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Application Guidance Notes: Technical Information from STAMFORD | AvK

# AGN 234 – Generating Set Assembly - Alignment

## INTRODUCTION

This Applications Guidance Note is the third 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

## ALIGNMENT

Shaft alignment is the process of satisfactorily connecting two or more shafts with each other to within a specific tolerance. For a Generating Set, the prime mover and the alternator must be correctly aligned to ensure a long and serviceable life. Shaft misalignment is responsible for as much as 50 percent of all costs related to rotating machinery breakdowns. When coupling, the prime mover is mostly defined as the reference point, and the alignment adjustment is typically carried out on the alternator.

Alignment is critical to the operational characteristics and service life of the Generating Set. Operating vibration, rubber coupling operating temperature, bearing serviceability and rotor alignment (airgap) are areas that are susceptible the causes of misalignment. Various methods of ensuring alignment are required, depending on the design of the Generating set; open coupled, close coupled, single bearing, two-bearings. Single bearing alternators and close coupled two-bearing alternators rely on the adaptor mating face housing and spigot to provide shaft alignment. Open coupled two-bearing alternators rely on accurate shaft alignment procedures. Typically, rubber coupling manufacturers will have maximum misalignment tolerances that needs to be adhered to. Also, consideration of operating temperatures and shaft centre heights are required to minimise radial misalignment during operating conditions. Table 1 provides the recommended maximum values for radial misalignment allowed for different speeds.

| Nominal speed: | Maximum radial offset: |
|---|---|
| 1800 revs/min | 0.05 mm / 1.96 mil |
| 1500 revs/min | 0.06 mm / 2.36 mil |
| 1000 revs/min | 0.08 mm / 3.15 mil |
| 750 revs/min | 0.09 mm / 3.54 mil |
| 600 revs/min | 0.11 mm / 4.33 mil |
| 375 revs/min | 0.15 mm / 5.90 mil |

Table 1: Recommended radial alignment offset as per operating speed.

## Thermal Expansion

The temperature inside an alternator will increase considerably during normal operation. The materials used in the construction of an alternator, such as copper, electrical steel, iron and aluminium, will expand as the temperature increases. Overall, the alternator will increase in size both horizontally and vertically, during operation. The increase may be small, but may be significant. It will therefore; be necessary to thermally-compensate for true alignment, the increase in length ($\Delta L$) as shown in Figure 1. It may be necessary to compensate for the alternator/engine axial thermal expansion, depending on the type of mounting arrangement and base frame design.

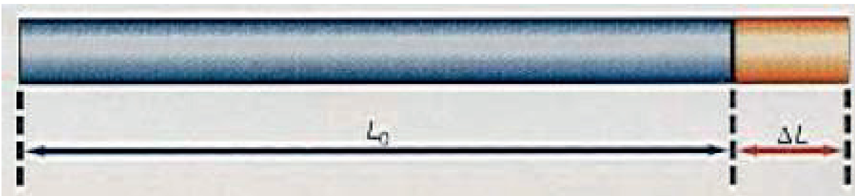



Figure 1: Typical linear expansion of an object.

The change in length $\Delta L$ depends on the temperature change, $\Delta T = T_f - T_i$; the initial length of the rod $L_0$; and a constant that is characteristic of the material being heated. The experimentally observed linearity between $\Delta L$ and $L_0 \Delta t$ can be represented by the equation;

$$\Delta L = \alpha L_0 \Delta t$$

Where

- $\alpha$ is the coefficient of linear expansion ($10 \times 10^{-6}$ $K^{-1}$).

- $T_f$ is the final temperature (°K).
- $T_i$ is the initial temperature (mm).

**Axial Thermal Expansion**

The axial thermal expansion of the alternator can be calculated from the non-drive end bearing on the alternator to the end of the shaft on the drive side, as shown in Figure 2. The non-drive end bearing is fitted with an O-ring that allows it to thermally grow horizontally for about +/- 2mm during operation. On a two-bearing alternator, the drive end bearing is fixed.

