AGNI
MOTORS

Workshop Manual

Contents

Application Notes and Workshop Manual for the Agni DC Motor

To get the best results from your Agni motor, please read these installation notes carefully.

Safety

Before carrying out any maintenance or repair, read the workshop manual section of this publication; this is important because the motor contains very strong permanent magnets which could cause serious injury or damage if the motor is dismantled or reassembled incorrectly.

Please carefully observe maximum speed limits, which are 4000 rpm for the standard models without reinforcing bands and 6000 rpm for models with reinforcing bands around the armature. **Particularly with the reinforced version, overspeeding could lead to the armature bursting apart and pieces being thrown out with enough force to cause serious injury.** The voltage applied to the motor should not exceed the maximum speed divided by the rpm/volt figure for the motor; deduct 10% from this figure in an application where there is a possibility that the motor will be run at maximum speed with no load on it, and deduct 15 to 20% where the motor may be mechanically overdriven above its no-load speed so that it is operating as a generator.

Please also read the section on **Current and Voltage** (page 9).

Mounting

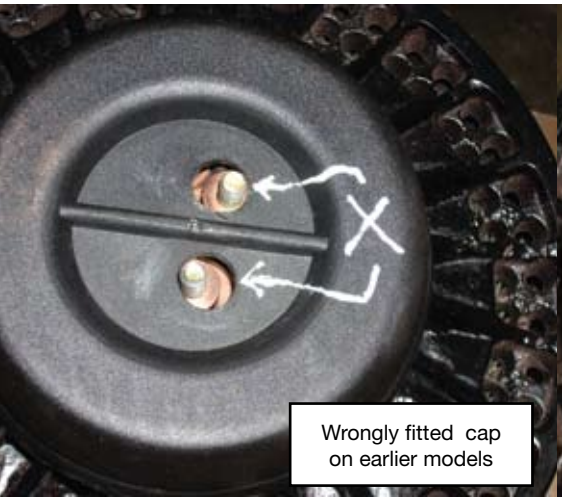
The motor has 8 mounting holes tapped M6x1.0 on a pitch circle diameter of 194mm and also 4 holes tapped M8x1.25 on a pitch circle diameter of 62mm. (On early models with one 3204 bearing the inner holes are on a 60mm PCD). If the motor is to be coupled to its load by chain or belt it is normally more convenient to use the outer holes. It is not necessary to use all of them; three or four (not all adjacent) are normally sufficient. The shaft has a diameter of 19mm and length of 40mm, and has a hole in the end which is tapped M8x1.25. Position the chain or belt as close to the bearing as possible.

The bearing can accept axial loads (thrust), so if the motor is coupled directly to the propeller shaft of a boat (or aircraft) it is not necessary to use a separate thrust bearing. In such an installation the shafts should be connected by a universal joint or the motor should be on flexible mounts symmetrically positioned around it. The motor can withstand occasional splashes of water when it is running, but it should be protected against falling rain, sea water, oil (and other liquids that are corrosive or that do not evaporate without leaving a deposit) or direct impingement of water thrown off the wheels of a vehicle. It should not be in a small unventilated space, except in low current or intermittent applications.

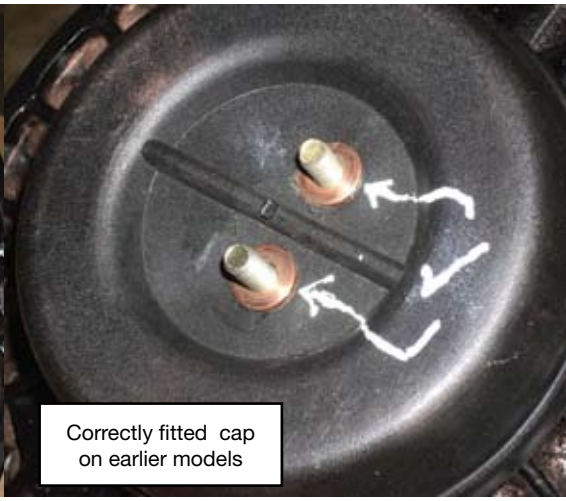
Note that when the motor is used with an electronic controller the current in the motor can be several times the current being taken from the battery when the motor is running slowly. The motor should not be mounted where a flammable or explosive atmosphere could be present.

