Wind turbine rotor disk manufacturing guide

Produced by: VSO & SIBAT (Philippines)

Version 1.0

April 2008

Author: Andrew Corbyn

Introduction

This is a guide to the manufacture of the rotor disks in the permanent magnet generator (PMG) of the 1 kW wind turbine. These are for use with the wind turbine design produced by Hugh Piggott and described in detail in his 'How to build a wind turbine: the axial flux windmill plans' guide (from which sections and photos are directly borrowed), available from http://www.scoraigwind.com/ (this guide is also available on the Practical Action website).

This is a practical guide which is designed to show the process of producing the rotor disks for the wind turbine. This guide stemmed from work to producing a 1kW version of Hugh's design for use by SIBAT in the Philippines.

A rotor disk is made up of a 14" diameter steel plate, onto which 16 magnets are adhered. Encase the steel plate and magnets in a resin and fibreglass mix. 2 rotor disks are required per wind turbine. The rotor disks are built according to the Hugh Piggott guide.

An aluminium mould and aluminium magnet positioning jig are available for the manufacture of the rotor disks.

Overview of the production process

The production process is as follows:

1. Fabricate 2 magnet rotor plates in a metal workshop.
2. Attach 16 magnets to each magnet rotor plate using the magnet positioning jig.
3. Place the magnet rotor plates in the aluminium moulds and encase in a resin / fibreglass mix.
4. Remove the completed rotor disks from the moulds and clean the moulds.

Health and Safety

BE ESPECIALLY CAREFUL WHEN HANDLING THE MAGNETS, individually or when on the completed rotor disks. The magnets are very strong and can surprisingly 'jump' large distances when attracted by another magnet. It is not a waste of time mentioning that all steel objects can have the same effect - beware of spanners, nuts, bolts and other steel items when working with the magnets. This author has experience of painful bruised and blistered fingers from the magnets.

Magnets also pose a real threat to magnetic media such as credit cards, mobile phones, digital cameras, watches etc. Remove vulnerable items from pockets and keep a safe distance away. A previous SIBAT engineer damaged his digital camera while taking a close up photo of a rotor disk.

When dealing with the composite materials please follow the health and safety guidelines provided by the supplier. Here are some useful guidelines:

The process uses many different chemicals. Most of these are **TOXIC** and **FLAMMABLE**.

Ensure that they kept away from flames and sources of ignition at all times.

NO SMOKING at any point during the production process.

Wear **GOGGLES**, **GLOVES**, **MASKS** and **PROTECTIVE CLOTHES** while working with resin.

Most of the chemicals will cause agitation to the skin and cause blindness if they come into contact with the eyes. If any chemicals come into contact with the skin then wash immediately with plenty of soapy water. If any chemicals come in contact with the eyes the **IMMEDIATELY SEEK MEDICAL HELP**. Show the packaging of the chemical to the medical services.

ALWAYS follow the procedure shown in this guide when mixing chemicals.

COBALT AND HARDENER MUST BE KEPT SEPARATE AT ALL TIMES. If mixed they are explosive. This includes in syringes, mixing, cleaning and storage.

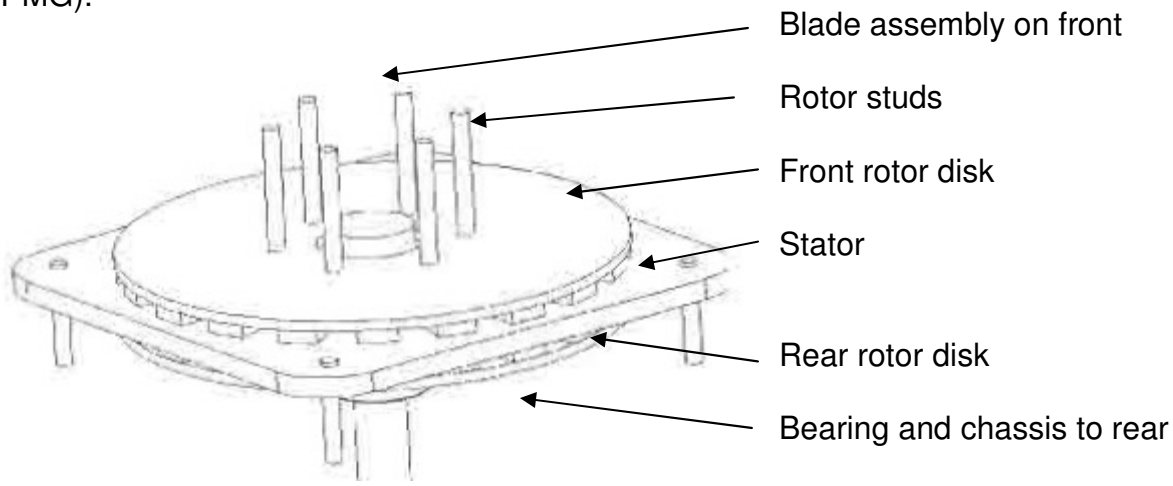
The fumes from the chemicals are **TOXIC**. **ALWAYS** work in a well ventilated environment. Wear a respirator mask.

