Comparison between Wood Plastic Composites (WPCs) and Woods

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Abstract

Composites can be defined as materials that consist of two or more chemically and physically different phases separated by a distinct interface. The different systems are combined judiciously to achieve a system with more useful structural or functional properties non attainable by any of the constituent alone.
New materials are becoming an essential part of today's materials due to the advantages such as low weight, corrosion resistance, high fatigue strength, and faster assembly. They are extensively used as materials in making aircraft structures, electronic packaging to medical equipment, and space vehicle to home building like wood plastic composites.
In this research we take a sample of wood plastic composites from Moawia's Factory in Khartoum north and other samples are different types of wood to compare between them and define what is the best type of wood which gives a good mechanical properties by using tests like density, absorption test, hardness test, impact test and fire test. The tests were carried in Sudan University of Science and Technology.
There was found that the WPCs were resistant to water (absorption percentage 0.034%), the density was 0.68 g/cm^3, hardness was 0.21Kg/mm^2, the impact was 1.24 N, and the burning test show that its good fire retardant (1min). So, the wood plastic composites are the best for using in different application. The musky was the best one to use in compounding.

Keywords: composites, plastics, polypropylene, polyvinylchloride (PVC), property, wood.

Introduction

It would be difficult to imagine our modern world without using plastics. Today plastic plays an important role in our daily life due to their relatively low cost, ease of manufacture, versatility and imperviousness. Plastic are used in an enormous and expanding range of product, from paperclips to spaceship. They have already displaced many traditional materials, such as wood, stone, lather, metal, glass and ceramic.
There are two types of plastic: thermoplastics and thermoset polymers. Thermoplastics are the plastic that do not undergo chemical change in their composition when heated and can be molded again and again, examples are polyethylene (PE), polystyrene (PS), polypropylene (PP), and poly vinyl chloride (PVC). Thermo sets can be melt and take shape once after they have solidified, they stay solid examples are phenolic and unsaturated polyester. Plastics can be classified by their various physical properties, such as density, tensile strength, glass transition temperature and resistance to various chemical products.
Nowadays, we are using materials with specific properties to give a good quality product with low cost, this material produced by combination of two different materials with different properties (chemical or physical) during reaction under specific conditions and additives (filler, lubricant, stabilizer and coupling agent). This

material called composite. Composites can be defined as materials that consist of two or more chemically and physically different phases separated by a distinct interface. Composite can be made by mixing of two plastic materials with each other or using of plastic with other materials such as wood or metal.

For example of it wood plastic composites (WPCs) which contains polymer plastic (pure or recycle) such as PVC, PE, PP and wood of different shapes which are used to produce window/door profiles, railing, siding and furniture. In general, manufacturing of WPCs are a two-step process, combination of wood and thermoplastic such as high density polyethylene (HDPE), low density polyethylene (LDPE) and polyvinyl chloride (PVC) are mixed together dough-like-consistency called compounding. Mixing can be handled by either batch or continuous process. In addition to the main ingredient, wood with grain size ranging from 20 to 60 mesh, plastic coupling agents, stabilizer, foaming agents or dyes, are added to enhance properties of the final product for a particular use as, well. There are three common forming methods for WPC. Extrusion method, which forces molten composite through a die or injection molding method, molten composite is forced into a cold mold and the third one presses molten composite between mold halves. Most of the physical and mechanical properties of WPC depend mainly on the interaction developed between wood and thermoplastic material.

