Application Guidance Notes: Technical Information from Cummins Generator Technologies

AGN 076 – Alternator Bearings

BEARING TYPES

In the design of STAMFORD and AvK alternators, the expected types of rotor motion are considered when deciding on the bearings to be fitted. Rotor motions considered are as follows:

- Axial rotation e.g. shaft rotation
- Linear motion e.g. drawer
- Spherical rotation e.g. ball and socket

STAMFORD and AvK alternators employ anti-friction and sleeve bearings. It is accepted that these bearings create friction and heat losses, although the different types of bearing vary.

Anti-friction bearings

The advantages of anti-friction bearings are:

- Standardized and normally easily available, worldwide.
- Comparably cheap for smaller to medium alternators (does not apply to special applications and special bearings).
- Alternators are comparably compact/short, because of integrated bearing cartridges/ housings.
- Comparably low friction losses.
- Heat loss in the bearings is in most cases, lower than with sleeve bearings.
- The starting friction for ball and roller bearings is rather low.

The disadvantages of anti-friction bearings are:

- Susceptible to brinelling during extended stationary periods.
- Exact expected lifetime not easy to state.
- Sensitive during storage and transportation.
- Noisier than sleeve bearings.

Sleeve bearings

The advantages of sleeve bearings are:

- Theoretically, unlimited lifetime when in permanent operation and provided that all design parameters are met.
- Low maintenance costs. Oil exchange intervals about 8000 hours in case of self lubricated, self cooled sleeve bearings.
- Exchange of bearing shells is possible without major dismantling of the alternator, or disconnection from driver.
- Not sensitive towards vibration and shocks during standstill and transit.
- Low noise.
- Bearing monitoring by temperature measurement gives a safe input for safe and early shut down.

The disadvantages of sleeve bearings are:

- At 1500 and 1800 rpm, an external oil cooling system is required to extract heat away from the bearings.
- The breakaway torque of a sleeve bearing supported rotor is significantly higher compared to ball or roller bearings.
- In case of excessive start and stops the expected lifetime of sleeve bearing shells is significantly reduced if a jacking oil pump is not used.

STAMFORD Alternators

All STAMFORD single bearing and two bearing alternators are fitted with anti-friction deep groove ball bearings. Sealed bearings are used on smaller alternators and regreaseable bearings are used on the larger alternators in the range.

The primary reason for the selection of ball bearings, as opposed to roller or spherical roller bearings are:

- The degree of misalignment that can be tolerated in single bearing configurations.
- The minimum loading required for satisfactory operation the bearing.
- The re grease interval time for regreaseable bearings.
- The resistance to brinelling.

More detailed consideration was backed up with testing the options for ball bearings, as opposed to roller or spherical roller bearings on the HC5E alternator. One of the most stressful applications for an alternator's bearings is Rail, where the alternator is subjected to excessive UMP (unbalanced magnetic pull), vibration and shock loading. In deciding the optimum design specific to alternators intended for Rail applications, the actual radial loading was taken into consideration, where the effect of UMP of up to 4999 Newtons is expected.

During assembly with the rotor resting in the stator bore, the misalignment angle of the rotor in relation to the stator centre line is 10 minutes (0.167 degrees). Considering bearing capabilities, which are as follows:

Bearing Type	Minimum Loading	Allowed Misalignment
• Ball	196 Newtons	10 minutes
• Spherical roller	4140 Newtons	1.5 degrees
• Cylindrical roller	1392 Newtons	3 minutes

Based on the minimum loading the Spherical roller bearing requirement is very close to the actual radial load and is likely to skid in the races rather than turn. Bearing in mind the HC5 core length options for this frame size, this would be a risky selection. Allowed misalignment is of course no problem and the bearing would provide some axial loading capability and location.

The cylindrical roller bearing has a minimum loading well below the actual, but in this case the allowed misalignment angle is too small to ensure that the bearing is not stressed and damaged during the assembly process. It might be expected that with well-machined components alignment, once assembled, would be within the limits of misalignment. There is of course no axial load capability or axial restraint, which will place any axial loading stress on to the discs and engine bearings.

The ball bearing on the other hand has a minimum loading well below the actual loadings and an allowed misalignment angle that should ensure no damage is inflicted on the bearing during assembly. There is also an axial load capability and location.

Both spherical roller and cylindrical roller bearings have a somewhat reduced regrease time period, as it is more difficult to retain grease in the bearing.

Since movement of the rolling elements of these bearing types is restricted within the races, compared to a ball bearing, there is a greater potential for damaging these types by brinelling.