The dust from cutting, sanding or grinding fibre glass is **TOXIC**. **ALWAYS** wear a good quality **MASK** and **GOGGLES**.

Power tools are used to cut and grind the fibre glass. Take great care when using these items and **ALWAYS** ensure **GOGGLES** and a **MASK** are worn.

Basic Design

The rotor disks are shown here as part of the permanent magnet generator (PMG).



The rotor disks are connected to the bearing on the chassis by 6 rotor studs. The blade assembly is attached to the rotor studs on the front side. 2 rotor studs pass through each blade root.

Equipment

Aluminium rotor moulds

Magnet positioning jig

Materials, Suppliers and Costs

This section will describe all the materials that are required to build the rotor disks, where they can be found, and an approximate cost. Costs are based upon purchases for the PP 2006 project, a contingency should be included in budgeting and new price changes recorded in this document.

Magnet rotor plates:

This is made from 5/16" mild steel plate (BI, or black iron, was used – this is a slang term used with the metal suppliers and refers to steel with black paint as opposed to being galvanised). For the 2 disks an area 14" x 28" is required. The 5/16" plate is also used for other parts of the turbine – the total amount required should be ordered in one piece (see CAD Drawings/Material template for template of all parts required for one wind turbine).

Supplier: Tiong Keng Metal & Hardware, 594 T. Alonzo St., Quiapo, Manila. 733-5393, 7336461.

Cost: 4' x 21" x 5/16" = P2200. Around P500 per rotor disk. Savings can be made if the steel plate is ordered as a whole 4' x 8' sheet.

Magnets:

Neodymium N40 iron boron blocks 2" x 1" x ½". 16 magnets are required per rotor disk, 32 in total for one wind turbine.

Supplier: China Magnets. www.chinamagnets.com

Cost: P360 per magnet, P11,520 per turbine. Cost is inclusive of air freight. NB. Magnets should not be shipped! This is to avoid high import taxes at the port. It may be cheaper to buy a large number of magnets in one go.

Magnet adhesive:

A strong metal epoxy is required to stick the magnets to the magnet rotor plate.

Supplier: Any good hardware store, ACE Hardware, DIY, Handyman, etc.

Cost: P100

Composite materials:

All of the composite materials were purchased from Polymer Products at distribution shop 372 Commonwealth Avenue, QC. 433 3588. Head Office is In

Pasig, 671 9837-39, 671 2773-74. See the 'Blade Manufacture Guide' for a description of all the composite materials. All the composite materials used for the rotor are also used in the stator, blades and nose cone – this should be considered when purchasing the materials.

Resin Type 'R 10-03':

Amount required: 700g

Cost: P507 / 4kg container.

Talcum powder:

Amount required: 700g

Cost: P200 / 3kg container.

Hardener

Amount required: Small quantity

Cost: P140 / pint container.

Cobalt

Amount required: Small quantity

Cost: P129 / Litre container.

Lowilite

Amount required: Small quantity

Cost: P350 / 100g container.

Durawax

Amount required: Small quantity

Cost: P260 / Litre container.

