Market and Technology Trends and Challenges for Wood Plastic Composites in North America

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Abstract

Wood Plastic Composites (WPCs) appear today as one of the most dynamic sectors in the plastic industry. This study was aimed at identifying the technology and market trends of the WPCs industry in North America (NA). More research about the manufacturing process is needed in order to take full advantage of the natural attributes of fibers. In terms of processes, extrusion is currently the primary technology for the manufacturing of WPCs. The incorporation of cellulosic fillers for WPCs from non-wood natural fibers such as agricultural fibers presents one of several new technological opportunities, especially in Canada where these resources are abundant. The most commonly used thermoplastic polymers in the plastic industry are polyethylene (PE), polyvinyl chloride (PVC), and polypropylene (PP). PE is the dominant polymer in the manufacturing of WPCs world wide. Thermoplastic polymers combined with natural fibers and new added compounds could significantly improve the mechanical properties of the new generation of WPCs. The results of this work show that residential repair and remodeling will continue leading the demand for WPCs in NA which is currently 2/3 of the market with over $1 billion. Specific products in the primary market are expected to grow in value at a 7-19% annual rate and developments of a second generation technology are expected to become commercialized in the next five years. Emerging products include fencing and siding, among several others.

Keywords: Wood Plastic Composites (WPCs), market trends, technology, fibers, decking

Introduction

In recent years, WPCs have seen phenomenal growth in NA because they fill a need in the construction and automotive industries. This growth has been driven by several market and societal factors, such as demand for environmentally friendly products, stricter regulations on the use of chemicals, changes in lifestyles, a growing builder acceptance, increased consumer awareness, and ultimately the intrinsic value proposition that WPCs bring about. (Smith P.M. & Wolcott M.P 2006)
There are about 30 main WPCs producers in the US and Canada. The top 20 concentrate 97% of the market value. This shows the concentration experienced in the industry from 2004, when over 40 suppliers dominated the market. Some other manufacturers exist in China, Japan and Europe. In global terms, as of 2007 NA produced 700,000 tons of WPCs, Europe 100,000 tons, China 50,000 tons, and Japan 40,000 tons. (Brown T. 2007)
Local governments in NA are aware about this phenomenon so that they have revealed their interest providing financial resources to continue research and development on these issues. US Department of Agriculture, US Department of Energy, Agricultural and Agri-Food Canada, and Renewable Auto Technologies in Canada are some examples of these investments. (Maine F. 2007)

WPCs have been largely manufactured from polyethylene (PE), polypropylene (PP) or polyvinyl chloride (PVC) polymers combined with wood under pellet or flour form. Non-wood natural fibers such as flax and hemp have also been used, acting as a cheap, largely inert filler. Availability, physical properties and closeness to market allow forecasting an increased participation of crop fibers, and a decrease of wood-based fiber.
Agricultural fibers have been used for decades in the automotive industry, with Europe as leader. Rice hull has been and will continue to be used, given its good properties (low water intake, lack of digestible nutrients that support the growth of mold and mildew), availability, and distribution channels. The latter points will likely limit the use of crop fiber only to species already readily available (e.g. wheat straw).

Some claimed attributes of WPCs include: lower life cycle cost, the use of recycled stock, low & easy maintenance, safe & non-toxic, improved thermal/dimensional stability over plastics, no or reduced twisting/warping/splitting/splintering, low moisture absorption, resistance to rot, ability to be engineered, and lower variability than wood. Their main disadvantages are: higher upfront costs, lower stiffness than wood, creep problems, lower fire resistance, thermal/discoloration and some surface finishing issues. Other challenges are the development of design specifications (codes & standards) and intellectual property (IP) issues.

Current WPCs applications include: decking, railing, windows and doors lineals, roofing, picnic tables and benches, fencing, landscape timber, patios, gazebos, pergolas, auto parts, playground equipment, etc. (Smith P.M. & Wolcott M.P 2006) (Wolcott M.P., Smith P.M., Englund K.R. 2006)
Several technologies are utilized to manufacture WPCs, including extrusion (1&2 steps, co-extrusion), compression molding, injection molding, and pultrusion depending on the

final plastic product (e.g. shape, mechanical properties) and/or polymers used as matrix. (Han C.D. 2007)

The intent of this paper is to update the scientific community on the market trends and the WPCs technologies.

Methodology

The study relied basically on literature review and commercial reports. The main sources for this study were scientific literature from the forest products industry, chemistry, composites, civil engineering, conference proceedings, commercial reports, the web and personal communications and interviews.

Results and Discussions

The results of this study have shown that the greatest potential for WPCs is in building products. NA market for WPCs is over $1 billion, and categories such as decking and railing (D&R) are expected to grow in value at a 7-19% annual rate for the next 5 years as it moves from traditional non-structural applications into new and/or more structural applications, captures higher market share, or high-end products increase their participation in the product mix.
Currently, D&R account for over 80% of the total value for WPCs, followed by windows and doors parts (W&D) with 12% approx. WPCs have successfully captured around 24% of the $4.3 billion 2007 NA market for D&R, mostly from treated lumber and plastic lumber. This growth is mostly driven by repair and remodeling (85%), followed by new housing. Nonetheless, the potential total market for WPC remains mostly untapped. Alternatives for decking applications include naturally durable species (Ipe, Cedar, Redwood), other Pressure Treated (PT) lumber (including conifers from South America and Scandinavia), plastic, vinyl, aluminum, and others. The low-end US market is currently underserved, as it competes with PT lumber.
Besides R&D, other applications are expected such as siding, fencing, bridge decking, foundation isolation elements, marine structures (chocks, wales, pier decking), laminate flooring, residential furniture (bathroom/kitchen cabinets & patio furniture), utility poles, railroad ties, exterior & interior trim (W&D components, molding and millwork). Categories like fencing have shown growth but are currently at overcapacity given the limited demand ($14 million). Similarly, siding will see strong growth, but still very small market share (N/A) and it will face entry barriers due to distribution channels considerations.

