INTROP: Highlight

Natural Fibers: The New Fashion of Modern Plastics Products

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INTRODUCTION

The utilization of biomass has gained increased importance due to threats of uncertain petroleum supply in the near future and concerns about environm pollution. Natural fiber composites are undergoing a high tech revolution and are replacing conventional composites in high performance applications d their advantages over conventional reinforcements. The annual global disposal of millions of tones of plastics, especially from packaging, has raised the der for means of managing this non-biodegradable waste. The use of biofibers in a thermoplastic matrix provides positive environmental benefits with res to disposability and raw material utilization. Since biofibers are relatively less expensive and biodegradable, biocomposites from biodegradable polymer render a contribution in the twenty-first century. Most sustainable plastics cannot compete economically with conventional petroleum-derived plastics in present state. Economically favorable composites, therefore, are expected to be made from costly sustainable plastics in combination with inexpensive na reinforcement fibers. Cellulosic materials are the most abundant form of biomass and the form most likely to be used as reinforcement fibers, not onl ecological and economical reasons, but also because of their high mechanical and thermal performance. To utilize and design materials successfully for indu applications, it is first imperative to determine material properties that will affect performance.

ENVIRONMENTAL BENEFITS OF USING NATURAL FIBER-REINFORCED THERMOPLASTICS

The primary environmental advantages of using natural fiber-reinforced thermoplastic are as follows:

- Biodegradability
- reduction of greenhouse gas emission
- enormous variety of structural fibers available throughout the world
- creation of job opportunities in rural areas
- development of non-food agricultural/farm-based economy
- low energy consumption
- low cost
- low energy utilization.

Using agricultural materials as raw materials for making composite products provides a renewable resource as well as generating a non-food source of economic development from farming and rural areas. Also, use of renewable fibers in the composites produces an overall CO_2 balance, as the amount of CO_2 taken up during their growth is matched (apart from the efforts necessary to grow and harvest the fibers) by the CO_2 released during their disposal, i.e. either by burning or by rotting. Replacing conventional fibers based on petroleum resources with natural fibers reduces the greenhouse emissions considerably. The amount of energy required for the product of natural fibers is less than that of glass fibers. Moreover, their lo density (>40%) compared to glass fibers leads to fuel-efficient product of composite products, especially in automotive applications: this, in t leads to a reduction in greenhouse gases[1]. The carbon sequestration storage potential of hemp-based natural fiber mat thermoplastic compos has been estimated to be about 325 kg carbon per metric tonne during t useful lifetime[2]. A net carbon sequestration of 0.67 ton/ha/yr was estima for a composite containing 65 wt % of hemp fiber. It has been found t replacing 30% glass fiber with 65% hemp fiber in thermoplastic compos produces a net saving of energy consumption of 50 000 MJ (about 3 ton emission) per ton of thermoplastic. Also, by substituting 50% of the g fiber by natural fiber in automotive applications, 3.07 million tons of carb dioxide emissions and 1.9 million m^3 of crude oil can be saved.

RECYCLING ASPECT OF COMPOSITES

Natural fiber-filled thermoplastic composites are easier to recycle than conventional mineral-based fiber filled thermoset composites. This is due the less brittle nature and softer texture of the fiber and the processibility of the thermoplastic. Unfortunately, not much literature is available regarding the recycling of post-consumer products. The repeated process of injection molding and granulation and the influence of this process on the mechanical properties of wood fiber-filled composites have been studied by Sain and Balatinecz (1997)[3]. The properties of the composites after reprocessing three, six and eight times are given in Table 1[3]. The deterioration in the properties is due to fiber attrition and oxidative degradation of the PP matrix during the repeated grinding and injection molding processes.