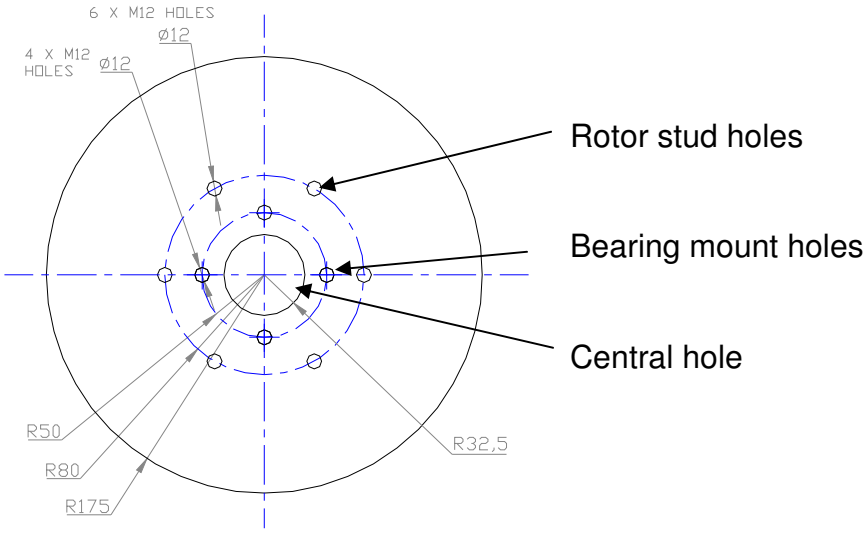
Chopped strand fibre glass mat (CSM) 300gsm

Amount required: 14" x 28"

Cost: P120 / kg.

Magnet rotor plate fabrication

AutoCAD drawings are available for the front and rear magnet rotor plates (see CAD drawings/Magnet rotor disks). The rear magnet rotor disk is shown in this diagram.



The large central hole is to allow the rear magnet plate to site flat on the bearing flange - it is also useful to have it on the front magnet plate. The hole can be made with a holesaw (or a laser if available). If the cost of making the central hole is very high it is possible to manage without the hole. Instead of the rear rotor plate being tight against the bearing flange it would have to be separated by 2-3 nuts on the bolts to avoid the bearing cap interference.

The 4 bearing mount holes are only required on the rear magnet plate. They should match the holes on the flange of the bearing exactly. When making the mount holes, the holes on the bearing flange should be used as a guide to ensure accurate positioning. The disk should be centred on the bearing flange before drilling the bearing mount holes. Fit the rear magnet plate onto the bearing and revolve the bearing to check for correct centring. Prop a ruler of piece of wire close to the edge and adjust the position until the plate runs true.

The 6 rotor stud holes and are present in both disks – they hold the two rotor disks and blade assembly together, 2 rotor studs pass through each blade root. (Only 4 rotor studs at a smaller diameter are used with the 500W design. Using an additional 2 studs at a greater diameter reduces the potential misalignment between the two rotor disks and improves the positioning of the holes in the blade roots). When drilling the 6 rotor stud holes it is critical that the holes are in exactly the same position on each magnet rotor plate – to ensure this the 2 plates should be clamped together when the holes are drilled.

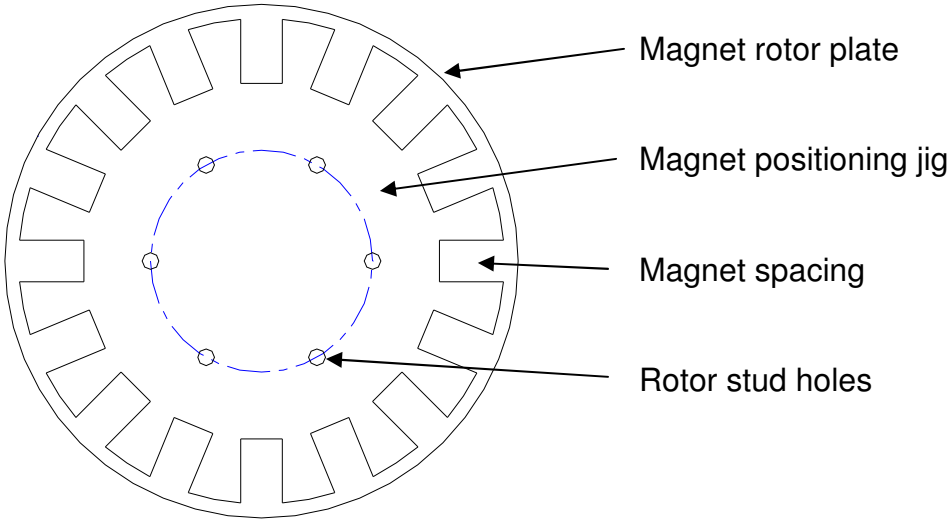
In the front plate there are 4 tapped holes to fit an M12 bolt (drill a 10.5mm hole to tap for M12). These holes are used to jack the front rotor disk on and off the PMG (necessary because the forces pulling the magnet rotor disks together is very large.