Given these considerations, ball bearings are selected as the most suitable. There appears to be no valid argument for fitting either a spherical roller or cylindrical roller bearings.

AGN009 details the expected life of a bearing. On a general note, it is possible that in a given set of circumstances, were the ball bearing to be replaced with a spherical or cylindrical roller bearing, that a similar bearing life could be expected, but the bearings might well be failing for different reasons. For example; where a ball bearing might fail because of axial vibration,

causing a fretting action in the housing, the cylindrical roller bearing might fail because of lack of grease or misalignment damage.

The anti-friction ball bearings used on STAMFORD alternators are not insulated bearings. The design of STAMFORD alternators is such that the shaft does not come under the influence of magnetic fields that result in excessive voltage being generated along the axial length of the shaft – know generally as circulating shaft bearing currents. For further information on shaft bearing currents, refer to AGN033.

Single Bearing Alternator Shaft End Float

The Non-Drive End (NDE) bearing assembly on a STAMFORD single bearing alternator is designed to allow the bearing to 'float' axially to ensure that under various less-than-ideal conditions, described below, the bearing never exerts, or is subjected too, an axially force.

Common practice is to design the NDE bearing assembly such that the bearing internal diameter is a tight fit when pressed onto the alternator shaft. But the bearing outer diameter fits into an end bracket bearing assembly with a level of fit to allow the bearing to axially float to a natural position of 'ideal' alignment.

Typically, the NDE bearing assembly will allow the bearing to float some +/- 2.0mm. This allows the bearing to 'self-align' during the assembly of the alternator to the engine, when the manufacturing tolerances of the alternator components such as frame, end bracket, adaptor, shaft length, coupling hub, etc., combined with the engine flywheel, flywheel housing, etc., which will change the axially length of the alternator and so the real position of the NDE bearing in its housing.

When the Generating Set is operating at working temperature, then differential thermal expansion of the engine and alternator components will again change the ideal axial running position of the NDE bearing in its housing.

By deciding to manufacture alternators with the NDE bearing having an unrestricted axial float of some +/- 2.0mm around the ideal designed position for the NDE bearing; ensures that under agreed component machining tolerances, plus differential thermal expansion, the bearing will not become mechanically constrained. If it did become constrained, it would exert an axial force onto the engine-alternator coupling, which in turn would exert an unwanted axial force onto the engine crankshaft bearing thrust faces.

AvK Alternators

AvK single bearing and two bearing alternators are fitted with either anti-friction bearings or sleeve bearings.

Anti-Friction Bearings

The anti-friction bearings used are all insulated, regreaseable bearings and may be ball or roller and ball bearings.

- Roller bearings are fitted to the Drive End (DE) of the rotor.
- Ball or ball and roller bearings are fitted to the Non-Drive End (NDE) of the rotor.
- The bearing fitted to the DE on a two bearing alternator is fixed into a bearing cartridge.
- The bearing fitted to the NDE on a two bearing alternator is fixed into a bearing cartridge.
- The bearing fitted to the NDE on a single bearing alternator is floating in a bearing cartridge, with an unrestricted axial float of some +/- 2.0mm around the ideal designed position for the NDE bearing.

Insulated anti-friction bearings are the standard fit on AvK DSG frames: 62, 74, 86, 99 and 114 (not 125). Anti-friction bearings are available on AvK DIG frames: 110, 120, 130, 142 and 150 (not 140 or 156).

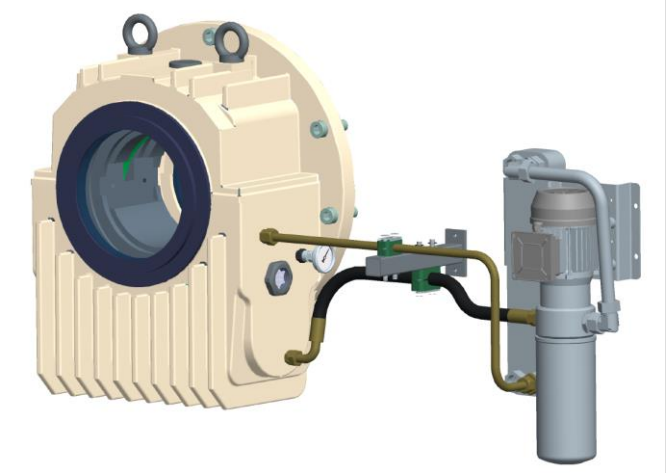
- Roller bearings at the DE.
- Ball or ball and roller at the NDE.
- Fixed NDE on 2-Brg. machines.
- Floating NDE on 1-Brg. machines.

