Wood Plastic Composites in Europe: an Introduction to Wood Plastic Composite Markets and Products

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Abstract

This paper deals with markets and product applications of wood plastic composites in Europe. At the present moment there are only a few industrial manufactures of Wood Plastic Composites (WPC) in Europe. The manufactures are usually small and specified in certain products, which is contradictory to the North American manufacturing structure. A WPC is considered as a competitive material mainly in the field of the window and door industry and outdoor furniture products. The first part of this paper deals briefly with the history of WPC as a product and introduces a general description on the production process. The second part of the paper presents European market trends and market segmentation and some common product and sales attributes for WPCs.

Key words: wood plastic composite, markets, wooden products

Introduction

WPCs as a material are composed of wood or similar to wood fibres, plastics and additives. The idea of a WPC is to combine the best features of both plastic and wood. The most usual wood material used in WPCs is a by-product of the mechanical wood processing industry (*i.e.* saw dust) from either conifer or hardwood species or other cellulose-based fibre fillers. Plastic or polymer material used in WPC is usually recycled or waste plastic: either thermoplastic (like polypropylene or polyethylene) or thermoset (like phenol plastic or urea formaldehyde). The ratio of wood, plastic and additives in WPC depends on the manufacturing process and desired properties of the end-product, but usually the amount of wood in WPC is in the range of 20…85 % (Koto and Tiisala 2004, Mali and Rautiainen 2005).

WPCs as a material and product are an old innovation. According to Clemons (2000) the first industrial experiment with WPCs took place in 1983, when American Woodstock started manufacturing automotive interior. The next phase in research started in 1991 when the first international conference on WPCs was held. The breakthrough from a market point of view occurred in the late 1990s in North America, where WPCs were used especially in outdoor decking. During the rapid development phase of the markets the annual growth rate of the WPC markets was close to 100 %. Other common uses for wood plastic composites are cladding, railings, fences and window and door frames (Optimat 2003).

The main objective of this paper is to create an overall view of the existing markets in Europe of wood plastic composites. Secondly to predict how characteristic product attributes of WPCs offer possibilities to expand the market share of WPCs in the future.

Basic production process

The basic production processes of wood plastic composites are usually derived from the production processes of the plastic industry. Also the machinery used in production is usually based on technology and the solutions of the plastic industry. There are many different kinds of WPC manufacturing methods, but the most general ones are injection moulding and extrusion (Clemons 2002, Koto and Tiisala 2004).

Injection moulding is a widely used technology for manufacturing a large series of products, which have complex three-dimensional geometries. When using injection moulding in WPC production the wood fibres must be dried. Drying increases lead-time and costs in manufacturing. After drying, wood fibres, plastics and additives have to be compounded (mixed) at elevated temperatures (< 200 ºC) to form granules. After making the granules the actual injection moulding begins. In injection moulding granules are fed the injection-moulding machine, heated and then injected with pressure into the mould cavity. Once the manu-

factured WPC is cooled the mould is opened and the ready part ejected (Mali and Rautiainen 2005).

In North America, extrusion is the most commonly used method in WPC production. A conventional extruder consists of one or two rotating screws, which are placed inside a heated barrel. Extruder machines are thus divided into single screw extruders or twin-screw extruders. The WPC material is fed into the extruding machine in granule, pellet or powder form on the top of the extruder. Screw or screws convey the material into the extruder where the molten material is pushed into and through a die, which gives these three-dimensional products a linear shape in one dimension. In extrusion the moisture level of the extruded material is also essential. The materials used in the manufacturing of WPCs must be pre-dried and kept dry. Usually the moisture level of the materials should not exceed 1.5 % before feeding them into the extruder. There are also one-step extrusion techniques available, which can utilize moist wood material. In one-step extrusion the need for compounding and grinding of the materials is eliminated because all the manufacturing phases are conducted in a single machine. This naturally decreases the manufacturing cost of the product (Mali and Rautiainen 2005).

