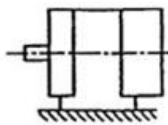
## **Types of mounting arrangement**

### **Alternator foot designs (standards)**

Alternators are manufactured in accordance to IEC 60034-7:1993, which is the standard for mounting and construction options. The standard refers to the two codes for mounting and construction design for rotating electrical machines:

#### **Code I (Alpha-numeric designation)**

Code I: a machine with a horizontal or vertical shaft is designated by the Code letters IM (International Mounting), followed by a space, the letter B (meaning horizontal) or V (meaning vertical) and one or two numeral digits that give construction type according to the standard as shown in Figure 4, on the next page. Depending on the application, customer could have either standard feet or raised side feet design at a height suitable for assembly.

Designation	Sketch	Type of construction				Mounting arrangement (Horizontal shaft)
		Number of endshield bearings	Feet	Flange	Other details	
IM B3		2	With feet	-	-	Mounted by feet, feet down

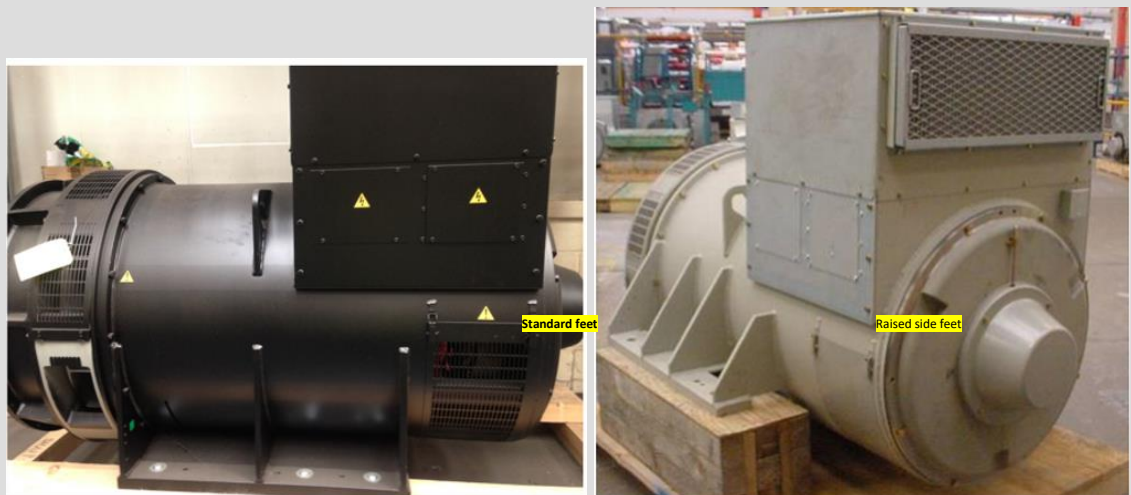


Figure 4: Examples of the IEC 60034-7:1993 designations for machines with horizontal shafts (IM B3).

### Code II (All-numeric designation)

Code II: a machine is designated by the Code letters IM (International Mounting) followed by a space and four numerals. The first, second and third numerals designate aspects of construction. The fourth numeral designates the type of shaft extension.

2	First numeral	Significance	Table relevant to the second and third numerals
	0	Not allocated	-
	1	Foot-mounted machines with endshield bearing(s) only	5
	2	Foot-and-flange-mounted machines with endshield bearing(s) only	6

10	2nd Digit	3rd Digit
	Normal feet	1 flange, no access to back
		IM 2101

1	Fourth numeral	Significance
	0	No shaft extension
	1	One cylindrical shaft extension

Table 2: IEC 60034-7 designations for machines with Code II design techniques (IM 2101).

## Solid Mount

The mounting of an alternator solidly to the base frame or supporting structure is typically done to increase the stiffness of the system or the requirement for a particular application. Although solid mount Generating Set construction provides additional stiffness to the engine/alternator combination, the base frame natural frequencies, thermal growth, accurate foot alignment and isolation to foundation needs to be considered and designed appropriately.

Figure 5 shows an example of a solid mounted close coupled Generating Set.