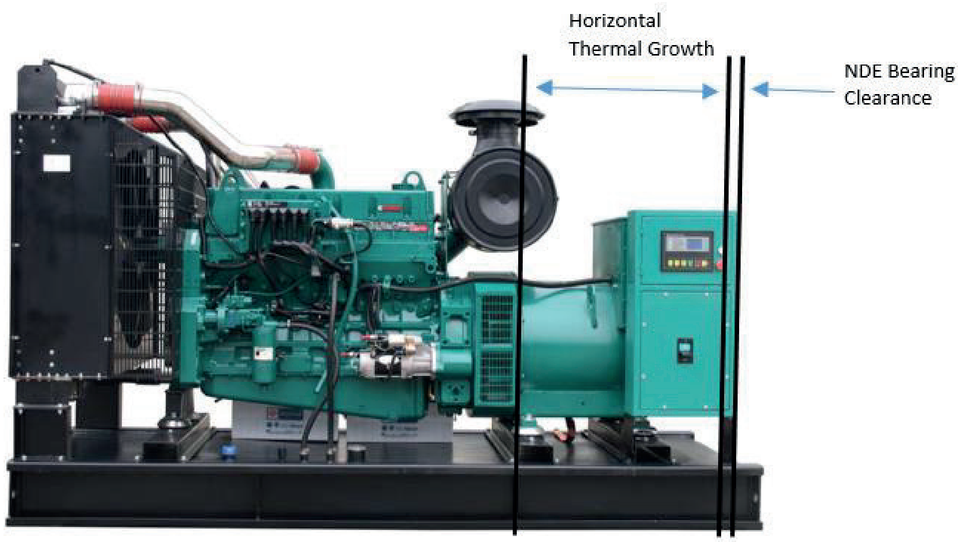



Figure 2: Axial thermal expansion.

Below formula can be used to calculate the axial thermal expansion of an alternator;

$$\Delta L = \alpha * \Delta T * L$$

Where

- $\Delta L$ is the thermal expansion (mm).
- $\alpha$ is the coefficient of linear expansion ($10 \times 10^{-6}\ K^{-1}$).
- $\Delta T$ is the temperature difference between alignment temperature and operating temperature to be expected (°K).
- L is the distance from the fixed bearing to the drive end of the shaft (mm).

**Vertical Thermal Expansion**

The vertical thermal expansion of the alternator can be calculated approximately using the distance between the base and centre of the shaft, as shown in Figure 3 on the next page.

Below formula can be used to calculate the vertical thermal expansion of an alternator;

$$\Delta H = \alpha * \Delta T * H$$

Where

- ΔH is the thermal expansion (mm).
- α is thermal expansion coefficient ($10 \times 10^{-6}$ $K^{-1}$).
- ΔT is the temperature difference between alignment temperature and operating temperature to be expected (°K).
- H is the Shaft height (mm).

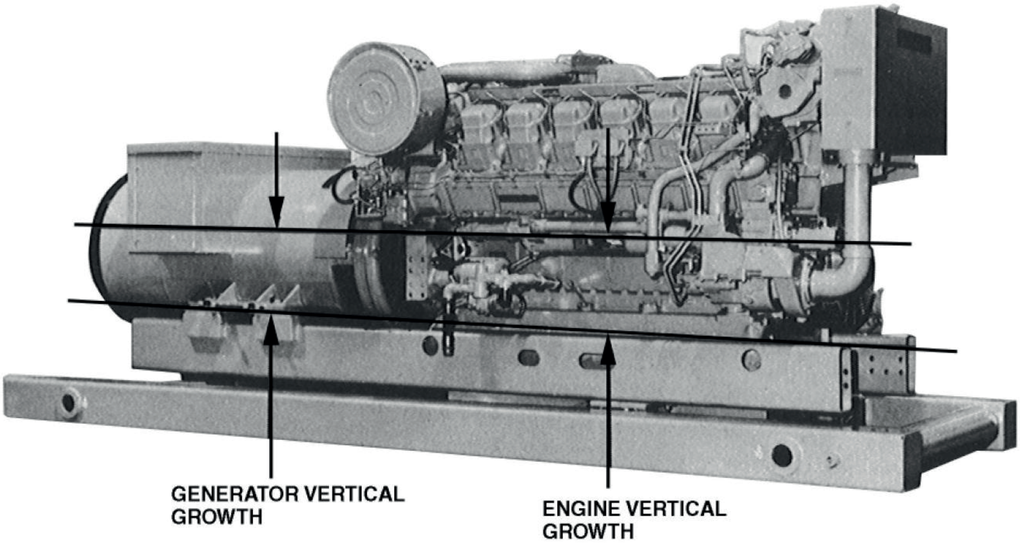



Figure 31: Vertical thermal expansion.

**<u>Types and Consequences of shaft misalignment.</u>**

Shaft misalignment can be due to axial misalignment, parallel (or offset) or angular misalignment, as shown in Figure 4.

