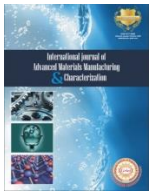

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Advanced Composite Micro-Hydro Turbine Wheel Design and Study Its Performance for Power Generation

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ABSTRACT

Recently, Advance composite materials have taken the significant share with other engineering materials due to its mechanical properties and high strength to weight ratio. Advance composite like Carbon fibre, woven roving, chopped strand mat, are not confined at the aerospace industry but gradually these are taking over the position of other industries as well. Micro-hydro power turbines are an attractive option for providing electricity in off grid areas of the country and a good alternative energy source for production of energy. The simple pelton and cross-flow turbines are predominantly used for these projects as they are cheaper to construct for this form of renewable energy. Pelton wheel is a most efficient impulse turbine for medium and high head hydro sites. It is general practice to use brass/aluminium or some time stainless steel for the construction of Pelton wheel buckets. Making some changes and improvements to the existing design we can use these micro turbines at the water pumps where the pressure in the water is not used. This can ensure that more households in the catchment area get more than just lighting, but are able to use other devices such as refrigerators, stoves etc., in their houses. Manufacturing buckets with Advance composite materials is not yet common though it is light, durable and corrosion resistant. In this paper endeavour has taken to design and fabricate a micro-hydro turbine wheel where runner and seven buckets have been designed and developed after careful analyzing the various parameters of Composite design criterion. Woven rowing, Chopped Glass fibres have been used as reinforcing fibres with polyester matrix for bucket design and manufacturing.

1. Introduction

A Composite Material is a materials system composed of a mixture or combination of two or more micro- or macro-constituents that differ in form and chemical composition and which are essentially insoluble in each other. Composites involve two or more component materials that are generally combined in an attempt to improve material properties such as stiffness, strength, toughness, etc.; the resulting properties are largely dependent on the distribution, relative amounts and geometries of the constituents. Composites are considered to be combinations of materials differing in composition or form on a macro scale. The constituents retain their identities in the composite; that is, they do not dissolve or otherwise merge completely into each other although they act in concert. Normally, the components can be physically identified and exhibit an interface between one another [1] Fibre-Reinforced Composites often aim to improve the strength to weight and stiffness to weight ratios (i.e. desire light-weight structures that are strong and stiff!). Fibres are available in 3 basic forms:

(i) Continuous fibres are long, straight and generally layed-up parallel to each other.

(ii) Chopped Fibres are short and generally randomly distributed (fibre glass).

(iii) Woven Fibres come in cloth form and provide multidirectional strength.

Yuji et al [8] developed a hydraulic turbine to utilize unexploited water resources as nano hydropower, they proposed newly–designed impulse turbine with the simplest components of the minimum requirements.

In this present work we develop the procedures to design and fabricate a prototype of micro-hydro turbine test assembly to generate energy and the procedure includes designing the turbine wheel with advanced composite materials and fabricating components of a complete wheel i.e. designing bucket & runner.

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For designing the buckets and runner of the wheel chopped strand mat and woven roving of glass fibre have been used with polyester resin as matrix by hand lay-up technique. In this system we have a wheel arrangement on which the blades are arranged and a shaft is connected to the wheel and the generator (Dynamo), connections are given to the battery and measure the power generated. This arrangement is very much useful in off-grid areas.

2.0 Methodology

Designing a micro-hydro turbine wheel with advanced composites and studying its performance involves the following sequential steps:

- Data accusation for turbine wheel design modelling using solid works.
- Design and manufacture of buckets.
- Design of runner wheel and fixation of buckets to its periphery.
- Assembly and Installation of the equipment.

3.0 Selection of Materials and its Properties

For any fibre composite two main constituents are essential one/more fibre and matrix. Normally for advanced composite thermo set or thermoplastic resins are used particularly thermo set resin polyester is used as matrix.

Table 1: Typical physical properties of Glass Fibres

Properties		**CSM**	**WR**
Glass content	% weight % volume	30 18	45 29
Specific gravity		1.4	1.6
Tensile Strength	Mpa	100	120
Tensile Modulus	Gpa	8	15
Compressive Strength	Mpa	150	150
Bend Strength	Mpa	150	250
Modulus in Bend	Gpa	7	15
Impact strength, Izod, Unnotched	KJ/m^2	75	125
Coefficient of linear Expansion	$x10^{-6}/^0c$	30	15
Thermal Conductivity	W/mK	0.20	0.24

CSM - Chopped Strand Mat
WR - Woven Roving

Basing on the properties of the fibres and matrix and the following points may be considered for the design and manufacturing the final product such as selection of fibre, matrix and fibre and resin volume fraction, Considering the manufacturability, ease of fabrication, availability, cost of the raw material, bonding strength, load what has to withstand by the product, life cycle of the composite, strength to weight ratio etc. constituents of the composite need to be selected.