It is necessary to understand the basics of different processing techniques used in WPC manufacturing from a marketing point of view. The production method of the WPC affects and defines the end product properties and narrows down the available options for the end products usage. The selection of the raw materials, composition of the WPC, the manufacturing method, the process parameters and the geometry of the manufactured product all have an affect on the WPC end-product and the marketing of the product.

Markets and manufacturer prospects

The reported market volume of WPC products in Europe (year 2003) is approximately 30 000 tons. This is approximately 4 % of the combined markets of North America and Europe with a total market value of around 780 million USD (Oberdorfer and Golser 2005).

Market opportunities for WPCs are considered to be huge. An overview of the WPC markets in the year 2003 show that the top ten producers (North American) collectively accounted for 70 % of the total industry sales. Many of these producers are large publicly traded companies with significant advertising and marketing expenditures. In Europe most of the manufacturers are small and medium sized enterprises (SME□s). The total amount of European WPC producers is around 25-30 (Oberdorfer and Golser 2005, Rossi and Morton 2005).

WPCs are promoted as a product made of recycled material for European being environmentally aware. Environmental awareness of consumers is increasing and this is affecting on the sales activity. Today there are several issues, which consumers want to know. It is not enough that product is made of recycled material, but disposal and use should also be environmentally friendly. Even though the markets seem to be growing there are some barriers to overcome. The message from the industrial experts is that the WPCs growth rate has been limited by the lack of product applications and standardization (Mali and Rautiainen 2005). In Europe and North America there have been a few campaigns, for the purpose of increasing consumer awareness. The lack of consumer awareness is even more serious in Northern-Europe. At the present moment it seems that there are only a few places where information about WPCs is available. This is a common feature for products in the introduction phase of their life cycle. For example in Finland there is no advertising by national stores (*i.e.* retail or DIY stores) to help educate consumers.

Another obstacle is the lack of established performance standards and the lack of performance consistency. Building code regulations and standards are established around existing materials. These standards and test methods are not necessarily directly suitable for WPC materials. The situation with standardization has been improving since 2004, when the ASTM (American Society for Testing and Materials) published the first quality standards in the world for wood-composite decking. This regulation (ASTM D 7031), which is a compendium of test methods, was approved in 2004 as a guide for producers of WPCs. In 2005 the ASTM published D 7032. The standard gives physical specifications for building-code acceptance of WPC deck boards and guard rails. The European standardization for WPCs started in 2003. At national level Austria and Belgium are furthest in the standardization process. So at this point the development of these products has just begun. Issues like aging and moisture resistance will be addressed. This means testing of several material properties like water absorption, strength, durability, weight loss, color fastness, resistance to fungi etc (Oberdorfer and Golser 2005, Mali and Rautiainen 2005).

Acquiring an extensive market review is problematic, because of the early stage of the WPCs life cycle. Market, product, manufacturing and statistical information on WPCs is closely protected by the manufactures. Companies with patents and trademarks often protect production methods, technologies and customer information. There are some big marketing and consulting companies, which have focused on the

research of WPC products (Principia Partners, Hackwell Group, Business Communications Co. Inc., Research and Markets). Usually these companies work in co-operation with the WPC industry.

Products

The success of WPC products is mainly due to their good adaptability to different uses. The WPCs technical properties are usually better than mere wood or plastic materials. Good durability and moisture resistance and also environmental and ecological aspects can be used as a sales argument for the benefit of a WPC material. The ability to machine surfaces, drill and cut a product with the same kind of techniques as wood is essential to its marketability. WPC products can also be coloured in a manufacturing process or painted or coated with other methods. This makes WPC products adaptable, which gives the designers more choices in product designing and selection of specific material properties for the right kind of use.