An index mark (eg. a small notch or an index hole) should be added to each rotor plate to mark the correct orientation relative to one another.

Magnet positioning

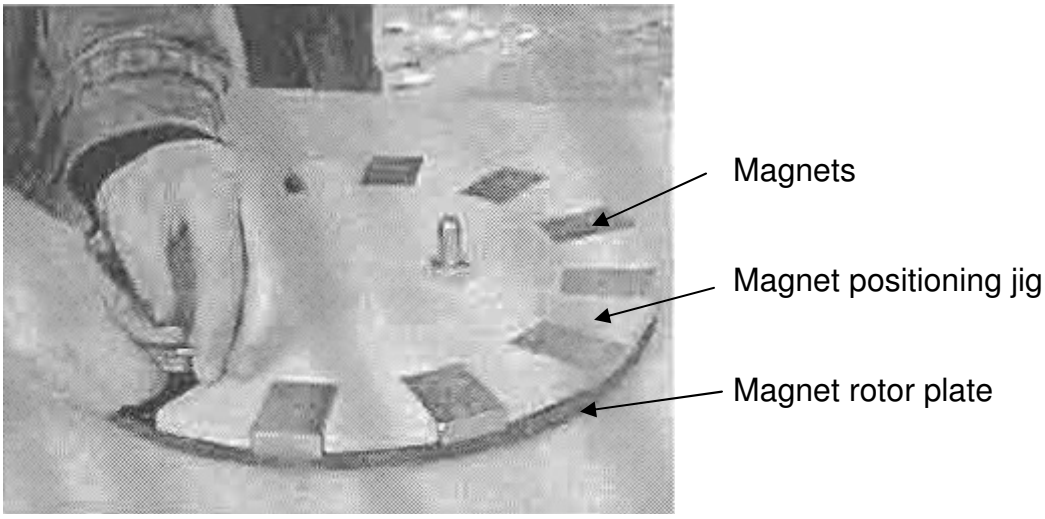
The 16 magnets are glued to the magnet rotor plate before the assembly is encapsulated in the resin / fiberglass mix. A magnet positioning jig is required for this purpose.

The CAD drawing shows a top view of the magnet positioning jig positioned on the magnet rotor plate (however, not all the rotor stud holes are drilled on the magnet positioning jig).



The first step is to sand or grind any mill-scale off the area where the magnets will sit, and clean them to remove any grease. Then position the magnet positioning jig on one of the magnet rotor plates. Since there is only one magnet positioning jig the 2 magnet rotor plates will be done separately.

The photo shows the magnets being glued onto the magnet rotor plate (the photo is of the 500W which has only 12 magnets).



Before gluing the magnets try a 'dry run' assembly. Take magnet blocks from the stock one by one, and place them onto the steel plate. Hold each block with both hands and slide it into place as far as possible before releasing it.

The magnet blocks need to alternate north-south-north around the circle, therefore each block has to be positioned the right way up.

Each time a magnet block is placed, hold it above its neighbour just previously placed. It should be repelled. If it is attracted, then turn it over and try again. If it is repelled then place it into its slot without turning it over again. This will ensure that it has different polarity from the previous block. Check all the magnets in position periodically with a magnet in your fist. Your fist should be alternately attracted and repelled as you progress around the circle. Hold on tight!

