Improving Thermal Properties and Reducing Total Cost of Plastic - Agricultural Residues Composites Used as Non-Traditional Building Materials

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ABSTRACT

Samples of plastic agricultural residues composites were prepared for different compositions. Mechanical, thermal and physical tests were performed for all samples. Tensile, flexural, compression, hardness and Izod impact tests were performed as mechanical tests. Optical, thermal mechanical and density tests and measurements were also conducted for all samples to insure and confirm the physical properties and stabilities. Results of 56 % weight percentage ratio of reinforcing phase (agricultural residue) shows a good properties for samples which include coupling agent , UV Stabilizer and lubricants as 7% of weight percentages.

Keywords: Composite material, matrix material, polypropylene, wood -plastic composite, plastic- agricultural residues, reinforcing phase, coupling agent.

تحسين الخواص الحرارية وتقليل الكلفة لمتراكبات بلاستك – مخلفات زراعية تستخدم كمواد بناء غير تقليدية

الخلاصة

تم تحضير متراكبات من بلاستك – مخلفات زراعية وبنسب مختلفة لمكوناتها. تم دراسة وتحديد الخصائص الميكانيكية والحرارية والفيزياوية لجميع العينات. الفحوص الميكانيكية شملت تحديد إجهادات الشد، الثني، الانضغاط، الصلادة، فحص الصدمة . اما الفحوص الفيزياوية فقد شملت قياسات الكثافة والفحص البصري وتحديد التشوه الحراري الميكانيكي ودراسة سلوك النماذج. تم استخدام مخلفات زراعية (مادة مالئة)وبنسب عالية وصلت الى 56% أما المضافات الأخرى فكانت بنسبة لا تتجاوز7% والتي شملت عامل الربط، مضادات الأشعة فوق البنفسجية، مواد مزيته. وقد أظهرت النتائج المتحققة تحسين الخواص الميكانيكية والحرارية للمتراكب المحضر من مخلفات زراعية (سليلوزية قشور الرز) المطحون بحجم حبيبي (300mesh) مع المادة البلاستيكية الأساس (البولي بروبلين) مما يتيح استخدام تلك المتراكبات كمواد بناء غير تقليدية .

INTRODUCTION

The composite material can be defined as those materials resulting from the participation of two materials (or more), by physical or chemical bonds. In some cases at interface region, each material has separate phase in the composite system. In order to obtain materials with new properties and appropriate structures between properties of the raw materials, composite materials will be more suitable for some industrial applications [1].

The matrix material called binding material which bond reinforcement materials (fillers). Fillers which works to strengthen the polymeric materials, were as particles or fibers or sheets [2,3].

Agricultural and plastic wastes have become burden heavy in the style of dealing with it or get rid of them, so take most recent researches is about the optimal use of the wastes, where it has reached the rate of consumed materials to (190) million tons in 1994 from the wastes in the United States only, where the waste is an important raw materials in the manufacturing of wood- polymer composites. The wood-polymer composites (WPC) are one of the important channels in using the defective materials (agricultural residues, cellulosic and waste polymers) to be disposed of without resorting to destroy them as in traditional methods (incineration, burial), which cause pollution of environment, that is why this research is friendly research to environment [4].

The industry of non-traditional building materials and its composites especially that prepared from wood– plastic, were used in a wide range in Europe, America and China for the following reasons [5]:-

1 - Use plastic and cellulose waste without its disposal by the traditional methods, which is important to clean the environment.
2 - Cheap compared to traditional building materials.
3 - High mechanical, thermal and physical properties and high resistance to moisture.
4 - Final product does not need to terminations as the smoothing and paint.
5- - the possibility of re- industry of produced materials (Recycling).
6 - Quick and easy production, as well as the easy of mounting as building materials.
7 - Light weight materials.

One of the most important property of polymer/wood composites is its resistance to water and to difficult circumstances of outdoor mounting. Picture (1) illustrates of these challenges, in Europe.

Picture 1. Plastic/ wood composite materials outdoor applications.

The composites materials contain the added materials (coupling agent, lubricate materials, anti-UV) by rate did not exceed 7%. The coupling agents such as malice anhydride or polypropylene malefic anhydride used to increase the coherence between all matrix materials, which is considered non-polar material and the cellulosic sawdust waste (polar) increasing multi- effective totals bonding.

The wood contains lignin substance which is organic polymeric material with a dark color. It is different in chemical nature and percentage by sources, which is responsible on the binding characteristics between the reinforcement material and plastic material[6].lignin material contain methylol groups and phenolic hydroxyl groups, and primary and secondary alcohols, ether alcohol benzyl, Ariel ether, Carbonyl, double bonds [6,7].

The lubricated materials have an important role in the flow of composite during the forming process and giving smooth texture of the product. But the increase of lubricated materials give brittle composites [6]. There are other additives can be added to improving the composite physical properties such as UV stabilizer that increase the resistance of to the sun ray and thus prolong the age, according the end use nature of the composite [6].