The motor should be connected up using cables suitable for the current at which

the motor will be run. Normally they will be between 16 and 50 sq.mm. They should have terminal lugs with 6mm holes (8mm holes are also acceptable). On early models check that the brush holder cover of the motor is correctly fitted (see photos below), and not positioned where it will be trapped under the terminal lugs (see photos below). Current production covers have integral sleeves that fit over the terminal posts so that they cannot be trapped in this way.



Wrongly fitted cap on earlier models



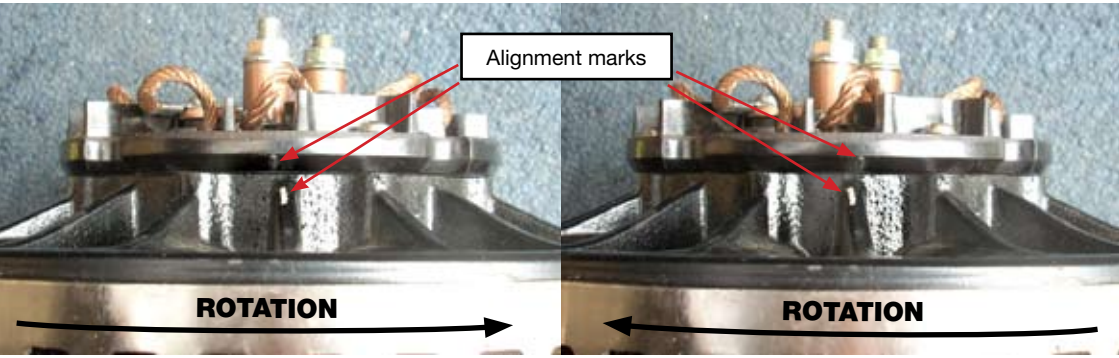
Correctly fitted cap on earlier models

The terminal studs are fitted with flanged nuts which in effect have built-in washers. Do not put any washers (except, if necessary, plain copper washers) under the terminal lugs, and do not use spring washers, self-locking nuts or any nuts or washers not made of metal. If the original nuts get lost, it is satisfactory to use ordinary nuts with plain washers between them and the lugs. The direction of rotation can be changed by swapping over the two cables.

Loosening screws to adjust the brush holder

The motor is supplied with the brush holder set in the 'neutral' position, suitable for running in either direction and giving maximum efficiency at light and moderate loads. If it will be run in one direction only, or in one direction most of the time but with occasional reversing which is not for long periods at high power, then the efficiency at high loads can be slightly increased by 'advancing' the brush holder. To do this, slacken the four screws which hold the brush holder (see left photo) and turn the holder a little in the OPPOSITE direction to that in which the motor will run until the white mark on the end plate and the moulded pip on the brush holder are 1mm apart. For an application in which the current will always be high (150A or more) when

operating at maximum speed, such as a speedboat, an aircraft, some motorcycles that do not have streamlining, or a fan or centrifugal pump that demands this much current, set the advance so the marks are 2mm apart.



Gently retighten the screws and refit the cap. Do not advance the brush holder further than shown in these photos, about 2mm measured at edge of the holder. Too much advance will cause the motor to take excessive current at light loads and will also shorten brush life.

If the motor is to be used as a generator the brushes should be in the neutral position or turned about 1mm in the SAME direction as the rotation. In a vehicle which has regenerative braking it is quite OK to advance the brush position; the time spent braking is usually a small proportion of total running time and it is more important to have the optimum setting for normal running.

When attaching driven components to the shaft, lock the shaft against rotation by holding the driven component with a suitable tool. Do not try to lock the motor by pushing anything through the ventilation holes to jam the armature, because this will cause serious damage.

Components which are a tight fit on the shaft should be pressed on using an M8 screw and suitable distance pieces, and removed using a puller whose pressure screw presses on a short M8 screw inserted in the end of the shaft to protect it. The use of a hammer or levers is likely to damage the bearings, making them noisy and shortening their life. We recommend using taper bushes to fit components to the shaft; they avoid the need for force fits and also prevent fretting.