When you are happy with the positioning fix the magnets in place with the metal adhesive.

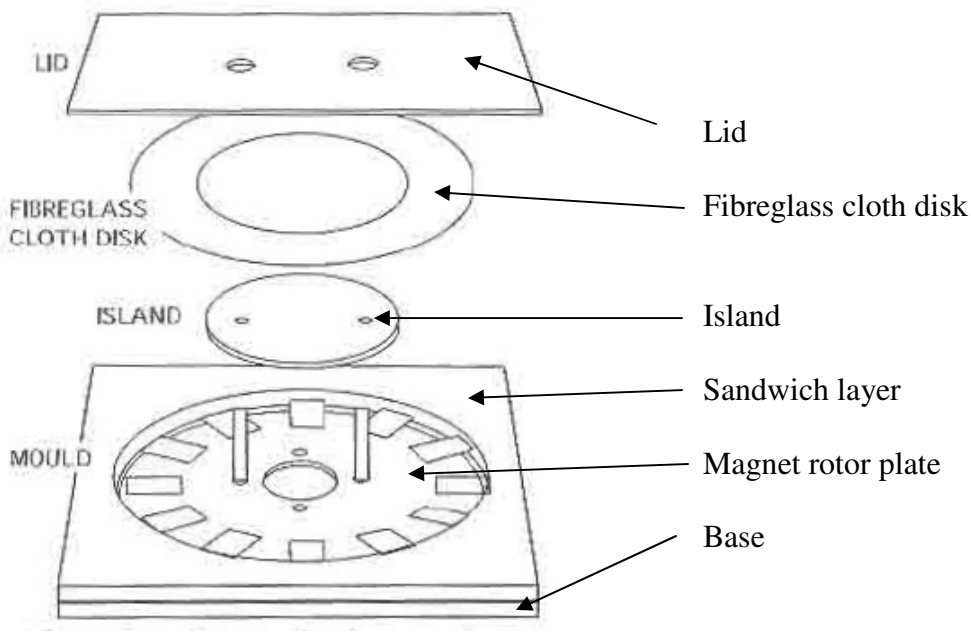
When the adhesive is dry and strong the magnet positioning jig can be removed and positioned on the other magnet rotor plate. **It is important the magnet positioning jig is in the same orientation for the 2 magnet rotor plates,** so that when the generator is assembled the pairs of magnets are aligned. This should be done by **comparing the magnet positioning jig and magnet orientation relative to the index mark,** on the magnet rotor plate. This is to ensure the rotor disks attract each other, if this is done incorrectly it may lead to large losses from the PMG.

When positioning the blocks you must ensure that **the pairs of magnets opposite each other are of opposite polarity.** This should be done by **comparing the magnet orientation relative to the index mark,** on the magnet rotor plate. This is to ensure the rotor disks attract each other, if this is done incorrectly the PMG will not work!

When you are happy with the positioning fix the magnets in place with the metal adhesive. When the adhesive is dry and strong the magnet positioning jig can be removed. You are now ready to cast the rotors.

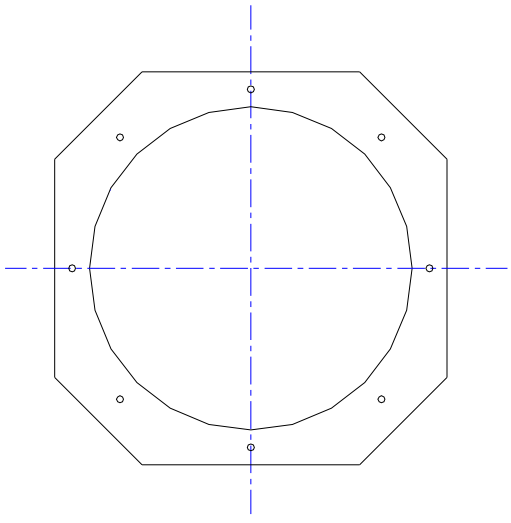
Casting the rotors

The diagram shows the assembly for the casting as in the Hugh Piggott book. The magnet rotor plate is placed in the mould with the island on top. The mould is then filled with a resin mix before placing the fiberglass disk on top. The lid is then bolted down and the resin is left to set. It will be quicker if both magnet rotor plates are cast at the same time.