Product properties of a WPC largely depend on the ratio of wood, plastic and what kind of additives (coupling agents, pigments, UV- stabilizers etc.) are used in manufacturing to improve and enhance the WPC properties. Encapsulation of the wood content by plastic uniformly throughout the WPC and high plastic content at the surface layer usually enhances the moisture resistance of the WPC. The ratio of wood and plastic has a major influence when looking at WPCs strength properties. Research indicates that strength properties (tensile strength) and MOE (modulus of elasticity) of WPC increase but impact strength decreases with higher wood content ratios. Also the addition of a good coupling agent considerably affects the strength properties of the WPCs. (Elvy *et al*. 1995, Youngquist 1999, Clemons 2000, Ichazo *et al*. 2001, Paunikallio *et al.* 2003, Stark and Rowlands 2003, Mali and Rautiainen 2005, Neagu *et al.* 2005, Sombatsompop and Chaochanchaikul 2005).

The disadvantages of filling polymers with wood fibres are the poor compatibility between the fibres and the polymer, and the high moisture absorption. Using coupling agents very often helps in both of these problems (Ichazo *et al.* 2001). The coupling agents provide a bond between the wood fibres' hydroxide groups (polar) and the polymer's non-polar groups. The mechanism of bonding between the coupling agent, wood and polymer is very complex and is still not fully understood, as different coupling agents and different polymers tend to show different types of interfacial adhesion (Sombatsompop and Chaochanchaikul 2005). There are many types of coupling agents, but the main ones used in WPCs are silanes (Elvy *et al*. 1995) and Maleic anhydride modified polypropylene (MAPP). Stark and Rowlands (2003) report that composites containing 40 % wood fibre and 3 % MAPP are approximately twice as strong and at least three times as stiff as wood fibre composites without MAPP (Stark and Rowlands 2003).

Current end-uses of WPC products are focused mainly on three different areas; building materials, outdoor products and the automotive industry. The biggest markets can be found at the building material and outdoor products sector. These sectors contain products such as windows, doors, insulation applications, constructional parts, roofing, decking, railings, and garden products and structures. Window frames and outdoor panels and planks made of WPC have better dimension and colour stability, weather durability and heat insulation properties than wood in these end-uses. When these WPC products are compared to other substitute products they usually have better strength properties and weather durability than competing materials. In some cases also the abrasion durability of WPC is better (Seppälä 2000, Schuler 2002, Mali and Rautiainen 2005).

The price level of a WPC is still quite high, but it can be lowered in several ways. The production price level of a WPC can be lowered by using cheaper raw materials like recycled plastic and locally less-expensive fibre materials like jute or hemp (natural fibres) in Europe. Upgrades and developments in the manufacturing process and technology and an increase in the quantity of production sets lower unit costs for the products. It is also possible to add value to WPC products by using special coatings, protection treatments or additives, colourings and machining for different end-user purposes. Comparing the current market prices of basic plank or board profile WPC to pressure treated wood shows that WPCs cost almost twice as much (Mali and Rautiainen 2005, Törmänen 2005).

Most competitive utilization area for WPCs can be in geometrically complex structures. Normally hand or machine made wood structures, like asymmetric window frames, require a lot of processing before they are ready for use. WPC products can be easily pressed in moulds or through an extruder to form complex and ready-to-install products. Outdoor products, which are exposed to the sun and humidity, are a big product group in the North American market. It is likely that WPCs can replace some of the rare tropical hardwood species used in outdoor products and furniture. One important advantage of WPC products is their cost-effectiveness when compared to wood. Studies of WPC material market also point out the fact that WPC products have significantly longer expected lifespan than non-preservative treated wood in certain end-use pur-

poses like waterfront decking or cladding. (Smith and Wolcott, 2006)

When analyzing potential markets for a product, there should always be a quick review of the products history in order to understand the stage of the products life cycle. In North America WPC products are near the growth stage of the product life cycle. At growth stage, the product quality is maintained and additional features and support services may be added to increase the demand. In European markets the product life cycle stage of the WPCs is more diverse. It can be said that all European WPC products are at the introduction phase of their life cycle, but it is quite difficult to point out the exact stage in different countries. Overall the activity in the European market has been slower, but is now showing an increasing trend. Some research (Mali and Rautiainen 2005, Rangaprasad 2003) suggests that the European WPC industry is somewhere between 5-10 years behind North America. Figure 1 illustrates the lifecycle of WPCs and the different wood products. It is evident that WPC products and their market in Finland, Europe and North America are all in their introduction phase of the lifecycle. The market share of WPC products is expected to grow considerably.