Current and voltage

When the motor is being ventilated by its own rotation (i.e. there is no separate fan) the current (**measured at the motor;** we recommend that an ammeter should be installed between the motor and controller) in continuous running should not be over the figures given in the following table for the relevant voltage, **also measured at the motor:**

	armature version			
voltage	**95**	**119**	**135**	**143**
12 volts	120A	90A	80A	70A
24 volts	140A	120A	110A	100A
36 volts	180A	150A	140A	130A
48 volts	230A	200A	170A	140A
60 volts	**230A**	200A	180A	150A
72 volts	**230A**	**200A**	180A	150A

Figures in red refer to **reinforced armature models only**; speed will exceed 4000rpm

Short-term current for up to about 30 seconds at a time may be up to 400A for the 95-turn armature, 300A for the 119 and 135-turn armatures and 250A for the 143-turn armature. (For racing or similar applications these figures may be briefly exceeded).

Voltage should not exceed that giving a speed of 4000 rpm (if the motor is a version with reinforcing bands around the armature then it may be run up to 6000 rpm). The maximum speed should not be exceeded even briefly; doing so can cause immediate damage, and in the case of a reinforced motor exceeding 6000 rpm there is a risk that the armature could suddenly burst apart with heavy pieces being ejected through the motor casing, liable to cause serious injury.

Cleaning

The outside of the motor can be cleaned with a damp or oily rag or with a stiff brush. Any aerosol cleaning product used should be sprayed on the rag or brush, not directly on the motor. Do not clean the motor with a pressure-washer, because the water gets into the bearings and causes trouble with them.

Routine maintenance

The frequency with which this is required depends on the severity of the application. In an application not involving very high currents, dust or other contamination it could be every few thousand hours. In a vehicle used for racing, it is advisable to check the motor after each race meeting. In an aircraft, turn the propeller slowly forwards and listen to the motor as described below before each flight.

Turn the motor very slowly in its normal direction of rotation. There should be a faint, smooth hissing sound from the brushes. Rasping or clicking sounds indicate a possible problem.

Take off the terminal cap and check that the flexible leads leading to the brushes have plenty of slack in them and are not close to being pulled tight between the terminals and where they pass into the individual brush channels. Gently pull each flexible lead to check that the brushes are free to move in their channels. In case of any doubt, see the section below on “Removing the brush holder” and check. Also if the motor has accumulated very many hours of running, remove the brush holder and blow dust out of the armature with compressed air. Do this outdoors and do not breathe the dust.

Try to shake the shaft. If there is significant play or if there have been unusual noises with the motor running, see the section below “Dismantling and reassembly of the motor” and replace the bearings.

Dismantling and reassembly of the motor

Tools required

- **A bench vice with soft jaws** (alternatively slip a piece of copper pipe over the motor shaft to protect it from damage by the vice jaws)
- **A 10mm spanner**
- **A screwdriver**
- **A strong 6mm Allen key** (long-arm type, or of the socket type that can be used with a torque wrench or T-handle)
- **Three 100mm lengths of M6 threaded rod (studding)** each with two nuts locked against each other at one end so they can be turned with a spanner (not to be used with reinforced-armature versions of the motor; see page x for description of a tool to be used instead)
- **Internal circlip (snap ring) pliers** (only for early model with 3204 or 5204 bearing)
- **A small hammer**
- **A length of steel rod about 10mm diameter** (for current models with two 6304 bearings)
- **A drift** suitable for pressing on the outer race of the bearing, which is 47mm diameter on early models and 52mm on current ones
- **A short M8x1.25 screw and some thick washers that fit it**
- **A 150mm length of M8 threaded rod (studding) and a nut**
- **A piece of steel tube** with 25mm (1 inch) inside diameter and length of 80 to 100mm
- **Anaerobic adhesive**
- **Anti-seize assembly compound** (for current models, and also for fitting a current-type armature and shaft to an early model)
- **Commutator surfacing stick**

DO NOT DISMANTLE THE MOTOR WHEN IT IS HOT, AS THIS COULD CAUSE PARTIAL DEMAGNETISATION OF THE MAGNETS. LET IT COOL FIRST.

Removing the terminals from brush holder

(so as to replace them in case of a stripped thread; the studs can be replaced without removing the brush holder from the motor):

Unscrew the terminal nuts and detach the cables.

Take off the plastic cap.