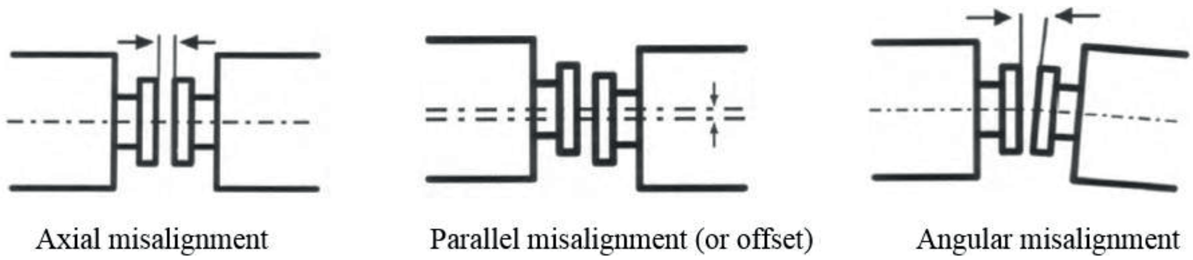



Figure 42: Shaft misalignment.

A Generating Set that is not properly integrated will increase the amount of stress on each assembly unit, resulting in a range of potential problems as listed below:

- Failure of coupling and foundation bolts.
- Increased vibration and noise.
- Increased rubber coupling temperatures and service life reduction.
- Excessive seal lubricant leakage.
- Premature shaft and coupling failure.
- Excessive wear on bearings and seals, leading to premature failure.

- Increased friction, resulting in excessive wear, excessive energy consumption, and the possibility of premature breakdown of equipment.

**Types of alignment equipment**

The three alignment methods used in the Generating Set industry include; visual inspections (straightedge), dial indicators and laser guided tools, as shown in Table 2.

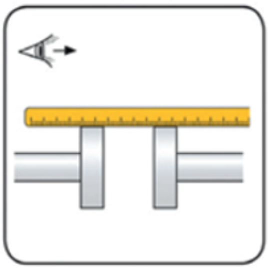
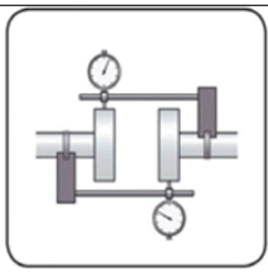
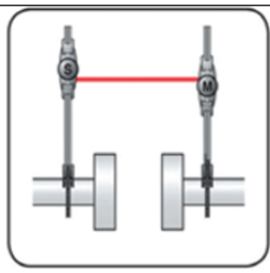
| Visual inspection or Straightedge alignment | Dial indicator alignment | Laser alignment |
|---|---|---|
| <br>Accuracy - -<br>Speed + +<br>Ease of use + +<br><br>The visual inspection method results in a rough alignment with the advantages of being quick and relatively easy but highly inaccurate. | <br>Accuracy + +<br>Speed - -<br>Ease of use - -<br><br>A dial indicator offers a higher degree of accuracy compared to the visual inspection method as it requires a high level of technical skill to be used properly. | <br>Accuracy + +<br>Speed +<br>Ease of use +<br><br>Laser alignment method is the most accurate method. It is quick, easy-to-use, requires only a single installation, deliver consistently better accuracy than dial indicators. |

Table 21: Overview of shaft alignment equipment and characteristics.

**<u>Alignment Process</u>**

Dial gauges and laser measuring instruments are recommended. There follows, alignment tips used in the Generating Set industry for connecting a single bearing alternator and a two-bearing alternator to a prime mover, using a dial gauge. The Owner’s Manual for the alternator will include the detailed alignment process. This process can be streamlined by using a dedicated laser alignment tool.

Alignment process:

1. Roughly align the alternator on the Generating Set base frame or the bed plates.
2. Couple the prime mover and alternator without using force.

**Single bearing alternator alignment**

When aligning a single bearing alternator to a prime mover, the primary objective is to ensure that the alternator’s air gap between the rotor and stator is maintained equidistant and the rotor is exactly aligned radially. Shims are used on the alternator's feet arrangement to achieve the correct level.

Pay attention to the following points:

- Crankshaft clearance on the combustion engine.
- Air gap between rotor and stator.
- Axial dimension.
- Check the radial alignment accuracy by measuring the distance between the shaft and the machined inside diameter of the bearing plate.

**Two-bearing alternator alignment**

If aligning when the Generating Set is cold, due consideration must be made to the measurements of alternator, gearbox and prime mover, as these measurements will increase due to thermal expansion.

- Align the coupling (minimum axial offset) according to the instructions from the coupling manufacturer.
- Use flexible coupling designed to suit the specific engine/alternator combination to minimise torsional vibration effects.
- Ensure the alternator is levelled vertically, horizontally and axially. Make the necessary adjustments by placing alignment elements or shims under the feet to achieve level.
- During this process consider the linear expansion of the shafts when reaching the operating temperature.

stamford-avk@cummins.com
www.stamford-avk.com



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