Fabrication of light weight farms yoke with the use of composite material

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Abstract: Natural fibers are subdivided based on their origins, coming from plants, animals or minerals. All plant fibers are composed of cellulose while animal fibers consist of proteins (hair, silk, and wool). Plant fibers include bast (or stem or soft sclerenchyma) fibers, leaf or hard fibers, seed, fruit, wood, cereal straw, and other grass fibers. Over the last few years, a number of researchers have been involved in investigating the exploitation of natural fibers as load bearing constituents in composite materials. The use of such materials in composites has increased due to their relative cheapness, ability to recycle and for the fact that they can compete well in terms of strength per weight of material. Natural fibers can be considered as naturally occurring composites consisting mainly of cellulose fibrils embedded in lignin matrix. The cellulose fibrils are aligned along the length of the fiber, which render maximum tensile and flexural strengths, in addition to providing rigidity. The reinforcing efficiency of natural fiber is related to the nature of cellulose and its crystallinity. The existing traditional yoke is made up of the wood of trees like Tun and Haldu which are not easily available in different parts of India. The life of a yoke is about three to five years, due to this 628 t of wood is required at every three to five years in India that would create a burden to the presently available forests. To overcome these problems, there is a need to develop yoke from waste bio-materials. Keeping this in view, a yoke from composite material was designed and developed and relative comparison between traditional wooden and developed yoke has been done.

Keywords: composite material, fibers, yoke

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1 Introduction

Agriculture in hills of Uttarakhand is bestowed with mixed farming system. Hill agriculture has scarcity of resources particularly in terms of land, water, technology, mechanization and transportation. The small and fragmented land holding, lack of proper media for dissemination of agricultural information and low investment capacity of farmers are the major reasons for low productivity of different crops. Crop cultivation is still being undertaken with the help of primitive hand tools and animal drawn implements. The tillage operations are performed by age old wooden plough locally called ‘Nasuda’. The major source of carriage power still is the animals. The major constraints in mechanization of hill agriculture are undulated and terraced land as well as small and fragmented land holdings.

Several factors by using the draft animals influence the efficiency; those include the use of correct harness and yoke and equipment, and matching animals in a fit and healthy condition. The use of poorly designed yokes and harnesses cause inefficient transfer of power from animal to the implement. Improper hitching requires the animals to exert a greater tractive effort than

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is actually needed to overcome implement draft.

The most common type of yoke is shoulder yoke which besides being inefficient can also be cruel to draft animals. Ramaswamy (1979) gave many illustrations on the types of suffering inflicted on draft animals by this type of device. It was found that when an uncomfortable yoke is used, a 380 kg steer was willing only to pull a load of 30 kg. But when the yoke was padded with foam rubber, it willingly pulled 50 kg load. This indicates that the pulling capability of animals may be enhanced by proper design of yoke and harnesses.

These days, yokes are developed by using of locally available woods like Haldu and Tun etc. About 0.7 million bullocks are being used as draft animals in Uttarakhand. If 60% (approx.) of total population of bullocks is being used as to carry out different agricultural operations in pair, it means 0.21 million (approx.) wooden yokes are required to perform different agricultural operations. If average volume of wood to make a yoke is 6,500 cc (130 cm×10 cm×5 cm), then 1,360 m^3 amount of wood is required to fulfil the total demand of Uttarakhand. The life of a yoke is about 3-5 years depending upon the wood material and type of use. This result shows that 628 t of wood is required at every 3-5 years that would create a burden to the presently available forests. So keeping above points in view, it is important to develop a material from the waste bio-material to replace wood effectively. Hence, the composite material has been selected to study as an alternative material for manufacturing of yokes.