Future forecast

Researches (Mali and Rautiainen 2005, Törmänen 2005, Pirhonen 2005) show that the growth of the WPC demand in Europe is expected to be high until 2010, especially for building products and infrastructural applications. The development of markets will be affected in several areas. The main trend is in the embryonic building products market. It is expected to grow at a rate of over 20-30 % per year over the next four years (Principia Partners 2006). A significant portion of this growth is expected to come from door profiles, cladding, fencing and railings. Overall the market picture from different forecasts looks promising. The Western European market for WPCs is forecasted to grow at a rate of 15-20 % per year through 2010 (Principia Partners 2006). These high expectations are based on the fact that the WPC material and products can be used in several different end-uses. Developing the structure of the industry and increasing the number of producers can also boost market growth.

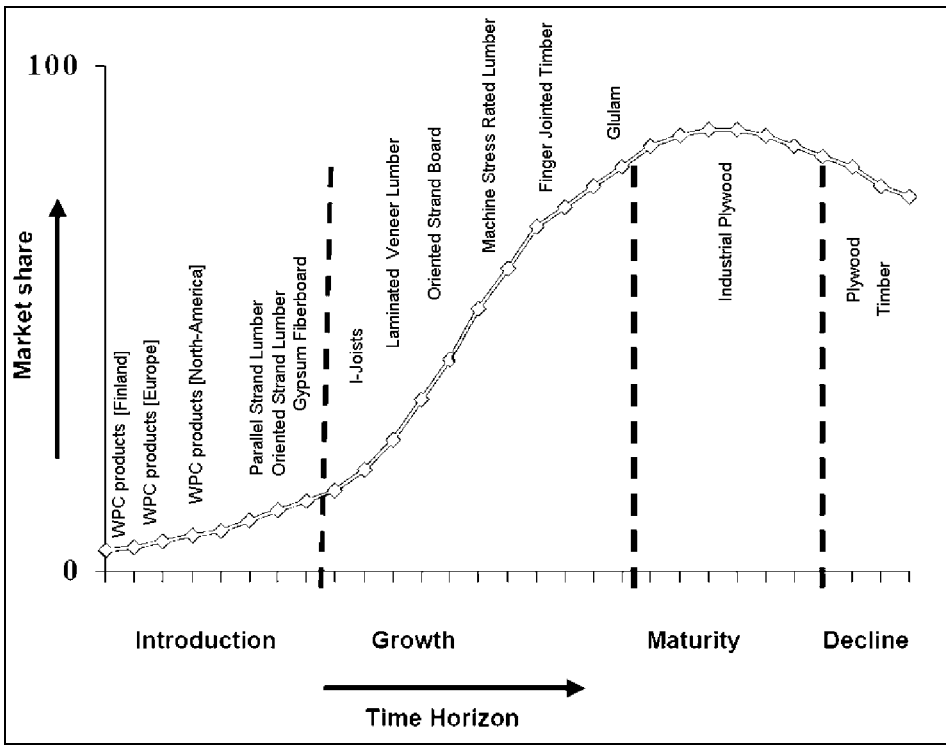

Figure 1. WPC and different wood based products, product life cycle. (Schuler 2002, modified)

The growth is expected to happen at the expense of competing materials and innovation of new kinds of products for different end-uses. The main competitor for future markets of WPCs is wood, but there are

also other competitive materials like biocomposites (including cellulose, and natural fiber reinforced polymers), vinyl, fibreglass reinforced plastics, concrete, and aluminium (Seppälä 2000, Principia Partners 2006).