History of wood composite plastic WPC

The development of plastics accelerated with Charles Goodyear's discovery of vulcanization as a route to thermoset materials derived from natural rubber. Many storied materials were reported as industrial chemistry was developed in the 1800s. In the early 1900s, Bakelite, the first fully synthetic thermoset was reported by Belgian chemist Leo Baekeland. In 1933, polyethylene was discovered by Imperial Chemical Industries (ICI) researchers Reginald Gibson and Eric Fawcett. After the First World War, improvements in chemical technology led to an explosion in new forms of plastics; mass production began around the 1940s and 1950s. Polypropylene was found in 1954 by Giulio Natta and began to be manufactured in 1957. Among the earliest examples in the wave of new polymers were polystyrene (PS), first produced by BASF in the 1930s , and polyvinyl chloride (PVC) was accidentally discovered at least twice in the 19th century, first in 200 by French chemist Henri Victor Renault and then in 1872 by German chemist Eugen Baumann. On both occasions the polymer appeared as a white solid inside flasks of vinyl chloride that had been left exposed to sunlight. In the early 20th century the Russian chemist Ivan Ostromislensky and Fritz Klatte of the German chemical company Griesheim-Electron both attempted to use PVC in commercial products, but difficulties in processing the rigid, sometimes brittle polymer blocked their efforts. Waldo Semon and the B. F. Goodrich Company developed a method in 1926 to plasticize PVC by blending it with various additives. The result was a more flexible and more easily processed material that soon achieved widespread commercial use.

Until the 1990s, wood was the material of choice for deck construction. However, new products, composites, began to emerge at this time. These new products offered the look and workability of wood, but they were more water resistant and required less maintenance. Over time, these lower maintenance decking options increased in popularity. Although the majority of decks are still built of pressure treated pine, redwood, cedar or mahogany, use of composite woods has increased as outdoor decks and living areas have become popular as home features.

A 2011 discovery in the Canadian province of New Brunswick uncovered the earliest known plants to have grown wood, approximately 395 to 400 million years ago. People have used wood for millennia for many purposes, primarily as a fuel or as a construction material for making houses, tools, weapons, furniture, packaging, artworks, and paper.

In the past ten years wood polymer composite (WPC) has become a state of the art commercial product with a growing market potential in the area of building, construction, and furniture. The market share of WPC in the area of automotive is also increasing in Europe and Asia. Although WPC has a long history in Europe from the beginning of the twenty-first century, the main commercialization has happened only since the early 1990s. A major manufacturing initiative was undertaken by small and medium enterprises (SMEs) in North America in the mid-1990s that resulted in a fully commercialized decking product for the building industry. Since then, many other innovative products have been commercialized in the United States and Canada. A major market trend is now to expand the product range in construction with enhanced mechanical performance and durability. In recent years we have seen that WPC products are slowly penetrating the European market, in automotive applications, furniture, and in building products. On the research and development front WPC has gained significant popularity as evidenced by a threefold to fourfold increase in international symposia and workshops in the past five years. Major growth in the technology is coming from equipment design, process formulation and product design.

Wood composite materials

Wood plastic composites (WPCs) are roughly 50:50 mixtures of thermoplastic polymers and small wood particles. The wood and thermoplastics are usually compounded above the melting temperature of the thermoplastic polymers and then further processed to make various WPC products. WPC can be manufactured in a variety of colors, shapes, sizes and with different surface textures. Depending on the processing method, WPCs can be formed into almost any shape and thus are used for a wide variety of applications, including windows, door frames, and interior panels in car, railing, fences, landscaping timbers, cladding, siding, park benches, molding and furniture. To understand wood plastic composite (WPC) adequately, we must first understand the two main constituents. Though both are polymer based, they are very different in origin, structure and performance. In WPCs, a polymer matrix forms the continuous phase surrounding the wood component. These matrix polymers are low typically low cost commodity polymers that flow easily when heated, allowing for considerable processing flexibility when wood is combined with them. These polymers tend to shrink and swell with temperature but absorb little moisture and can be effective barriers to moisture intrusion in a well-designed composite.

Wood

Wood is a hard, fibrous structural tissue found in the stems and roots of trees and other woody plants. It has been used for thousands of years for both fuel and as a construction material. It is an organic material, a natural composite of cellulose fibers (which are strong in tension) embedded in a matrix of lignin which resists compression. It is sometimes defined as only the secondary xylem in the stems of trees, or it is defined more broadly to include the same type of tissue elsewhere such as in tree roots or in other plants such as shrubs .In a living tree it performs a support function, enabling woody plants to grow large or to stand up by them. It also mediates the transfer of water and nutrients to the leaves and other growing tissues. Wood may also refer to other plant materials with comparable properties, and to material engineered from wood, or wood chips or fiber.