Polymeric materials reinforced with synthetic fibers such as glass, carbon, and aramid provide advantages of high stiffness and strength to weight ratio as compared to conventional construction materials, i.e. wood, concrete, and steel. Despite these advantages, the widespread use of synthetic fiber-reinforced polymer composite has a tendency to decline because of their high-initial costs, their use in non-efficient structural forms and most importantly their adverse environmental impact. On the other hand, the increased interest in using natural fibers as reinforcement in plastics to substitute conventional synthetic fibers in some structural applications has become one of the main concerns to study the potential of using natural fibers as reinforcement for polymers. In the light of this, researchers have focused their attention on natural fiber composite (i.e. bio-composites) which are composed of natural or synthetic resins, reinforced with natural fibers. Accordingly, manufacturing of high-performance engineering materials from renewable resources has been pursued by researchers across the world owning to renewable raw materials are environmentally sound and do not cause health problem.

In the present work fiber reinforced epoxy composites are used. It further outlines a methodology based on Taguchi's experimental design approach to make a parametric analysis of erosion wear behavior. The systematic experimentation leads to determination of significant process parameters and material.

2 Theory

2.1 Yokes and harnesses

Yokes and harnesses are the methods of attaching the animals to the implements. There are many types of yokes and harnesses depending on the tradition of the farmers, type of animal used, the number of animals used and the type of work to be done. The attachment consists of a yoke or a harness (which receives the power directly from the animal) and the linkage which receives the power from the yoke or harness and transfers it to the implement. Different types of harnesses utilize the strength of animals to varying degrees; hence their improvement could lead to an increase of the quantity and quality of work as well. The comprehensive review of various types of yokes and harnesses has been done by Vaugh (1947), Hopfen (1960), Rao (1964), FAO (1972) and Devnani (1981).

Pant hill yoke was developed by department of farm machinery and power engineering, college of technology G.B. Pant University of Agriculture and Technology for hill bullocks. The body weight of hill bullocks ranged between 200-350 kg. On the basis of the body weight the bullocks are categorized into two groups. To suit these categories of animals, two types of yokes were developed. The Tun and Haldu wood is used for manufacturing the hill yokes. This wood is commonly available in Uttarakhand. The basic property of Tun and

Haldu is lighter in weight and high in strength. The dimensions of Pant hill yoke are 1,280 mm×90 mm×43 mm (Figure 1). The cost of hill yoke is Rs. 450.

Figure 1 Pant hill yoke

2.2 Composite material

Natural fibres can be easily obtained in many tropical and available throughout the world. Today these fibres are considered as environment friendly materials owing to their biodegradability and renewable characteristics. Natural fibres such as sisal, jute, coir, oil palm fiber have all been proved to be good reinforcement in thermo-set and thermoplastic matrices (Varma et al., 1989; Joseph et al., 1996). Nowadays, the use of natural fibres reinforced composites is gaining popularity in automotive, cosmetic, and plastic lumber applications because it offers an economical and environmental advantage over traditional inorganic reinforcements and fillers (Murali and Mohana, 2007). However, plastics alone could not provide enough strength for structural applications. Reinforcement was needed to provide the strength, and rigidity.

Fiberglass, when combined with a plastic polymer creates an incredibly strong structure that is also lightweight. This is the beginning of the Fiber Reinforced Polymers (FRP) industry as we know it today. It appears from the past work that the composite material can be used for replacement of wooden component of exiting agriculture implements and equipments however this present work is taken to develop yoke for hill bullocks by using composite material.

3 Material and methodology

This section describes about the material used in casting of hybrid composite, their physical properties and chemical properties etc. In this section, the method used to determine the mechanical, physical properties are also discussed.

3.1 Material

3.1.1 Matrix material

3.1.1.1 Resin

Resin is widely used in industrial application because of their high strength and mechanical adhesiveness characteristic. Araldite is a liquid solvent free resin. It has versatile applications in technical and industrial applications. Curing takes place at room temperature and atmospheric pressure after addition of hardener. Cure shrinkage is generally very less and may be still further reduced by the addition of fillers such as silica flour, china clay etc. The resin can be coloured easily. Fully cured mixture has excellent mechanical, electrical properties and highly resistant to chemical and atmospheric attack. The castings have good ageing characteristics. It is odourless, tasteless and completely non-toxic. Resin can be stored for at least a year if they are stored under cool, dry conditions in the original containers.