SIBAT have fabricated aluminium rotor moulds for the casting of the rotor disks (see CAD drawings/Rotor mould). The mould consists of a base, sandwich layer, island and lid. 2 sets of moulds are available so the magnet rotor plates can be cast at the same time. Ensure the moulds are clean and smooth, and all the necessary bolts, nuts and washers are available. The rotor disks should be cast on a flat surface in a well ventilated area. Allow 2-3 hours for this task with a minimum of 2 people.

The SIBAT mould design, shown below, has a different profile to the Hugh Piggott design to make it more manageable. The base and lid have the same profile.



First cut out the 2 fibreglass cloth disks, 360mm diameter with a 210mm central hole.

Durawax needs to be liberally applied to any areas of the aluminium mould that will be in contact with the resin so it will not stick - this includes bolt holes, bolts, nuts, washers and between the mould layers where the resin will seep out. 3-4 layers of Durawax is sufficient.

Place the mould base and sandwich layer on a flat surface with bolts and washers in the holes, with the bolt heads under the base. Place the magnet rotor disks onto the mould base ensuring it is central and positioned on the 2 bolts. Place the island on top of the magnet rotor plate and bolt them down.

You are now ready to prepare the resin and cast the rotors.If you are using new or substituted composite products it may be worthwhile to do a test run first with a small amount using the suggested proportion. This will give you confidence the mix will cure properly, not curing too fast and cracking or failing to cure at all – bearing in mind the high cost of the magnets and steel plate.

2 resin mixes are required to cast the rotor disks, a main body casting and a surface layer on the front face of the rotor disk. The casting resin mix and amounts for 1 rotor disk are given in the following table. It is very important the resin is mixed thoroughly – an electric mixer was used with the whole batch. If this is not available you should do it in 2 or 3 batches and mix thoroughly by hand.

Batch	Resin type	Cure time	Cobalt (%)	Talcum powder (%)	Hardener (%)
Casting	10 03	1.5 hrs	0.3	100	0.5

	Resin (g)	Cobalt (mL)	Talcum powder (g)	Hardener (mL)
Amount	600	1.8	600	3

When the resin is well mixed it can be poured into the mould. Pour the mix around the outside of the disks so as to fill the space without bubbles. Take care to avoid trapping air in the space around the edge of the steel disks. Use vibration to dislodge the bubbles and settle the resin mix.

The casting resin mix should be level to the top of the magnets but avoid going onto the top.

You can now mix the surface layer according to the table below - again take care to mix well. Paint the resin onto the top magnet surface then lay the fibreglass cloth disks on top, taking care to centralise them. Then add the remaining surface layer resin to the top of the fibreglass cloth to consolidate the cloth. Use a stippling action but be careful not to disturb the resin underneath. Beware of the magnets pulling on the brushes.

Batch	Resin type	Cure time	Cobalt (%)	Lowilite (%)	Hardener (%)
Surface	10 03	1.5 hrs	0.3	0.5	0.5

	Resin (g)	Cobalt (mL)	Lowilite (mL)	Hardener (mL)
Amount	100	0.3	0.5	0.5

Once the fibreglass cloth has been consolidated with resin the aluminium lid should be put on. Tighten the nuts down on the top of the lid, not forgetting the washers. Resin will seep out of the hole in the lid and between the layers of the mould. Once the nuts have been tightened heavy steel objects can be added to the lid to squeeze the resin layer to a minimum.

Wait a minimum of 12 hours before removing the rotor disks from the mould so the resin has chance to fully harden. Take care when removing the disks from the moulds, do not use violent blows to release the casting in case you break the resin or a magnet. A good technique is to hold the mould upside-down and tap the mould upwards, so that it does not fall hard. Cut off the rags of resin.

Wrap the rotor disks in newspaper and place somewhere safe where steel objects will not be attracted. The rotor disks should be painted before being installed.

Clean the resin off all the mould parts and nuts and bolts in preparation for the next rotor disk casting.