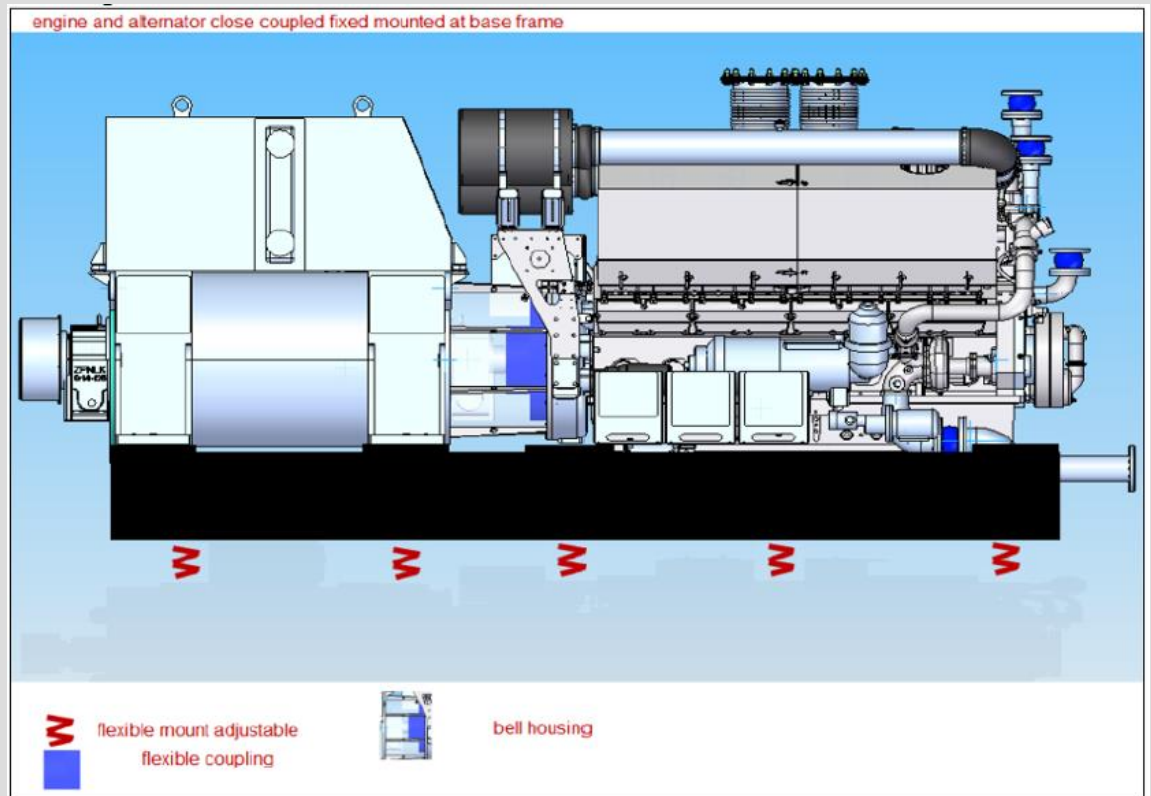


Figure 5: Solid mounted Generating Set (Engine solid – Alternator solid – Close coupled).

Table 3 shows some advantages and disadvantages of a solid mounted close coupled configuration.

Advantages	Disadvantages
<ul style="list-style-type: none"> <li>• Easy alignment with vibracons or minor shimming required.</li> <li>• Off the shelf/ standard flexible coupling can be utilised.</li> <li>• Housing mounting faces and spigots provides shaft alignment.</li> <li>• Better load distributions for Anti Vibration Mount load.</li> </ul>	<ul style="list-style-type: none"> <li>• Vibration levels from engine could be transferred to the alternator.</li> <li>• Extra manufacturing process for the base frame to ensure flat mounting surfaces and alignment.</li> <li>• Design consideration for thermal growth of the engine and alternator required.</li> </ul>

Table 3: Advantages and disadvantages of a solid mounted close coupled configuration

Figure 6 shows an example of a solid mounted open coupled Generating Set.