The Earth contains about one trillion tones of wood, which grows at a rate of 10 billion tons per year. As an abundant, carbon-neutral renewable resource, woody materials have been of intense interest as a source of renewable energy. In 1991, approximately 3.5 billion cubic meters of wood were harvested. Dominant uses were for furniture and building construction .The efficient structure and anatomy make it a stiff, strong, tough and lightweight material that can efficiently perform functions such as moisture transport that are critical for survival of the tree. From a polymer composite standpoint, wood is less expensive, stiffer and stronger than many commodity synthetic polymers, making it a candidate for filling and reinforcing them. We will first discuss the structure, anatomy and types of wood.

Materials and Methods

Most WPCs are manufactured using profile extrusion, which creates long continuous elements, such as deck boards and window components. The wood-thermoplastic mixture (in pellet form) is conveyed into a hopper that feeds the extruder. As the material enters the first zone of the extruder, the heated screws and barrel melt or soften the thermoplastic. The molten material is then forced through a die to make a continuous profile of the desired shape. Molten WPC material is highly viscous, so the equipment needs to be powerful enough to force the material though the machinery and out of the die. As the material exits the extruder, it is cooled in a water spray chamber or bath to rapidly harden the thermoplastic matrix, embossed with a desired pattern, and cut to a final length. Extruders can have single screw or twin feed screws, which are counter- or co-rotating. These screws can be parallel, for mixing only, or conical, to increase pressure in the die to aid in consolidation. Tandem extruders have one component for the compounding step and one for the shaping process. While extrusion methods create lineal elements, injection molding produces three-dimensional parts and components. The unique shapes and profiles that can be created with injection molding provide the potential for diversifying from the current WPC markets. The injection molding process involves two steps. The first is to melt-blend or compound the wood-plastic mixture, and the second is to force the molten WPC into a mold under high pressure. The molten material fills the cavity in the mold and solidifies as it is cooled. Injection molding is used to manufacture a variety of parts, from small components to large objects. Injection molding is a common method of production and is especially useful for making irregularly shaped pieces.

Other types of molding processes include compression, vacuum bag, resin transfer (RTM), reaction injection (RIM) and matched die molding. These manufacturing technologies each have the ability to keep the full length of the fiber and provide high strength composite, such as those used in automotive applications. The main disadvantages to these techniques are that they are batch processes, which re- quire longer processing times and are more costly. All of these methods could have application to WPCs; however, only limited research has addressed their use.

Figure 1. The WPCs components: chemical (plastic, polyvinylchloride (PVC)] and wood (mahogany, musky, sunut, sugar cane).

Samples were taken from Moawia's Factory for wood furniture in North Khartoum which made by compounding the PVC with wood (sugar cane) and some additives then produce a sheet by using extrusion machine. WPCs samples and other wood types were used for testing if WPCs was best than wood itself; to compare different types of wood to show the better one, using in composites with PVC, available in Sudan.

The experimental tests

Density. Calculate the density of samples that defined as the mass per unit volume of material.

$$\text{Density} = \text{Weight of dry sample} / \text{Volume}$$

Absorption test. By using samples in triangles shape weighed with boot in air; put them in water for 24 hours and weight again; then take these samples full of water and put in oven 110-115 o for one hour to dry and weight again; finally by using law to found the percentage of absorption for each samples. Samples shape rectangle (1.5*15*52.6) cm

$$\text{Absorption } (\%) = (w3-w2/w2-w1) * 100$$

Where:

W3 = weight of sample full of water

W2 = weight of dry samples

W1 = weight of empty boot

Hardness test

By using Berinll Hardness Number (BHN) put the samples under the indenter (metal boll) on the surface then press it into the samples making shore that is parallel to the surface; then measured the penetration by using lenses to reading the number of dimension of indenter penetration in it; finally using the expression below to calculate the BHN. Samples shapes were rectangle (11*11*152) mm.

$$BHN = 0.102\ [2*F(N)/pi*D(D-(D2-d2))]$$

Where:

F(N) = 20 kg * 9.81= 196.2 N

D = diameter of metal boll

d = diameter of penetration

Impact test

By using Sharp MT220 put the samples parallel to the surface after moving the leg of machine to app then let it move down to impact with sample and crush into two half's. Samples shape were rectangle (8*8*75) mm.

$$P = mgl [\sin (\Theta 1-90) + \cos \Theta 2]$$

Where:

P = absorbed energy
ϴ1 = angle before impact
ϴ2 = angle after impact
M = 2 kg
L = 0.39 m
G = 9.8 m/s2

Burning test. By using samples for each type of material, put it on fire and let them until burn completely then calculate the time which take them.
All tests were performed at the Sudan University of Science and Technology.