Sleeve Bearings

Insulated Sleeve Bearings are available on the AvK DSG frames: 74, 86, 99 and 114. They are the standard fit on AvK DSG frame 125, but they are not available on the AvK DSG frame 62.

Insulated Sleeve Bearings are available on all AvK DIG frames and are standard fit on the AvK DIG frames: 140 and 156. Different options of lubricant cooling methods are available for sleeve bearings.

The alternator's rotor will turn on a bed of oil. The oil system can be a dedicated oil reservoir feeding the sleeve bearing in a separate and isolated system or the oil can be a shared supply with engine. The following illustration shows a typical Sleeve Bearing lubrication system, including the oil pump, reservoir, cooling unit and the mini water cooler:



During continual operation, theoretically, the sleeve bearing will offer unlimited lifetime. That is provided that all parameters are safe and stable. Frequent starting and stopping of an alternator fitted with sleeve bearings and any significant variability in operational parameters, can cause serious issues to the sleeve bearing outer races. Anti-friction bearing should be selected for alternators that are intended for this type of application. However; in case of untypical high number of starts and stops, hydrostatic jacking equipment is highly recommended.

Hydrostatic jacking needs external oil flow and a considerable pressure in order to create a sufficient oil film which can carry the bearing load. Hydrostatic jacking is effectively used to minimize:

- Start-up torque.
- Bearing wear at start-stop sequences.
- Prevent the bearing from weak oil wedges at low speeds (cold turning in case of turbine application, maintenance on piston engines).

BEARING SELECTION FOR GENERATING SETS

All STAMFORD alternators are available with single bearing or two bearing rotors, with the exception of the UCD alternators, which are single bearing only and the largest P80 alternators

(W, X and Y cores), which are two bearing only. AvK alternators may be designed to specific customer requirements.

The UCD alternators have a special cooling fan and voluted end bracket to give the alternators improved cooling and a slightly higher output rating.

Single Bearing Alternator or Two Bearing Alternator?

This is regard as a decision that must be based on GOEM engineering considerations into their unique Generating Set design intended for their product package functionality, which explores the following considerations:

- Cost effective engineering for the power generation package.
- Application specific constructional needs.
- Site location and associated transport- handling risks.
- Proposed and contractually acceptable mobility of the in-service package.
- Size-weight-shape issues of package.

If the GOEM has undertaken the necessary technical assessment and so produced an appropriate design where all critical aspects have been duly considered, then this should ensure the areas of risk are mitigated. There should then be no commercial or technical concerns regarding the type of alternator and therefore; no preference regarding a single bearing or two bearing Generating Set construction. Historically, the use of single bearing alternators was driven by the Generating Set industry. In more recent years, the drive for high power to weight engines (high BMEP for given swept volume) has initiated a reverse to that trend brought about by torsional analysis concerns. The net result; manufactured quantities of two bearing alternators has increased.

The GOEM's mechanical engineers must conduct the necessary torsional analysis and take the following design considerations into account:

- The suitability of the prime mover to support the alternator's rotor mass.
- Having a suitable flywheel housing design in terms of stiffness and rigidity with the engine cylinder block.
- Provide the necessary support for the total mass of the alternator.
- The design and construction of a suitable Generating Set mechanical support scheme in terms of Base-frame design and carefully considered AVM location.

If it is intend to build a 'close-coupled' two bearing Generating Set, then it requires the fitting of an adapter onto the Drive End (DE) of the alternator in order to fit to the engine's flywheel housing. Then it will be necessary for the Generating Set manufacturer to buy and install a coupling that will fit within this limited space. It must be a coupling type that fits together as a sliding assembly because, with the adapter around the outside of the coupling, there will be very limited access for any difficult coupling assembly procedure.

If it's intend to build an 'open-coupled' arrangement with no direct 'adapter' connecting together the alternator frame DE bracket to the engine flywheel housing, then the Generating Set manufacturer must design a very strong and carefully considered base frame, to support the engine and alternator. This base frame must have no (absolutely minimal) angular twisting / bending moment under full load torque, or load step changes, and also stiff enough in the axial direction not to flex/bend lengthways and cause misalignment. This base frame will also need to be Anti-Vibration Mounted (AVM) to a bedplate and when the Generating Set is installed, care must be taken to 'set-up' and 'level' the assembly into a perfect and unstressed plane of alignment.

Note. Engine adaptors and couplings are available with single bearing alternators. Engine adaptors only are available with two bearing alternators.