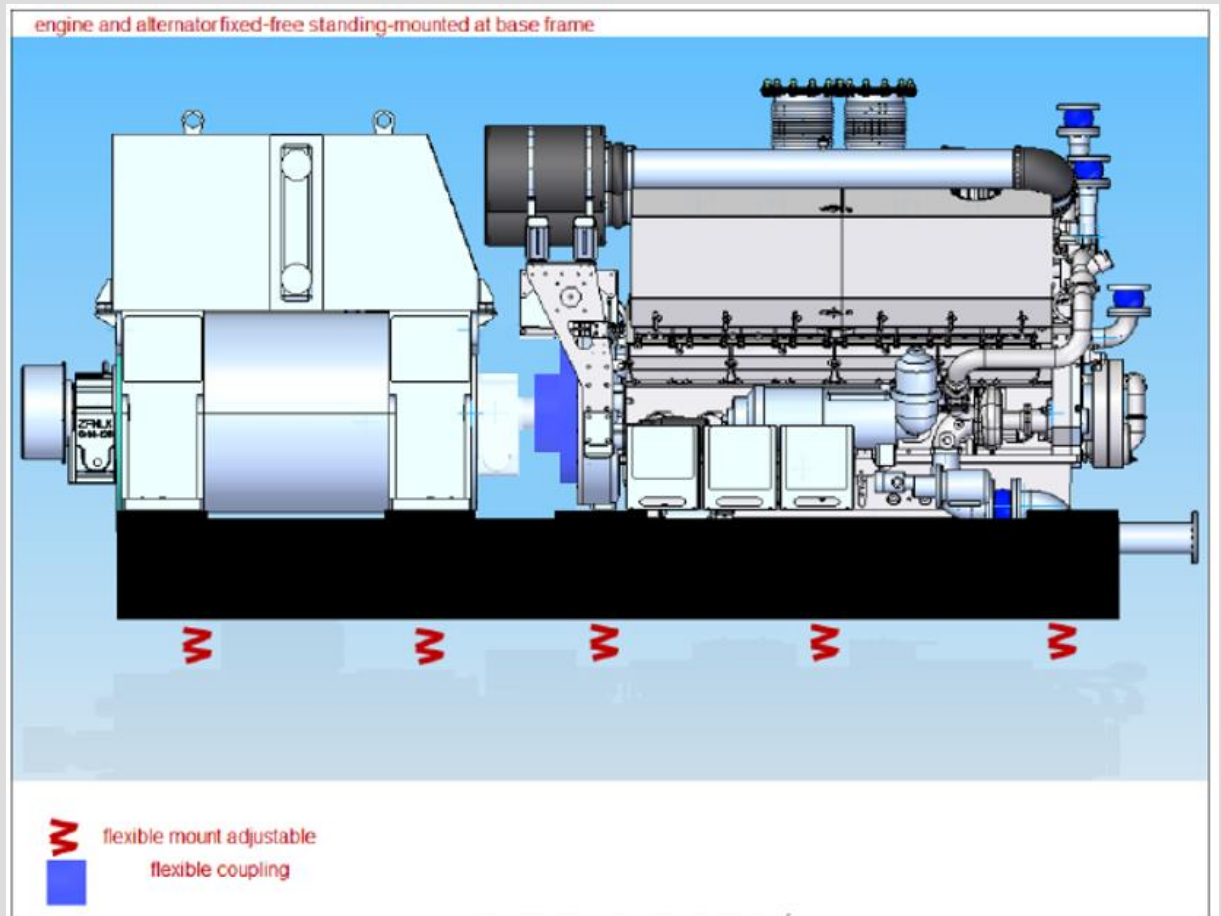


Figure 6: Solid mounted Generating Set (Engine solid – Alternator solid – Open coupled).

Table 4 shows some advantages and disadvantages of a solid mounted open coupled configuration.

Advantages	Disadvantages
<ul style="list-style-type: none"> <li>• Vibration levels from engine is transferred to the base frame and less on generator.</li> <li>• Off the shelf/ standard flexible coupling can be utilised.</li> <li>• Better load distributions for Anti Vibration Mount load.</li> </ul>	<ul style="list-style-type: none"> <li>• Higher strength and stiffness of base frame required.</li> <li>• Shaft alignment required.</li> <li>• Standard engine supports to be modified.</li> <li>• Flex mounts can be installed aside the frame to increase stability and to lower height.</li> <li>• Torque reaction via frame more sensitive to vibration issues.</li> </ul>

Table 4: Advantages and disadvantages of a solid mounted open coupled configuration.