Note the positions of the flexible leads and of their tags; if the leads are mis-routed they may prevent free movement of the brushes in the holder or they may short-circuit to leads of opposite polarity.

Undo and remove the eight screws which hold the brush terminal tags

and you will be able to lift out the terminal plates with their studs.

These studs are M6 hexagon-headed bolts, 30mm long. The one for the lower plate has a flanged hexagon head. In emergency you can instead use an ordinary hexagon-headed bolt or screw with a thick washer under the head, but you will need to apply a little adhesive (silicone sealant is suitable) around the head to stop the bolt dropping down inside the brush holder. The terminal for the upper plate is a hexagon-headed full-thread screw with a flanged nut fitted to it. This nut may be transferred to the new screw.

Reassembly

Insert the small screws into the terminal plates by three turns only, so they are not yet projecting under the plates. If they are of two different lengths the longer ones go in the UPPER plate. Hold the lower plate in position against the brush holder and screw the screws several turns further in. Repeat this with the upper plate. Check that there is a gap of about 2 mm between the two plates. Locate the tags of the flexible leads under the screws and tighten them fully.

The copper terminal posts should stay attached to the plates, but if they come out simply push them back. They are securely held in place when the connecting cables and nuts are fitted.

Removing the brush holder from the motor

First check the position of the alignment marks, and make a new mark if they are not visible.

Unscrew the four screws which retain the holder and carefully lift it out. Note that the brushes will easily break if they are knocked against anything.

Check that the brushes slide freely in their guides and that they have adequate length. The length of a new brush is about 25mm and the minimum permissible length is about 10mm. Below this length the metal tag will contact the commutator and cause scoring or burning of the surface, so the brushes should be replaced if they would be likely to wear to 10mm before they will next be checked. Normally the rate of wear is very low. If the brushes seem to have worn at an excessive rate check that they are not sticking in the holder, that the commutator is not in a burnt or uneven condition and that the holder position adjustment is correct for the direction of rotation. The rate of wear will be higher than normal if the motor is exposed to large amounts of dust.

The brushes can be removed by loosening the screws which hold their terminal tags, then taking them out from the underside of the holder. Care is needed to pass the tag through the holder.

If any brushes are sticking, remove them and clear their guides with a diamond needle-file, a folded piece of emery paper or an emery board sold for filing finger-nails.

The commutator can be resurfaced if necessary with a surfacing stick. The motor should be securely mounted and spun at 2000 to 3000 rpm, which can be done with an electric drill coupled to the shaft with a 6mm Allen key bit and an M8 Allen screw. Brace the surfacing stick firmly against the motor end-plate and bring it into only light contact with the commutator (otherwise it could smear the metal and cause short-circuiting between adjacent segments of the commutator). Continue until the commutator is smooth and uniform. You will see some sparking from the surfacing stick because of the voltage generated by the rotation of the motor.

Motors that we have supplied for some very low-voltage applications have four copper-coloured brushes and four dark grey brushes; these must be fitted as positive (copper-coloured) and negative (dark grey) respectively, otherwise there will be extremely rapid wear.

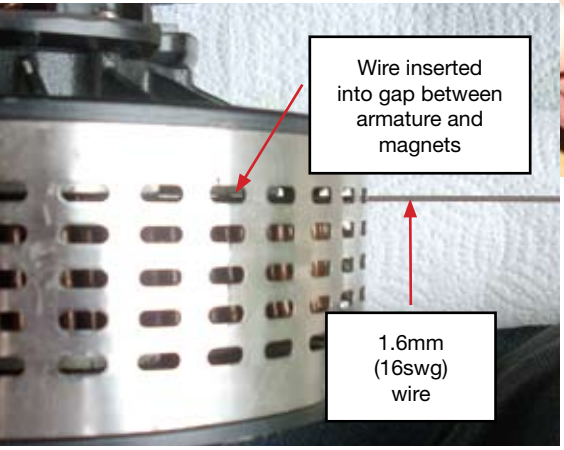
When fitting the brushes to the holder, take care to position the flexible leads and tags so that the brushes move freely for their whole usable length but do not spring right out of the holder. If it is difficult to stop them springing out of the holder, push them fully in and insert rolled-up pieces of cardboard under the loops of flexible lead on top of the holder. Remove the pieces of cardboard after fitting the assembly to the motor.

