ECONOMIC OPPORTUNITIES IN NATURAL FIBER-THERMOPLASTIC COMPOSITES

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INTRODUCTION

Combining agro-fibers (lignocellulosics) with other resources provides a strategy for producing advanced composite materials that take advantage of the properties of both types of resources. It allows the scientist to design materials bated on end-use requirements within a framework of cost, availability, recyclability, energy use, and environmental considerations. Lignocellulosic resources have low densities, are low in cost renewable, non-abrasive, have excellent specific mechanical properties, and are potentially outstanding reinforcing fillers in thermoplastic composites. The specific tensile and flexural moduli, for example, of a 50 % by volume of kenaf-PP composite compares favorably with a 40 % by weight of glass fiber-PP injection molded composite. These new composite materials are finding new applications and new markets never before envisioned by the agro-based industry.

Properties of natural fiber-thermoplastic composite materials are given in another paper in this book called “Lignocellulosic fiber reinforced thermoplastic composite materials” by R.M. Rowell, A.R. Sanadi, D.F. Caulfield, and R.E. Jacobson (also see Sanadi et al. 1994 and In Press). The reader is asked to refer to these papers for the technology on how these materials are made and their mechanical properties.

This paper will deal with the economics of producing these composite materials.

PLASTIC INDUSTRY

In 1994, the world plastic production was 110 million metric tons. Global plastic consumption is expected to rise 3.8 percent per year to over 135 million metric tons by the year 2000 (Modern Plastics Encyclopedia, 1996). Table 1 shows the breakdown of the world plastics production for 1994.

While many plastics can be used in natural fiber-thermoplastic composite, the plastic we have concentrated on is polypropylene. As seen in Table 1, polypropylene represents about 14 percent of the total plastics production in 1994 and markets for this plastic are expected to grow 5 to 10 percent per year over the next few years (Chemical and Engineering News July 15, 1996). The rapid growth in polypropylene markets is due to its versatility. Uses of polypropylene include substitutions of traditional paper packaging, containers, roofing membranes, irrigation canal liners, apparel, films, automotive interior components and carpeting. Table 2 shows world polypropylene production in 1994 by region and the expected production by the year 2000. The largest markets are now and projected to be in North America with Western Europe close behind. The fastest growing segment of the market is Asia followed by Africa and the Middle East.

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Table 1. World plastics production in 1995.

Plastic	Metric tons	Percent of market
Polyethylene	34.1	31
Polyvinyl chloride	18.7	17
Thermosets	16.5	15
Polypropylene	15.4	14
Other thermoplastics	15.4	14
Polystyrene	9.9	9
Total	110	100

Table 2. World production of polypropylene by region

Region	1995 million of lb.	2000 million of lb.	Percent change 1995-2000
North America	10,928	13,693	4.6
South America	1,708	2,293	6.1
Western Europe	10,845	13,109	3.9
Eastern Europe	1,218	1,422	3.2
Africa/Middle East	650	926	7.3
Japan	5,127	6,395	4.5
Other Asia	7,507	10,981	7.9
Total	37,983	48,819	5.1

Table 3. Distribution of polypropylene in the United States in 1995

Use	Percent of market
Fibers	33
Consumer products	13
Rigid packaging	13
Film	10
Transportation	9
Appliances	3
other	19

Table 3 shows the uses of polypropylene in the United States in 1995. The largest single use is for fibers. The “other” category includes blending and compounding resins and uses such as pipe fittings, battery cases, drinking straws, foams, wire and cable insulation and medical tubing.

Polypropylene ha been called the “poor man’s engineering resin” since its price is lower than the price of traditional engineering resins while offering engineering resin properties. Commodity grades of polypropylene sell for about $0.45 per pound which is well below the $1.00 per pound cost for typical engineering resins.

Polypropylene can also compete with lower price commodity polyethylene. Polypropylene, with a density of 0.9 g/cc is the lightest of all commodity plastics. It is 5 percent lighter than high-density Polyethylene, 14 percent lighter than polystyrene and ABS and 33 percent lighter than PVC. Polyproylene has a high melting Point (165-170 C) which enables it to be used up to temperatures of 120 C before it softens. It has good chemical resistance to hydrocarbons, alcohols and non-oxidizing agents. It is supplied in a wide range of melt-flow rates and is suitable for virtually all types of processing equipment, injection molding, blow molding, extrusion, blown and cast film and thermoforming.

In terms of end use consumption in the United States (1994), polypropylene is used for injection molding the most (31%). followed by fiber forms (29%), followed closely by compounded or tilled applications (24%). Other uses include films (10%), sheets (2%), blow molding (2%), and all other (2%).

Fillers have been used in the plastics industry for almost 90 years. Wood flour was first used to extend and improve the processability of thermosetting resins in 1907. The total amount of all fillers used in 1993 in the plastics industry was estimated to be 700 million pounds. The reason manufacturers use filled plastic is to replace part of the high cost polypropylene with a low cost filler such as wood flour or talc or calcium carbonate. Plastic pellets are produced from mixtures of polypropylene and filler which is used in high volume, low cost markers such as interior automotive panels, garbage pails, crates, and lawn and garden equipment. Current fillers for polypropylene include wood flour, talc, and calcium carbonate. Filled plastic usually improves the characteristics of the polypropylene. Talc and calcium carbonate provide some increase in strength to the plastic, but also add weight and decrease the life of the molds and extruder due to abrasion by the filler. Fiberglass and nylon add considerable strength to the product, but at a substantial cost.

There are several economic advantages of using a natural fiber as a filler in polypropylene. Processing temperatures are reduced which decreases energy costs, cycle time may be reduced up to 25 percent which means more parts turned out per unit time, less material is used per unit volume of pellets due to lower specific gravity of the natural fiber, shipping costs are reduced due to lower weight and molds last longer due to less wear and tear on them due to the less abrasive nature of the natual fiber. In addition, the product allows a more "green" marketing strategy to be developed based on the recycling possibilities of the product (Jacobson et al. 1995).

DETERMINATION OF PRODUCT COSTS

Using a very simple formula, it is possible to estimate the cost of different blends of natural fiber-polypropylene pellets.

$$\$/\text{lb} = \frac{[P(X) + F(Y) + C]}{E}$$

Where: $/lb is the product cost in dollars per pound,
P is the percent of plastic in composite,
X is the estimated cost of the plastic in cents per pound,
F is the percent of agro-based fiber in the composite pellet,
Y is the estimated cost of the agro-based fiber filler in cents per pound,
C is the cost of compounding in cents per pound, and
E is the efficiency of operation

If P = 70%: X = 0.50: F = 30%; Y = 0.03; C = 0.20, and E = 1
Then $/lb is $0.559

If P = 60%; X = 0.50; F = 40%; Y = 0.03; C = 0.20, and E = l
Then $/lb is $0.512

If P = 50%; X = 0.50; F = 50%; Y = 0.03; C = 0.20, and E = 1
Then $/lb is $0.465

If P = 40%: X = 0.50; F = 60%; Y = 0.03; C = 0.20, and E = 1
Then $/lb is $0.418

It is obvious that the more natural fiber at three cents a pound that can be put into the pellet the lower the cost. The compounded pellets are cheeper than pure polypropylene when the mixture has a natural fiber content of about 50 percent. Compounded mixtures have been made with up to 65 percent natural fiber in them and experiments are presently underway to extend the fiber content to 70 to 75 percent. This makes the economics of using natural fibers as reinforcing fillers in polypropylene very attractive.

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