## Flexible Mount

Flexible mounts are placed between the structural base frame and the alternator/engine. Flexible mountings enable the supporting structure to be isolated from engine and alternator vibration sources, minimising the risk of exciting base frame natural frequencies, reducing vibration transmission to auxiliary components, isolation to foundations etc. Figure 7 shows an example of a flexible mounted close coupled genset.

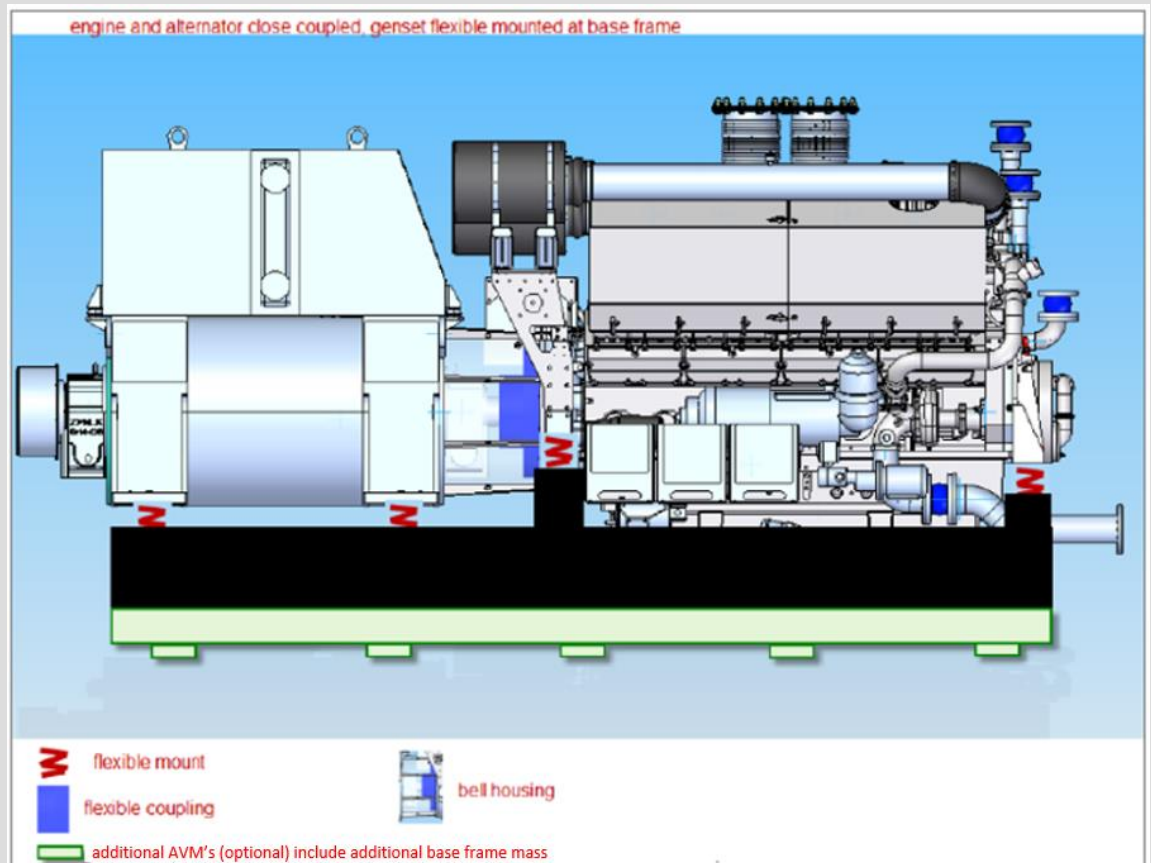


Figure 7: Flexible mounted Generating Set (Engine and alternator-as a coupled pair flexible mounted – base frame solid to base structure).

Table 5 shows some advantages and disadvantages of a flexible mounted close coupled configuration.

Advantages	Disadvantages
<ul style="list-style-type: none"> <li>• Basic flexible coupling between flywheel and generator.</li> <li>• Base frame is less susceptible to resonance conditions.</li> <li>• Less stress in base frame during transient events.</li> <li>• Minimizes shaft misalignment relative to thermal expansion.</li> </ul>	<ul style="list-style-type: none"> <li>• Generator removal and installation is more difficult.</li> <li>• Vibration levels from engine can be transferred on alternator.</li> <li>• High bending moment may cause failures or vibration issues.</li> <li>• Consideration of bending moment required.</li> </ul>

Table 5: Advantages and disadvantages of a flexible mounted close coupled configuration.