When refitting the assembly check that it is in the neutral position or with the correct advance, as required.

Separating the parts of the case

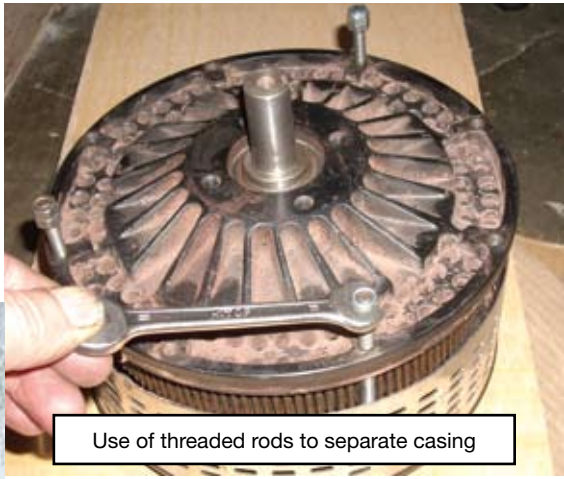
First remove the brush holder as described above.

Before separating the case, measure the clearance between the armature and the magnets (unless the bearing is in very bad condition, which would make the measurement unreliable). Insert a length of 1.6mm (16s.w.g.) wire into the gap on each side of the armature (photo). It should go in with about the same clearance on each side. If the gaps are different, make a note of them.



Also note whether the armature rotates freely with the brushes removed. If there is a feel comparable to turning it in a viscous liquid (it turns easily very slowly but strongly resists turning faster), either all the time or releasing momentarily at eight positions per revolution, there is a short-circuit in the armature and it will have to be replaced (or repaired if the cause is externally visible).

Insert the three lengths of M6 threaded rod into three of the outer mounting holes 135, 135 and 90 degrees apart and turn them until they make contact with the other cast-iron end-piece. Continue to turn them by equal amounts and they will push apart the case, which is held together only by the magnets.


Use of threaded rods to separate casing

If the threaded rods tend to slip into ventilation holes in the end-piece, insert pieces of wood into the holes concerned so that the pieces of wood project inside the case and prevent the threaded rods entering the holes. When the parts have been pushed about 25mm apart they can be separated by hand.

Warning: the magnets are very strong and if carelessly handled they can cause serious injury. We recommend that for safety reasons the lengths of threaded rod should be left in place in the end-piece until after the case is reassembled. This avoids the risk that the two parts of the case come together with only your fingertips between them!

An alternative method of separating the case is to make a tool like that in these photos. **On special versions of the motor with reinforcing binding around the armature this method must be used, because the armature has a larger diameter and there is no room to insert pieces of threaded rod.**

Case-separating tool for motor with reinforced armature

This method must also be used if you are replacing the outer band of the case, because the method using three threaded rods will not guarantee accurate alignment of the two end-pieces if the locating indentations in the outer band are not already present.

The pressure screw should be at least 8mm diameter, and needs to be turned to a diameter of 6mm for a short length at its business end.

Removing the armature

Clamp the shaft in the suitably protected jaws of a vice. Try not to grip on the keyway.

Unscrew the central screw in the hub, using a 6mm Allen key. Do not unscrew the six outer screws.

unscrew central screw

not the outer ones

The screw will turn one or two turns after loosening and then seem to go tight again. Continue turning it and it will push the armature off the shaft against the pull of the magnets (see photo). On current models the screw will continue to be stiff to turn until the armature is almost off the shaft; if the screw disengages from the thread while the armature is still tight, grasp the edges of the armature and carefully wobble and twist it while pulling. There may be one or more shims between the armature and bearing.

Take care not to lose them. If you found different gaps on the two sides of the armature before dismantling, measure the shims and calculate the alteration needed to equalise the gaps (assuming that no components other than the bearing(s) and/or shaft are to be replaced).

Examine the magnets. If the plating is blistered or peeling off any of them, remove the affected plating and smear the bare areas with anaerobic adhesive.

Examine the armature and the inside of the casing. If the motor has been seriously overheated it is possible that solder could have been melted in the joints around the outside of the armature and thrown out onto the inside of the casing. If this has happened the joints should all be re-soldered using flux-cored solder and either a large (200 watt) electric soldering iron or a miniature gas blowtorch.