Fibres used:

Chopped strand mat*:* CSM is a form of reinforcement used in fibreglass. It consists of glass fibres laid randomly across each other and held together by a binder. It is typically processed using the hand lay-up technique, where sheets of material are placed in a mould and brushed with resin. Because the binder dissolves in resin, the material easily conforms to different shapes when wetted out. After the resin cures, the hardened product can be taken from the mould and finished. Using chopped strand mat gives fibreglass with isotropic in-plane material properties.

Fig 1: Chopped strand mat

Woven roving: Woven roving is made from continuous glass fibre roving which are interlaced into heavy weight fabrics, compatible with most resin systems. Used in most cases to increase the flexural and impact strength of laminates. Ideal for multi-layer hand lay-up applications where great material strength is required. Good driveability wet out and cost effective. With Woven Roving as a general rule estimate the resin/reinforcement ratio at 1:1 by weight. Woven Roving is available in a variety of weaves, weights, widths and finishes to suit a wide range of applications.

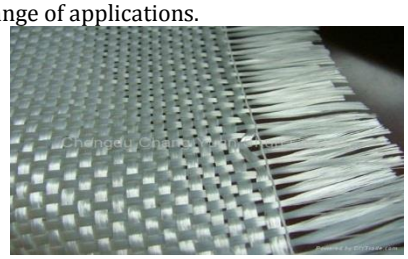


Fig 2: Woven roving

Matrix used:

Resin: Typically, most common polymer-based composite materials, including fibreglass, carbon fibre, and Kevlar, include at least two parts, the substrate and the resin. Polyester resin tends to have yellowish tint, and is suitable for most backyard projects. Its weaknesses are that it is UV sensitive and can tend to degrade over time, and thus generally is also coated to help preserve it. It is often used in the making of surfboards and for marine applications. Its hardener is peroxide, often MEKP (methyl ethyl ketone peroxide). When the peroxide is mixed with the resin, it decomposes to generate free radicals, which initiate the curing reaction. Hardeners in these systems are commonly called catalysts, but since they do not re-appear unchanged at the end of the reaction, they do not fit the strictest chemical definition of a catalyst.

Catalyst: Catalysts are added to the resin system shortly before use to initiate the polymerisation reaction. The catalyst does not take part in the chemical reaction but simply activates the process. Methyl Ethyl Ketone Peroxide (MEKP) is used as catalyst in this process.

Accelerator: It is a chemical substance that increases the speed of a chemical reaction. In this process we use cobalt as accelerator. Cobalt accelerator with 2% and 6% Cobalt content helps Catalyst (MEKP) 50% in Polymerization of Unsaturated Polyester Resins.

4.0 Fabrication of Runner and Buckets

This fabrication is done by hand lay-up process. Hand lay-up is the method of cutting lengths of fibre reinforcement off of rolls. The reinforcement most often comes in the form of chopped fibre, woven fibre, or stitched fibre. Once a layer is placed in the mould, resin is applied either by pouring on by hand, or it can be sprayed on with a mixing gun. The layers are consolidated and air bubbles are removed by using squeegees and hand rollers.

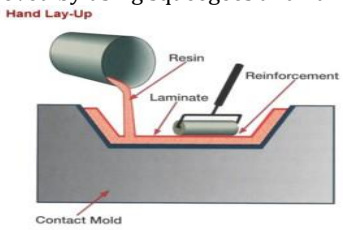


Fig 3: Hand lay-up method

The mould is applied with wax poll such that during the release of the piece there does not be any problem of blow holes or air gaps. And later it is cleaned using cotton, and after cleaning poly vinyl alcohol is applied so that the laminate is removed without any difficulty. Firstly, on the prepared mould chopped strand mat (0.75mm) is placed and PV resin which is mixed with cobalt accelerator and MEKP catalyst is applied on the CSM and rolling is done by using a roller such that air gaps are avoided .Later after the rolling is done woven roving (0.45mm) is placed and similar steps are followed, this is continued for 7 to 8 layers of each CSM and roving but the initial and final one should be CSM. The prepared laminate is allowed for curing for 5 to 6 hours .and later it is grinded to get a good surface finish. Similarly buckets are also fabricated using this hand lay-up method in these four layers of CSM (0.75mm) and three layers of woven roving (0.45mm) are used.