The WPC markets will also be affected from new technological marketing environments. During the globalisation process the markets inside the EU will change. Changes in the markets can already be seen in agricultural products. Agricultural supports inside the EU are distributed unevenly, based on political decision-making, which affects the production of WPCs by focusing support and production on certain countries and areas inside the EU. Environmental aspects can also boost the markets of the WPC. The environmental policy of the EU supports and regulates the manufacture of environmental friendly and recyclable products. Among other treaties the Treaty of Amsterdam has reinforced the profile of the European Union environment policy. Changes strengthen the principle of sustainable development, which is now one of the main objectives of the EU.

The future of WPCs markets in Europe depends on various economic and development factors. Market development is closely linked to product quality, consumer preferences, design and versatility of products as well as growth of the general economic well being.

The focus in further research of utilisation of WPC in European market should be on specific demands like quality standards, standardisation and recycling. Also consumer acceptance has to be discussed and focused on the research and development of WPCs. The main technical problems that occur when dealing with WPC material are linked to insufficient material/product properties for some purposes e.g. wet-stability (outdoor) and moisture absorption (indoor/outdoor), UV-stability for outdoor usage, flammability for indoor used products and dynamically stressed outdoor products.

References

Clemons, C. 2000. Woodfiber-plastic composites in the United States – history and current and future markets. 3rd international wood and natural fibre composium. Germany.

Clemons, C. 2002. Wood-Plastic composites in the United States - The interfacing two industries. *Forest Products Journal* Vol. 52 No. 6.

Elvy, S., Dennis, G. and Ng, L-T. 1995. Effects of Coupling Agent on the Physical Properties of Wood-Polymer Composites, Journal of Materials Processing Technology Volume 48, Pages 365-372.

Ichazo, M., Albano, C., Gonzįlez, J., Perera, R. and Candal, M. 2001. Polypropylene/Wood Flour Composites: Treatments and Properties, Composite Structures Volume 54, Pages 207-214.

Koto, T., Tiisala, S. 2004. Muovi + Puu, puukuitulujitteiset muovikomposiitit. [Plastic + Wood, wood fibre reinforced plastic composites] Jyväskylä, Gummerus Kirjapaino Oy. 100 p. ISBN 951-827-025-2 (in Finnish)

Mali, J. and Rautiainen, L. 2005. Puumuovikomposiitit: teknologia ja markkina-analyysi. [Wood fibre plastic composites: technology and market analysis]. 19 p. VTT Technical Research Centre of Finland (in Finnish)

Neagu, C., Gamsted, K., Berthold, F. and Lindström, M. 2005. Stiffness contribution of wood fibers to composite materials. Presentation at 8th International Conference on Woodfiber-Plastic Composites. Madison, Wisconsin. [internet document]. [cited 26.2.2006] Available: *http://www.forestprod.org/woodfiber05powerpoints.html*

Oberdorfer, G. and Golser, M. 2005. Wood-Plastic Composites. Analysis of environmental impact on highly-filled wood plastic composites by laboratory simulation and full scale testing. Presentation at 8th International Conference on Woodfiber-Plastic Composites. Madison, Wisconsin. [internet document]. [cited 20.2.2006] Available: *http://www.forestprod.org/woodfiber05powerpoints.html*

Optimat Ltd, MERL Ltd. 2003. Wood plastic composites study – technologies and UK market opportunities. The Waste and Resources Action Programme (WRAP). The Old Academy, 21 Horsefair, Banbury. ISBN 1-84405-041-6

Paunikallio, T., Suvanto, M. and Pakkanen, T. 2003. Composition, tensile properties, and dispersion of polypropylene composites reinforced with viscose fibers. *Journal of Applied Polymer Science*, 91(4).