Results and Discussion

The observed data showed that the density of WPCs was approximately equal to other samples of wood (musky and sugar cane), and lower than mahogany and sunut. Mean weight of composite was lighter (Table 1), and WPCs were good for shaping and work.
Absorption tests showed that absorption (%) of WPCs was the lowest compare to other materials. Absorption of WPCs was 0.034% versus 0.06% for musky, 0.15% for sugar cane, and so on (Table 1). WPCs moisture absorption was very low, which means that the composites are resistant to water.
Observed results showed that the hardness of WPCs was high, which means they are flexible so we can use it in different forms (From Table 1 we see that WPCs hardness show the highest value (9.22). Also sunut is low reading).

Table 1. Density (g/cm^3), absorption (%) and hardness (Kg/mm^2) of different tested materials (mean values)

Sample	Density (g/cm^3)	Absorption (%)	Hardness (Kg/mm^2)
WPC	0.68	0.034	9.22
Musky	0.625	0.06	8.04
Sugar cane	0.662	0.15	6.76
Mahogany	0.777	0.251	6.5
Sunut	0.859	0.104	4.46

Impact test showed that WPCs were weak and can break easily, refer to the type of wood (sugar cane), also weak in the same test. Results showed that impact of WPCs was the lowest (1.24), followed by sugar cane (1.86), used in WCP composite. Musky was found to have the highest impact value (3.52), so we recommend replacing sugar cane with musky or sunut (Table 2).
WPCs were not burning at all which proved its excellent resistance to fire and safe for use. Sunut showed also lower resistance than sugar cane, so we can replace sugar cane with sunut in WPCs (Table 2).

Table 2. Impact (N) and burning time (min) of different tested materials (mean values)

Sample	Impact (N)	Burning time (min)
WPC	1.24	1.0
Musky	3.52	7.666
Sugar cane	1.86	9.333
Mahogany	2.99	10.00
Sunut	3.58	7.000

Table 3. Hardness test (Kg/mm^2)

Sample	HR	HR	HR	HR	HR	AVG
WPC	10	8.9	10	8.1	9.1	9.22
Musky	8.0	8.6	8.5	8.0	7.1	8.04
Sugar cane	5.9	6.8	7.0	7.0	7.1	6.76
Mahogany	6.5	6.5	6.5	6.5	6.5	6.5
Sunut	4.5	4.4	4.4	4.5	4.5	4.46

Table 4. Burning test

Sample	Time/min	Time/min	Time/min
WPC	≈1	1	1
Musky	7	8	8
Sugar cane	8	10	10
Mahogany	8	9	13
Sunut	6	7	8

According to data on the above table, WPC took a mint to catch on fire and then stopped because the type of plastic in this component was a flame retardant, while the other types of wood burned completely at different time.

Conclusions

WPC as a shape of sheets was very good, the surface was soft, flexible and weight was light. The mechanical properties tests approve its excellent in water absorption which it’s an important point for its produce. Other mechanical test showed that WPCs were lighter in weight and flexible, so they can be easily used for making furniture like beds, tables and cupboard; and sheets for flooring.

Impact test showed that WPCs were weak and can break easily, but refer to the type of used wood (sugar cane), which was also weak alone in the same test; we can choose other types of wood, such as musky or sunut to improve this parameter.

Fire tests showed that WPCs had an excellent resistance compared to the wood, due to the type of plastic used in the compound, which is known as a fire retardant.

In Sudan, instead of sugar cane, the other types of wood can be used in WPCs compound, in order to improve the impact of the product and other mechanical properties. Musky showed to have several better properties than sugar cane, which was used in studied compounds.

Recommendations

Make WPCs using musky as a wood and then study it to the mechanical properties. Use the waste of wood in the compounding to reduce the WPCs production cost and take more studies to improve the mixture between plastics and wood. Search about the biological attack test.

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