These composites can be used as non-traditional building materials such as flooring, doors, windows, ceilings, interior walls, fences as well as seats in parks and playgrounds can also be used in manufacture of the home and office furniture. This means that the search in this field have economic benefit. Figure 1shows the style of the distribution of production costs on raw materials also shows that the greatest weight in the price of composite due to the used polymer, and by increase the percentage of the reinforcement materials (cellulosic wastes) in the composite will lower the product cost.

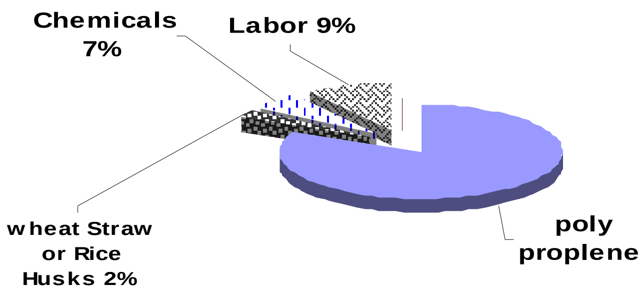


Figure (1). Shows the distribution of the raw materials costs used in production of polymeric wood [6].

Experimental

Materials: -

A - Matrix material :- polypropylene (PP) is used in this research, which is provided from (SABIC company) in Saudi Arabia in addition to large amount of locally consumed in cans , plastic boxes and consumption agricultural blankets.

B - Reinforcement materials :- The reinforcement material which used in this research is rice husks. The specifications where determined in terms of moisture, the percentage of lubricated material, the length of the fiber and by physical and chemical methods.

C – Additives

(1) - Zinc Sterate :- White powder which chemical formula is [Zn $(C_{18}H_{35}O_2)_2$] with density of 1.095 gm/cm^3. Its melting temperature is 130 °C. Insoluble in water and alcohols and soluble in most organic solvents at heating[6, 7]. It is used as lubricant material to increase the flow of composite materials within the kneading or extruding machine more over it gives smooth and shiny surface of the final product.

(2) - maleic anhydride :- Colorless solid material with density of 0.934 and the melting degree of 53 °C. Soluble in water, alcohol and acetone. In this paper we used it as a coupling Agent [6].

(3) - UV Stabilizes :- Colorless granules and is composed from (Hydroxymethyl - Phenyl - Benotrizol & Bis- Tetrametheyl- Piperindinyl- Sebacat) and acts as light stabilizer of polyolefin in general, in addition to the polystyrene-sided and its derivatives, used in the range (2- 5%) as mentioned in ref. [8].

Equipment:

Table (1) shows all devices and equipment used in this paper with the main specifications

The type of devices	Specifications
laboratory mixer	kneading axis(Blade Sigma)
UV-Visible Instrument (Double Beam)	Optima –sp3000
Optical microscope	Nikon Optical microscope X 500
analytical balance	Accuracy 0.0001gm
Sieve	(300 micron)
Magnetic stirrer	Temp. range (0-250)°C
Hydraulic Press	pressure (150) bar
Mold	Dimensions(12X12X4)cm
Tensile test device 100KN	Tinus olsen HKT-50
Impact test device Pendulum charpy Impact	30 Joule
Hardness test device	Shore (D)
Thermal analysis system - Mechanical (TMA)	German license PT-1000

The laboratory tests of raw materials

Reinforcement material tests :- Some tests on Rice husks reinforcement material were conducted to determine the physical (Fiber dimensions) and chemical specifications (moisture, lubricant constraints).

A –Determination of moisture :- takes the weight (1 gm) from rice husks wastes by the delicate balance and then placed in bottle and then placed in oven for(1 hour) at (120 °C), and then allowed to cool in vacuum glass bottle contains silica gel substance to moisture absorb for half hour, weighed the specimen and then calculate the moisture content as follows:-

$$\left(\frac{\text{(Weight of sawdust before entering the oven - weight of sawdust after the entry of the oven)}}{\text{(Weight of sawdust before entering the oven)}} \right) *100$$

B - Determination of lubricate material :- lubricate material was calculated by extraction by the organic solvent in the laboratories of the general company for Vegetable Oils / quality control division, Ministry of Industry.

C- Determination of fiber length :- Optical microscope type (NIKON ECLIPSE) were used to determine the fiber average length of the reinforcement materials.

D – Determination of Grain Size :- Rice husks were screened by the sieve (300 micron).

E - Determination of Lignin:- lignin substance were separated by using dilute sulfuric acid as follows [11]:

(I) - Add 3 ml. from sulfuric acid by concentration 73% to the amount 84 ml. from distilled water.

(II) - The solution is placed in glass bottle of 250 ml with the rice husks and then placed on the magnetic mixer for one hour (without heating).

(III) - The solution is heated to temperature 70 ° C for one hour with mixing.

Filtering of the solution and preparing it to analysis process by UV spectroscopy.

The preparation stages of composite

The preparation of composite by successive stages in the mixing ,compounding and forming stages and complementary process as shown in Figure 2.