If the central screw in the armature hub has become damaged it is possible to replace it, but do try to avoid this because the procedure necessary could possibly lead to trouble with the armature. If it is necessary to replace this screw, remove the six Allen screws holding the hub cap. On the early type armature it is now possible to take out the central screw, fit a new one (with some anti-seize assembly compound applied to both the top and bottom of its head) and replace the six outer screws, tightening evenly to 18 Nm.

On the current type, and also on the early type if the cap becomes loose when the six screws are removed, make a mark on the hub cap and on the commutator so that you can see which of the six possible positions the cap was in. Then remove the cap. Do not scrape off any insulation material adhering to the cap or armature.

On the current type armature you can now replace the centre screw with a new one (with some anti-seize assembly compound applied to both the top and bottom of its head). Now apply some slow-setting epoxy adhesive such as Araldite Precision to the conical surface on the underside of the cap, re-fit it in the marked position and tighten the six screws evenly to 18 Nm. Place the armature in an oven at 130°C (260°F) for a few hours. After it has cooled re-torque the six screws to 18 Nm in case any settlement has occurred.

tightening hub cap screws

Shaft

The shaft is a separate part from the armature, so if it gets damaged it can be replaced at low cost. See under “bearing” for details.

Bearing *(early model with one double-row bearing)*

If the bearing needs replacing, remove the circlip (snap ring) which holds it in position. Fit short M8 screws into the ends of the shaft to protect it, then hammer on the end of the shaft which is on the outside of the motor to drive the shaft and bearing out of the end plate. The bearing can be removed from the shaft with a puller. Note that if you are removing the shaft and bearing in order to replace the shaft, you will need to replace the bearing as well because the force to remove it cannot be applied without being transmitted through the balls. This will probably cause indentations in the races of the bearing, so that if it is re-used it will be noisy.

The bearing is a 3204 or 5204 double-row angular contact type, with suffix 2Z (shielded) or 2RS (sealed). Where the highest possible efficiency is important, for example in applications using solar power, the shielded type is slightly better. In installations where the motor cannot be completely protected against water splashes or dust, the sealed type will last longer. Also use a sealed bearing if the shaft enters an oil-filled housing.

When fitting the new bearing hold it tightly so that it is not attracted onto the magnets, because a bearing which has become magnetised may have a shorter life. After inserting the bearing into the housing bore, drive it fully in by pressing or hammering on the OUTER RACE ONLY, taking care that the bearing does not tilt and become jammed in the bore. A large socket spanner may be used as a drift. Re-fit the circlip.

Bearings *(current models with two single-row bearings)*

It is possible to remove the shaft without any damage to the bearings. Place a length of steel tube with 25mm (1 inch) internal diameter over the shaft on the outside of the motor, screw a length of M8 threaded rod into the end of the shaft and use a nut and thick washers to draw the shaft out of the bearings and into the tube.

To remove the bearings, hold a piece of 10mm steel rod so that it passes through one bearing and tilt it so that it abuts the shoulder of the inner race of the other bearing, pushing aside the spacer that is between the two bearings. Hammer on the rod to drive the bearing out. Remove the spacer and drive the other bearing out in the opposite direction. There could be one or more thin shims in addition to the spacer; if so, keep them with the spacer and refit them with it on reassembly. The bearings cannot both be driven out in the same direction because the housing has an inward-projecting rib between them.

The bearings are 6304 single-row deep groove type, with suffix 2Z (shielded) or 2RS (sealed). Where the highest possible efficiency is important, for example in applications using solar power, the shielded type is slightly better. In installations where the motor cannot be completely protected against water splashes or dust, the sealed type will last longer. Also use a sealed bearing if the shaft enters an oil-filled housing. It is also possible to use bearings that have a shield or seal on one side only, suffix Z or RS; in this case they and the space between them must be one-third filled with **perfectly clean** high-quality grease.