Figure 8 shows an example of a flexible mounted open coupled Generating Set.

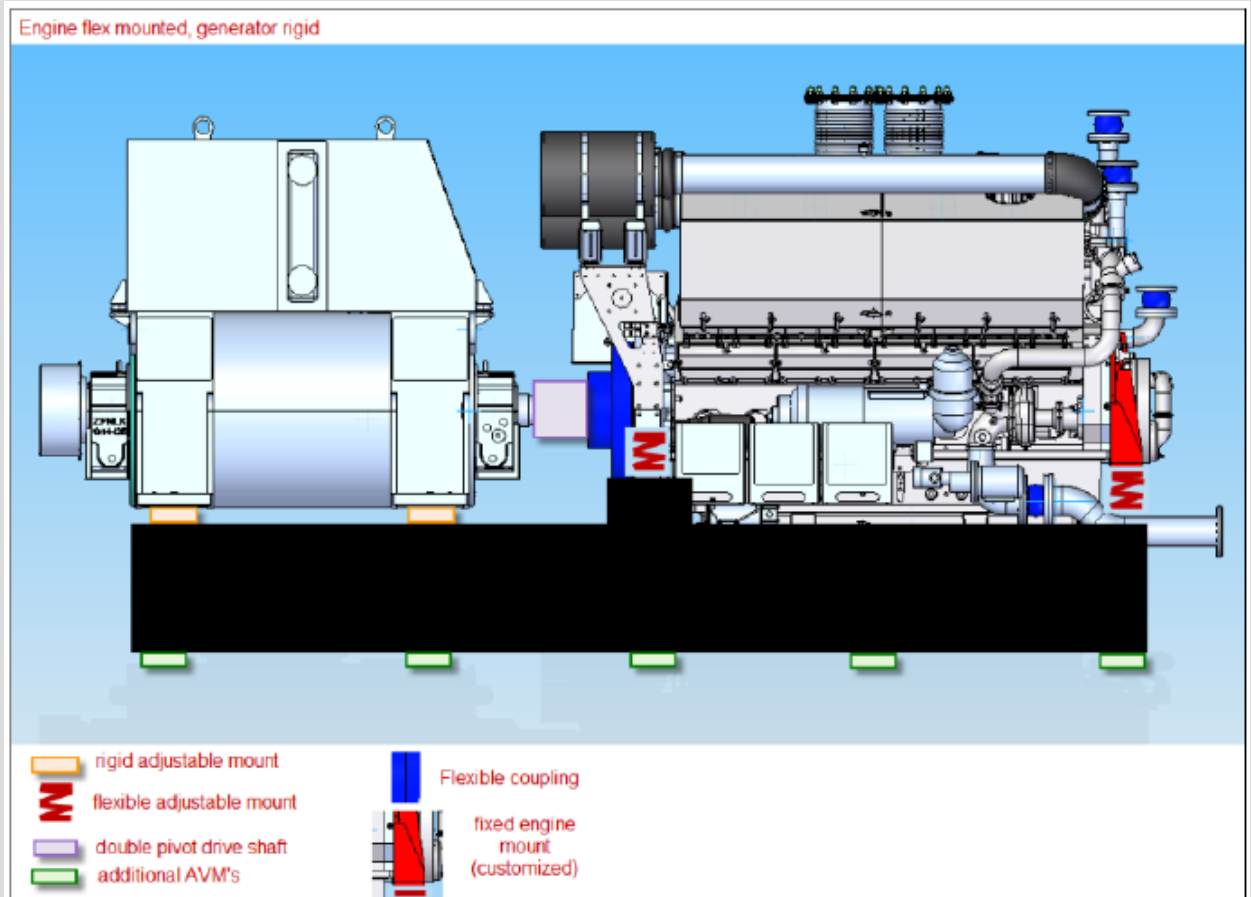


Figure 8: Flexible mounted genset base (Engine flexible – Alternator solid – Open coupled).

Table 6 shows some advantages and disadvantages of a flexible mounted open coupled configuration.