On the technical side, new manufacturing processes are under development, such as: weight reduction via foaming in extrusion (currently the leading process worldwide, see Tables 1&2), gas-assisted injection molding, continuous vacuum forming, and others not yet commercially available (e.g. injection molding of oriented polymers). These developments hold great promise and constitute the trend in the foreseeable future for expanding market applications.

In extrusion technology either single-screw or twin-screw extruders (1&2 steps) can be used. The raw materials are first mixed together in a process called compounding which is transformed into WPC product. Compounding is the feeding and dispersing of raw material and additives in the molten polymer which is forced through a die. Additives include coupling agents, light stabilizers, pigments, lubricants, fungicides and foaming agents. Intensive research has been carried out about all types of additives.
Raw materials as wood are used under pellets, fiber or flour form. The most common employed species are pine, maple and oak in 10-80 μm size mesh.
New alternatives are presented to replace the wood fibers for WPCs or diminish its proportion as filler (See Table 1). Agricultural fibers (wheat straw, soy straw, corn stover) can replace them as individual fibers as well as mixed. WPCs could also take advantage of nano-fillers during the manufacturing process.

Table 1. Typical proportion raw material & polymer according to WPCs

Raw materials (%) /Filler	Polymer (%) /Matrix	WPCs	Technology
Wood (50)	PE (50)	Decking	Extrusion
Wood (50)	PP (50)	Interior automobile paneling	Extrusion
Wood (50)	PVC (50)	Doors, windows	Extrusion

Source: Rowell R.M. (2005)

Some processing issues to consider include: compatibility of fibers and polymers, processing temperature, pressure, fiber-polymer adhesion. Physical, thermal and chemical properties of the polymers and fiber-polymer mixtures are key parameters for the quality of the final WPCs (e.g. length, diameter, microfibril angle, fiber orientation, density, viscosity, MOE, holocellulose composition). These parameters affect the strength of the fiber and its contribution to the properties of the WPCs.

Challenges

Regardless of the introduction of new products and applications describe above, D&R will continue to concentrate the largest share of the WPCs market, with PE & PP accounting for 90% of the volume by 2010 (80% & 10% respectively).
PE is the leading polymer in NA for the manufacturing of WPCs, although PP is expected to grow at higher rates.

The WPCs industry has a solid knowledge of plastic manufacturing and it will continue evolving its own technology. However, plastic processors or resin dryers are sometimes not appropriates for fillers such as wood fiber or other natural fibers failing in their attempts to introduce new formulations and/or products.

Table 2. Worldwide WPCs Extrusion Technology

Market leaders	**WPCs (%)**	**Fibers used (majority)**	**Fiber (%)**	**Process method (majority)**	**Rates (lb/hr)**	**Polymers used**			
						PP (%)	**PVC (%)**	**PE (%)**	**Others (%)**
North America	76	Wood fiber Flax Kenaf Rice hulls	50-60	Extrusion	2 500	14	16	65	5
Europe	12	Wood fiber (pellets) Flax Kenaf Jute	65-70	Extrusion Two-steps	1500	30	14	45	10
Asia (China)	8	Wood fiber Rice Hulls Bamboo Corn stalks	40-60	Two-steps	400-500	5	15	75	5
Others producers	Latin America Middle East South Africa								

Source: Brown T. (2007)

Table 3 shows the typical manufacturing processes of first and second generation WPCs and typical applications. To date, new processes are under development such as gas assisted injection molding, continuous vacuum forming, and others not yet commercially available (e.g. injection molding of oriented polymers) all of them with the purpose of ncreasing the performance of the end product.

Table 3. First & Second generation of WPCs technology

Processes	**Application (majority)**
Extrusion (single, twin)	Decking, railing, fencing
Co-extrusion	Decking, railing, fencing, siding, extern trim
Injection molding[2]	Accessories: railing post caps, trim pieces, siding and roofing shingles
Foam extrusion[2]	Windows and doors components, hollow railings
Compression Molding	Shingles
Pultrusion	Railing, fencing

It is important to note that second generation WPCs incorporate the orientation of the polymer, which translates into significant strength & stiffness improvement, as well as possible reductions in density (weight). Oriented WPCs will be the trend over the next five years. Other emerging developments include foaming, and nanocomposites.

Conclusions

- D&R are the primary markets for WPCs. They account for over 80% of the total value for WPCs, followed by windows and doors parts (W&D) with 12% approximately.
- Other WPCs applications are siding, fencing, bridge decking, foundation isolation elements, marine structures (chocks, wales, pier decking), laminate flooring, residential furniture (bathroom/kitchen cabinets & patio furniture), utility poles, railroad ties, exterior & interior trim (W&D components, molding and millwork). Those products are in various stages of development and market introduction.
- Availability of raw material such as wood fiber and agricultural fibers for WPCs especially in Canada is not a major issue.
- PE is the polymer most commonly used for WPCs. However, PVC and PP are expected to become more important in the next years.
- First generation of technology includes extrusion which is the leading process for manufacturing of WPCs. However, injection molding process is becoming more important. Raw material consumption as wood fiber diminishes level ranges from 50% to 40% of the total formulation in injection molding process.
- Second generation of technology includes oriented polymers in extrusion and injection molding. They give greater properties for WPCs. Efforts are currently underway to commercialize those developments.

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