Fig 4: Fabricated runner with buckets by composite materials

5.0 Installation of Equipment:

Shaft: A solid or hollow cylinder or bar, having one or more journals on which it rests and revolves, and intended to carry one or more wheels or other revolving parts and to transmit power or motion.

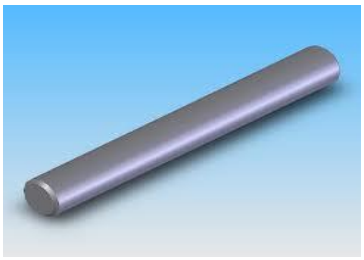


Fig 5: Shaft

Bearings: Bearings are used to compell relative motion and reduce friction between moving parts.

Fig 6: Bearing

Belt Drive: Here shaft is connected to the runner and fly wheel with the help of bearings for the free moment of the shaft and also to reduce the friction between the runners and fly wheel. We use a belt drive mechanism in which power is transmitted by the movement of a continuous flexible belt.

Fig 6: V-Belt Drive

Dynamo: The smaller pulley of this belt drive is connected to a dynamo which is a machine for converting mechanical energy into electrical energy, typically by means of rotating coils of copper wire in a magnetic field. This dynamo is connected to a battery in which the power generated by this dynamo is stored.

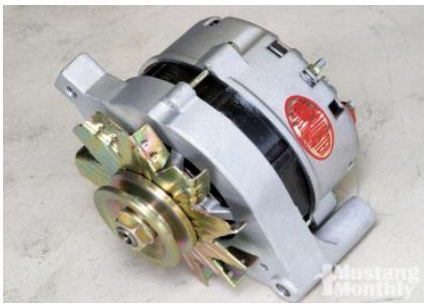
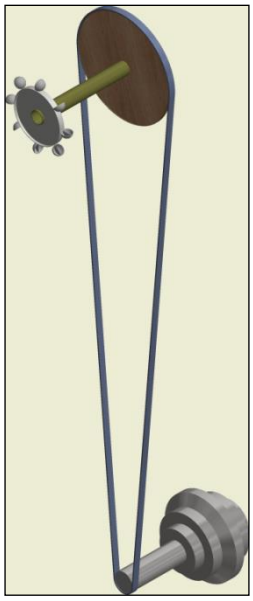


Fig 7: Dynamo



CAD Model of the Assembly: In this system we have a wheel arrangement on which the blades are arranged and a shaft is connected to the wheel and the generator (Dynamo) by means of v-belt drive, this dynamo is connected to a battery, in which the power generated by this dynamo is stored and use the power measuring device to measure the generated power.

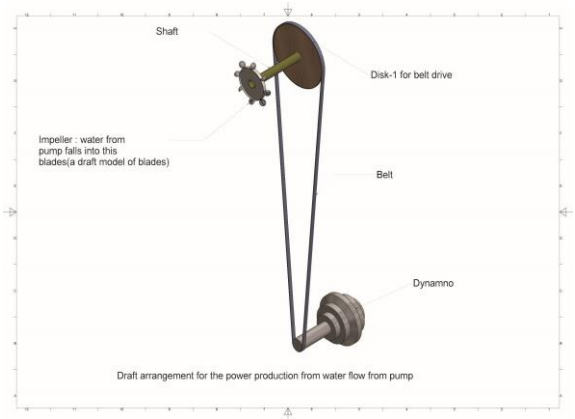


Fig 8: CAD Model of the Micro-Hydro Turbine

6.0 Results

When the water from the pump falls on the buckets of the runner which rotates with certain speed and the power is transmitted to the pulley by means of shaft from the runner. This pulley by means of v-belt is connected to the alternator. This alternator is in turn connected with the battery such that the power generated is stored in the battery.

Fig 9: Prototype of the Micro-Hydro Turbine

Conclusion

Designing a miniature model of hydraulic turbine with advanced fibres is a challenging task, proper selection of fibres and matrix materials and following proper ply orientation, a composite become a one of the strongest and high property material for making turbine wheel can be effectively use at corrosion enriched water site where metal wheel may eroded quickly and operation and maintenance will be challenging. In this paper we develop the procedures to design and fabricate a prototype of micro-hydro turbine test assembly to generate energy. By using this kind of equipments we can produce electricity in off grid areas by using the pressure of the water.

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