Pirhonen, T. 2005. Kierrätysmuovin käyttö etenee, mutta hitaasti [The use of recycled plastic is growing, but slowly]. Etelä-Suomen Sanomat 16.11.2005. (in Finnish)

Principia Partners 2006. News Archives. [internet document]. [cited 10.3.2006] Available: *http://www. principiaconsulting. com/publishing/news.cfm?article=23*

Rangaprasad, R. 2003. Wood Plastic Composites an overview. IPI Seminar on synthetic wood. Mumbai. 7.10.2003.

Rossi L.M. and Morton, J. 2005. WPCs: Putting Innovation on a Faster Track. Presentation at 8th International Conference on Woodfiber-Plastic Composites. Madison, Wisconsin. [internet document]. [cited 22.2.2006] Available*: http://www.forestprod.org/woodfiber05powerpoints.html*

Schuler, A. 2002. Innovative Uses of Wood Promotes Market Development and Supports Forest Sustainability: A win win Situation for Society, Forest Products Industry, and Forest Owners. UNECE Timber Committee & Forum, Forestier Lemanique Symposium, Neuchatel, Switzerland

Sherman, L. 2006. Wood-Filled Plastics – They Need the Right Additives for strength, Good looks & long life. [internet document]. [cited 22.2.2006] Available: *http://www.plasticstechnology.com/articles/200407fa1.html*

Seppälä, R. (eds.) 2000. Suomen metsäklusteri tienhaarassa. [The Finnish forest cluster at crossroad.]. 138 p. ISBN 952-457-020-3 (in Finnish)

Smith, P.M. and Wolcott, M.P. 2006. Opportunities for Wood/Natural Fiber-Plastic Composites in Residential and Industrial Applications. Forest Products Journal Volume 56 issue 3: 4-11.

Sombatsompop, N. and Chaochanchaikul, K. 2005. Average mixing Torque, Tensile and Impact Properties, and Thermal Stability of Poly(Vinyl Chloride)/Sawdust Composites with Different Silane Coupling Agents. *Journal of Applied Polymer Science*, Volume 96: 213-231.

Stark, N. and Rowlands, R. 2003. Effects of Wood Fiber Characteristics on Mechanical Properties of Wood/Poly-

proylene Composites. *Wood and Fiber Science*, Volume 35: 167-174.

Törmänen, E. 2005. Puumuovi voi korvata painekyllästetyn puun. [Wood plastic composite can replace pressure treated wood]. Journal of Technology and Economics. 24.11.2005. (in Finnish)

Youngquist, J.A. 1999. Wood-based composites and panel products. In: Wood Handbook Wood as an Engineering Material. Chapter 10.USDA Forest Serv. Forest Prod. Lab. Forest Prod. Soc., Madison, Wisconsin, p.27-28.

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КОМПОЗИЦИОННЫЕ ДРЕВЕСНЫЕ МАТЕРИАЛЫ НА ОСНОВЕ ПЛАСТИКА В ЕВРОПЕ: ВВЕДЕНИЕ В РЫНКИ КОМПОЗИЦИОННЫХ ДРЕВЕСНЫХ МАТЕРИАЛОВ НА ОСНОВЕ ПЛАСТИКА И ПРОДУКТЫ ИЗ НИХ

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Резюме

В данной работе говорится о ситуации на рынках и в сфере применения древесных композиционных материалов на основе пластика в Европе. В настоящее время в Европе существует всего несколько промышленных предприятий, специализирующихся на производстве древесных композиционных материалов на основе пластика (WPC). Обычно, производства такого рода небольшие и специализируются на производстве определенной продукции, что противоречит производственной структуре Северной Америки. Древесные композиционные материалы на основе пластика рассматриваются как конкурирующий материал, главным образом в сфере производства окон, дверей и изделий уличной мебели. Первая часть данной работы кратко описывает историю древесных композиционных материалов на основе пластика как изделия, и знакомит с общим описанием производственного процесса. Вторая часть работы описывает тенденции Европейского рынка, рыночную сегментацию и некоторые распространенные изделия, а также характерные черты реализации композиционных материалов на основе пластика.

Ключевые слова: древесные композиционные материалы на основе пластика, рынки, изделия из древесины