3.1.1.2 Hardener

Hardener is a yellowish-green liquid. Hardener has been used as curing agent in the industries. In the present investigation, optimized volume of hardener has been used in all material developed.

3.1.2 Reinforcing element

Reinforcing agents are added to the resin to improve the mechanical strength and wear properties. Some of the reinforcing agents such as silica, glass wool, jute ply, M.S. wire mesh etc. are used as reinforcing agents to improve the different properties of the composites material.

3.1.2.1 Silica

Induction of silica in the matrix hybrid material has been taken into consideration. Silica particles improve the mechanical properties significantly. Silica flour is directly mixed in resin and stirred mechanically.

3.1.2.2 Glass fibre

Glass fibre is produced in rolls or in slabs, with different thermal and mechanical properties. Glass wool is taken as a binding material for enhancing the adhesive property of the models. After certain layers of jute net, a single layer of glass wool has been introduced. This layer remains in sand-witched form in between two sets of jute layers.

3.1.2.3 Jute net

Jute net is a biodegradable matting manufactured from jute fiber. It is light in weight and widely used for housing and commercial purposes. It is considered as a waste material which is a key component here for developing a yoke.

3.2 Method

The solution obtained by mixing silica and resin is remixed by mechanical stirrer at high speed (recommended) at a room temperature. When mixing is done properly the hardener is mixed immediately. Due to addition of hardener high viscous solution has been obtained which is again mixed mechanically by high speed mechanical stirrer (recommended). The viscous solution so obtained is poured in to different moulds of yoke. The mould is prepared of first lubricating material (grease) is put into the inner surface of moulds so as to avoid the contact between solution and mould surface, then after a single layer of glass wool is introduced into the mould, after adjust it properly solution is thus pour on the surface of it. Once glass layer thoroughly dip into solution, four layers of jute net is set over it and fill solution between each layer of jute net so as each layer absorbs solution and get adhered with each other for imparting the desired strength. This process is repeated until reaches to the recommended ply rating. Rest solution is then poured on the upper surface of the mould and is left it for being dried up. This whole process is carried out at room temperature. The prepared composite yoke model is shown in Figure 2. The constituent in the different materials are given in Table 1.

Figure 2 Prepared composite yoke model

Table 1 Constituent of different model yokes

Type of treatment	Constituent				
	Jute net (Number of plies)	Glass wool (Number of plies)	Wire mesh (Number of plies)	Silica (Weight %)	Hardener (Weight %)
T_1	12	4	….	4	2
T_2	12	4	….	10	2
T_3	12	4	….	16	2
T_4	16	5	….	10	2
T_5	12	4	3	10	2
T_6	Wooden yoke				

4 Result and discussion

4.1 Properties of Materials

The Study was conducted for standardizing different parameters for development of yoke of composite material. The mechanical properties such bending, tensile and compressive strengths of different composite material were evaluated and compared. The results of different mechanical properties of various composite materials measured and their analytical interpretation are presented in this section (Table 2). Effect of silica percentage and the number of plies variations had been taken into account then different tests had been conducted on the different models (T_1, T_2, T_3, T_4, T_5 and T_6).

It is clear from the Table 2 that the tensile strength of sample T_6 which is made up of wood has considerable tensile strength as compared to the other samples. Wood is fibrous in nature that delivers significant tensile strength to the yoke. Sample T_1 has half of tensile strength than the T_6, but sample T_3 had shown strength almost close to sample T_6 that suggests silica percentage must fix in between 4% and 16%. In sample T_2 tensile strength was found more than sample T_6. Thus introducing 10% silica into model T_2 provides more strength as compared to model T_6, hence model T_2 proves itself more suitable model rest of others.