Table 1. Properties of recycled wood fiber polyolefin composites

Number of recycling	Property	Polypropylene	30% wood fibre-filled PP	45% wood fibre-filled PP
0	Tensile strength (MPa)	28.76	38.00	36.77
3		26.31	33.08	29.38
6		27.00	31.38	31.08
8		26.00	30.46	–
0	Flexural strength (MPa)	40.5	60.67	65
3		34.67	54.33	59.67
6		40.67	60.33	53
8		38.33	53	–
0	Flexural modulus (GPa)	1.7	4.3	8.0
3		1.1	4.4	11.3
6		1.8	5.1	6.9
8		1.5	4.0	–
0	Melt flow index (g/10min)	11.04	1.46	10.00
3		16.25	1.88	12.71
6		24.80	3.13	7.50

FUTURE TRENDS

Owing to their renewability, worldwide distribution and recyclability, the market for these composites will be able to expand. It will be possible for them to be used in a wide range of products, from those where very inexpensive low performance composites are suitable, to those where expensive high performance structural components are required. They have an increasing market demand, especially among automobile companies looking for light-weight materials with sound damping properties[4]. In 1941, the Ford Motor Company, USA, investigated composites, which were soybean oil based. The Toyota Motor Corporation, Japan, made a commercialized vehicle with door trim panels made of kenaf–PP composite and a cover for a spare tyre made of kenaf–PLLA composite.

So far, natural fiber composites are favored mainly because of their green image and sustainability. They also exhibit excellent mechanical and thermal properties, and low density as revealed above. Other disadvantages such as water resistance properties should be able to be overcome in the near future. In addition to their environmentally friendly characteristics, green composites should provide excellent economical performance for acceptance in large quantity markets. It has been reported that composites based on polyolefins offer advantages of a 30% weight reduction in addition to a 20% reduction in processing temperature and a 25% reduction in cycle time. Researchers are also trying to produce hybrid composites containing different types of fibers for high performance applications. Green composite materials based upon thermosetting resins in combination with long natural fibers such as flax and hemp, offer potential in true structural applications. With few exceptions, however, there has been little in the way of commercialization of such materials. Nevertheless, significant research efforts are being directed towards the development of fully bio-based composite materials suitable for structural uses, in applications ranging from leisure goods to construction components. Unlike biodegradable polymers, however, there are few thermosetting resins based upon renewable resources currently available commercially. This has tended to limit composites reinforced with natural fiber to those incorporating petrochemical-based resins such as unsaturated polyesters and epoxies. In time, it is to be expected that bio- based thermosetting resin systems, competitive in terms of cost and performance may well become available. This would open up new and exciting possibilities for true structural 'green' composites.

'GREENNESS'

If 'green' composites are to be marketed on this basis, then it is vital that they can substantiate their environmental credentials. Life cycle assessment (LCA) is a tool that can be applied to assess the environmental impact of a particular product on a 'cradle to grave' basis. The results of LCAs can be revealing and it is by no means a given that if, for example, glass fiber reinforcement is replaced directly with a natural fiber alternative the product will be 'greener'[4,14]. It has been demonstrated that the greatest impact in environmental terms often arises from the polymer matrix, usually derived from petrochemical resources, rather than from the reinforcement fiber[15]. It is partly for this reason that there is a significant amount of research interest being directed towards the development of bio-based thermosetting resins and of renewable resource-based biodegradable thermoplastics. Thermoplastics such as the Cargill Dow LLC 'NatureWorks™ PLA', a cornstarch-based polylactic acid thermoplastic or Novamont's 'Mater-Bi', a starch-based thermoplastic are examples of renewable resource-based polymers currently in commercial production. A number of bio-based thermosetting resins are under development. These include materials based on various vegetable oils such as soy, linseed, cashew nut shell liquid and oilseed rape. One of the most notable of these is Cara Plastic's thermosetting resin based on soy oil[16]. The development of polymer resins and plastics from renewable resources offers the potential for producing true green composite materials, which could carry real environmental advantages over the current range of synthetic composites and it is likely that these will feature at the forefront of green composite technology in the future.

CONCLUSIONS

Although the history of the application of green composites can be traced back to the mid-nineteenth century, it is only in the last decade or so that renewed interest has been shown in these materials. This interest has been spurred on by a number of factors, but potentially the most significant of these is the desire to lessen the effects of mankind's activities upon the environment to 'green' our materials. In this respect, there is significant potential for composites based upon renewable resources. Although at present the commercial applications for green composites are limited, principally to biocomposites for some construction and automotive applications, ongoing research and development programmes into bio-polymers and natural fiber-reinforced composites is likely to lead to further advances and new opportunities in this sector. Underpinning this potential growth is significant political impetus to reduce or recover waste and to increase the use of renewable materials in place of fossil reserves.

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