Advantages	Disadvantages
<ul style="list-style-type: none"> <li>• Eliminates vibration dampers under frame.</li> <li>• Base frame is less susceptible to resonance conditions.</li> </ul>	<ul style="list-style-type: none"> <li>• Alignment and maintenance for flexible mounted engine system required.</li> <li>• Expensive solution as highly elastic coupling is required to withstand misalignment.</li> <li>• Need more base frame length.</li> <li>• Need special engine front and rear support for vibration mounts with alignment studs.</li> <li>• Base frame must be torsionally stiff.</li> </ul>

Table 6: Advantages and disadvantages of a flexible mounted open coupled configuration.

## Anti-Vibration Mount Selections and Recommendations

Neoprene or rubber isolators, as shown in Figure 9, are regularly used on Generating Sets. These integral mounts are fitted by the Generating Set manufacturer between the engine-alternator assembly and the base frame skid. These isolators provide as much as 90 percent isolation efficiency, which is sufficient for most installations at or below ground level. The height of all mounting pads must be within 0.25mm for skid mounting, 3mm for non-adjustable anti-vibration mounts (AVM) or 10mm for adjustable height AVMs. Shims are used to achieve the required level. Cost is always a consideration; and the level of vibration that needs to be eliminated, will determine which of several types a designer could use to reduce the transmission of vibrations to surrounding surfaces.

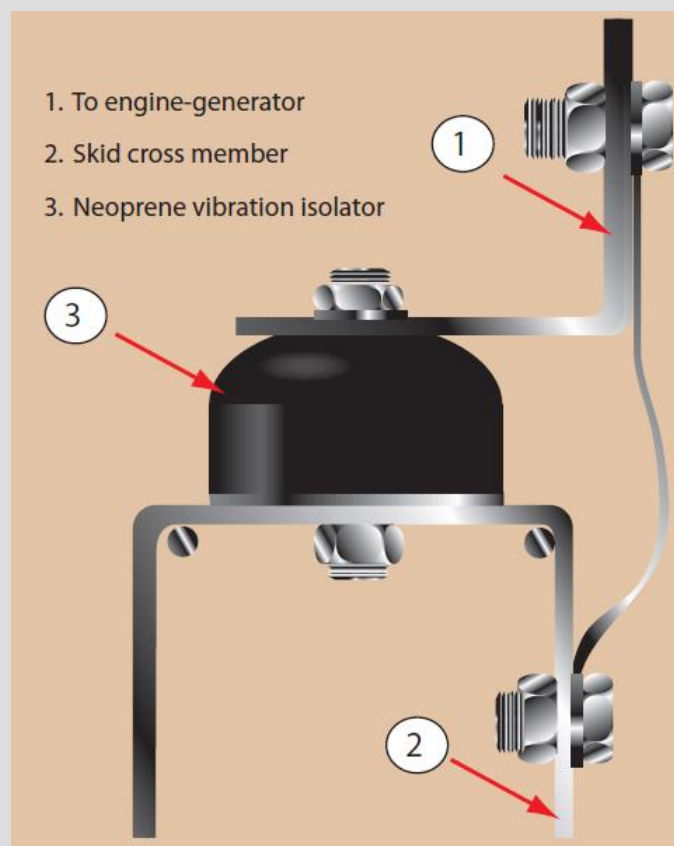


Figure 9: Neoprene or rubber integral vibration isolator system.

When selecting an anti-vibration mount, the following checklist should be considered to ensure optimum matching of the mount properties with the design requirements:

- Determine the combined centre of gravity of the diesel generator plant.
- Establish the positions of the machinery support relative to the centre of gravity.
- Take moments to find loads on the supports in the static conditions.
- Calculate the torque reactions at the mountings and check against manufacturer's figures for maximum permissible deflections.

- Where the generator is flange mounted to the engine flywheel housing, calculate bending moment (in the static condition) at the rear of cylinder block/flywheel housing interface.
- Decide upon the 'g' value (the anticipated vertical acceleration) for the application and then calculate the dynamic loads on the plant supports and the bending moment at cylinder block/flywheel housing interface.
- Select suitable mountings to withstand both static and dynamic loadings with required deflection.
- Calculate the natural frequency of selected mountings.
- Establish the lowest disturbing frequency for the plant being considered.
- Establish the degree of isolation that will be achieved from data supplied by the AVM manufacturer.