Table 2 Mechanical properties

Material Properties	Tensile Strength /MPa	Compressive Strength/MPa	Bending Strength / N-m	Density /g・cc^{-1}
T_1	15.7	156.4	41	1.11
T_2	24.5	167.7	32	1.11
T_3	21	135.5	26	1.24
T_4	26	169.4	44	1.21
T_5	19.2	138	37	1.33
T_6	22.1	111.5	13	0.72

The compressive strength of models T_2, T_4, T_5 and T_6 were found 167.7, 169.4, 138.0 and 111.5 N mm^{-2} respectively for 10% silica (Table 2). It is also clear from the Table that the value of bending strength for T_2, T_4, and T_4 was 1.5 times, 1.6 times and 1.2 times higher than T_6. From the Table, it is evident that more plies imparts more strength to the model however T_5 has been made up of taking wire mesh together with cellulose material, but strength was not increased considerably as compared to the yoke T_4 of 16 jute plies. In addition to it, wire mesh plies were increasing undesired weight of the yoke.

After optimizing the silica up to 10%, tests were performed for analyzing the effect of ply on bending strength with intention behind increasing more strength. The bending strength of models T_2, T_4, T_5 and T_6 were found 32, 44, 37 and 13 N mm^{-2} respectively at 10% silica (Table 2). It is also clear from the Table that the value of bending strength for T_2, T_4, T_5 are 2.5 times, 3.4 times and 2.8 times higher than T_6. From the Table, it is evident that more plies impart more strength to the model however T_5 has been made up of taking wire mesh together with cellulose material, it is observed that strength is not increased considerably as compared to the yoke of more plies i.e. T_4. In addition, it was increasing undesired weight of the yoke.

4.2 Optimization of constituent of the yoke materials

4.2.1 Hardener

When mixing of silica and resin is done properly the hardener is mixed immediately. Due to addition of hardener high viscous solution has been obtained which is again mixed mechanically by high speed mechanical stirrer (recommended). Less quantity of hardener is caused slow reaction rate and stickiness is observed on the surface of the models whereas more quantity is caused fast reaction rate, since mixing of hardener is an exothermic reaction so more quantity causes abrupt heat releasing which is resulted as cracks formation on the surface of yokes. So it has been optimized to 2 WT % and found more satisfactory.

4.2.2 Silica

On the basis of reported results 4, 10 and 16 WT %, silica is selected as filler weight percentage to form the hybrid composite material 10% W/V silica has been observed more efficient for developing a composite yoke.

4.2.3 Jute net

Jute net is light in weight and is considered as a waste material which is a key component here for developing a yoke. It is also clear from the table that varying the number of plies effect significantly on the mechanical properties. From the above Tables and Figures, it is evident that more plies impart more strength to the model.

4.3 Cost analysis

The cost analysis of designed yoke is given in Table 3. The Table shows that the cost of recommended composite material yoke is about Rs.325 whereas the cost of existing Pant hill yoke is about Rs.450. The cost of designed yoke is 27% less as compared to Pant hill yoke.

Table 3 Cost analysis of the developed yoke (T_4)

Jute net		Glass wool		Silica		Resin		Hardener		Net cost /Rs.
Mass 6.1g ply^{-1}	Rate Rs. 40 kg^{-1}	Mass 13.9 g ply^{-1}	Rate Rs. 140 kg^{-1}	Mass /g (10% of total)	Rate Rs. 25 kg^{-1}	Mass /g (85% of total)	Rate Rs. 90 kg^{-1}	Volume /ml (2% of resin)	Rate Rs. 90 lit^{-1}	
97.6	3.90	69.5	9.73	358.45	8.96	3312	298	34.93	3.14	324.6

5 Conclusions

On the basis of above all studies, it is found that the newly designed yoke of composite material (T_4) with using resin (87 WT %), silica (10 WT %), 16 numbers of jute net plies (2.5 WT %), 5 numbers of glass wool plies (1.75 WT %) is suitable for sustaining the momentary force of 30% equivalent to body weight of bullock. However Pant hill yoke having dimensions of 1,280 mm × 90 mm × 43 mm is less than calculated value of dimensions at 30% force equivalent to body weight of bullock.

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