When fitting the new bearing that fits from inside the motor hold it tightly so that it is not attracted onto the magnets, because a bearing which has become magnetised may have a shorter life. After inserting the bearing into the housing bore, drive it fully in by pressing or hammering on the OUTER RACE ONLY, taking care that the bearing does not tilt and become jammed in the bore. A large socket spanner may be used as a drift, but make sure it is clean inside. Now REMEMBER TO FIT THE SPACER and any shim that was with it (and if you are using bearings with single shield or seal, also put in the grease) and fit the second bearing in the same way.

Centralise the spacer so that it will not obstruct fitting of the shaft.

Fitting the shaft and armature *(early and current models)*

Insert the shaft into the bearing from the outside of the motor. DO NOT HAMMER IT IN but pull it into the bearing using an M8 screw, or studding and a nut, and suitable spacers (such as a socket spanner, an old bearing or a length of steel tube) applying pressure to the INNER RACE ONLY. This photo shows a screw, washers and an old bearing being used to draw the shaft into the bearings.

If the shaft is not a tight fit in the bearing, then it MUST be retained with anaerobic adhesive; otherwise there is a danger of trapping your fingers when you attempt to fit the armature!

Clamp the outer end of the shaft in suitably protected vice jaws. Place the shims over the part of the shaft to which the armature is to be fitted, making any adjustment which you have calculated to be necessary. In emergency additional shims can be cut from an old tin can, but use only the type which has seams at both top and bottom. The “deep drawn” type having no seam between bottom and sides may not be of uniform thickness.
On a current model, apply a thin smear of anti-seize assembly paste to the shaft and to the inside bore of the armature hub before fitting the armature.

Refit the armature, holding it tightly so that it does not tip. Turn the central screw to lower it into position. On an early model

also turn the armature until you feel it engage with the flats on the shaft. On a current model the armature fits in any position and the torque needed to turn the screw will progressively increase to about 35 Nm as the armature hub approaches the bearing.. Tighten the central screw tightly

and check that the armature is parallel to the magnets with a gap of about 2mm.

Check that the lengths of threaded rod used to separate the casing are still in position, and then lower the other part of the casing over the armature. Note that there are four positions in which the two parts of the casing are attracted together by the magnets, but the indentations which ensure accurate alignment will only engage in one of these positions.

Unscrew the threaded rods uniformly until the case is together and check that the clearance between armature and magnets is the same on both sides. Remove the motor from the vice and check that it turns freely and quietly. Check that the commutator is perfectly clean (free from oil, fingerprints etc); clean it with methylated spirit (wood alcohol) or other solvent that will evaporate without leaving a residue if it is not. Re-fit the brush holder, taking care that it is in the neutral position or advanced in the correct direction for the application.

Finding the correct brush holder adjustment if the alignment marks are lost, or if the motor is installed in a position such that they are concealed

As a motor:

- Mount the motor securely.
- Remove the cap from the brush holder.
- Slightly slacken the screws that hold the brush holder.
- Connect the motor to a fairly low voltage source such as a 12 volt car battery, so that it is running in the correct direction for the application (note that it will start with a strong jerk; also make the final connection away from the battery to avoid risk of an explosion due to a spark igniting gases given off by the battery).
- Turn the brush holder to the position in which the motor takes the least current, and then turn it slightly in the OPPOSITE direction to the rotation of the motor so that there is a VERY SMALL increase in the current.
- Mark this position, disconnect the battery and tighten the brush holder in the marked position.
- If it is necessary to perform this operation without any means of measuring the current, turn the brush holder to the position giving the lowest speed and then turn it very slightly against the direction of rotation until you can hear a VERY SMALL increase in speed.
- If the motor has to work equally in both directions, perform the operation in both directions. If the resulting marks do not coincide, set the brush holder halfway between them.

As a generator:

- Remove the cap from the brush holder.
- Slightly slacken the screws that hold the brush holder.
- Connect a voltmeter to the terminals.
- If the voltage is likely to be over about 20V and your hands could be wet, take care not to touch the terminals or brush leads. Otherwise there is a danger of a serious electric shock.
- Take care also that the brush leads and terminals do not touch each other or anything else at opposite polarity; if this happens, sparks and molten metal could be ejected.
- It is advisable to wear goggles.
- With the apparatus running, turn the brush holder until the highest voltage is produced.
- Mark this position.
- Stop the apparatus and tighten the brush holder in the marked position.

In case of doubt, or if you have questions not covered here, please contact us on:

info@agnimotors.com

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