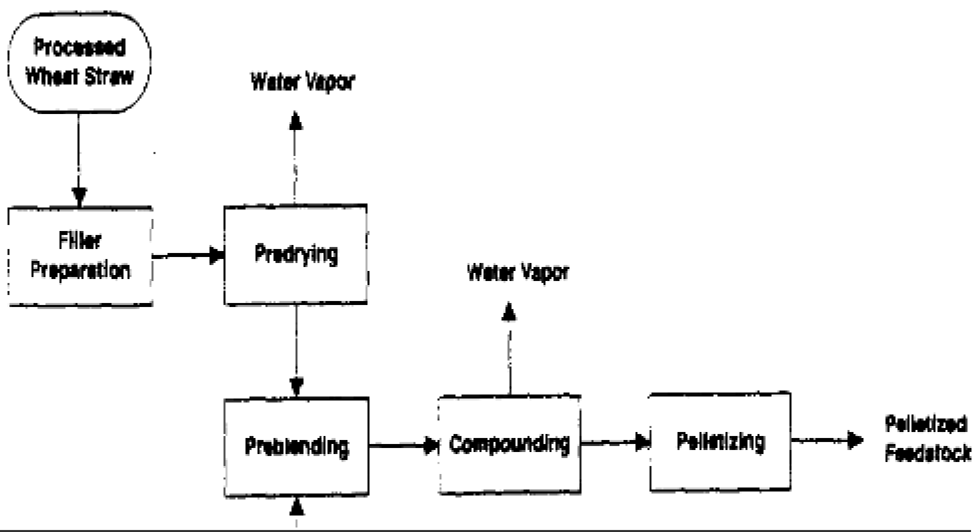


Figure (2). Shows the preparation stages of composite.

Mixing stage:- In this stage all reinforcement materials and additives (sawdust wastes, coupling material, lubricated material, anti- UV stabilizer) were carefully prepared for dry mixing.

Compounding stage:- In this stage the laboratory kneading shown in Picture 2, were used. Heating temperature was between 225- 250°C. After the melting process of polymeric material (inside kneading room), the reinforcement materials and the additives that have been configured in the mixing stage ,were added manually and carefully.

Picture(2). Shows the laboratory kneading used in forming of composite.

Forming stage :- It is a metal mold stage with dimensions 12x12x 4 cm. The mold has been cleared by anti-adhesion material, the prepared composite was transferred to the mold and then to the press. Under pressure up to 140-150 bar. A prepared composite from this mold was shown in Picture 3.

Picture (3). Shows a sample of the prepared composite.

The tests

(1) Tensile test :- Specimens prepared to the tensile test according to (ASTM-D - 390) [9], by using Tinus Olsen HKT-50 device.

(2) Flexural test :- Specimens prepared to Flexural test according to (ASTM-D - 390) [9], by using the same Tinus Olsen device.

(3) Compression test :- Specimens have been prepared to the compression resistance test according to standard (ASTM - D695-85) [10] by using the same Tinus Olsen device.

(4) Hardness test (Shore D) :- This method is used to measure the hardness of prepared composites materials.

(5) Charpy Impact test :- The Pendulum type hammer (Model: THERCO MT220) device were used applying impact standard (ISO 79) [11].

Results and Discussion

Table (2) represents some chemical and physical tested results for the raw materials.

Table (2). Shows Rice Husk properties.

Substance	Moisture %	Lubrication material (%)	Length of the fiber (μm)	Particle Size (μm)
Rice Husk	6.5	3.09	1226	300

Figure 3 revels the microscopic pictures for rice husk (cellulosic wastes) ,which clearly illustrates a fibrous shape after preparing process of milling and sieving.

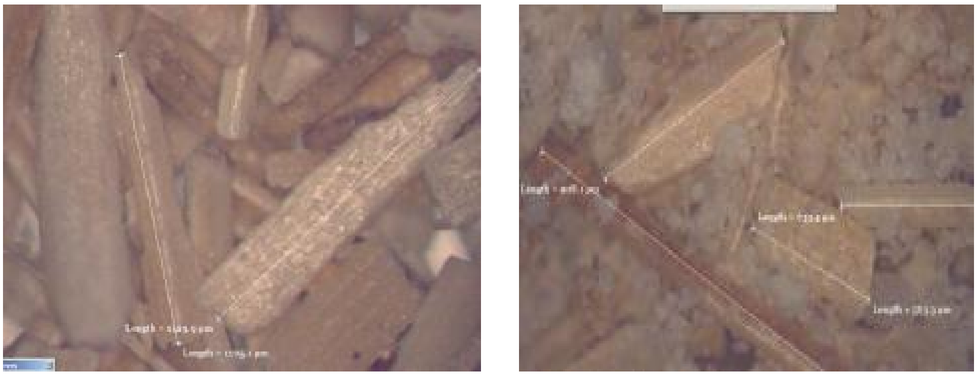


Figure (3). Microscopic pictures describe the shape and dimensions of the fiber rice husks.

Figure 4 represents the absorption spectrum of the UV test of lignin substance which is extracted from rice husks to improve its presence.

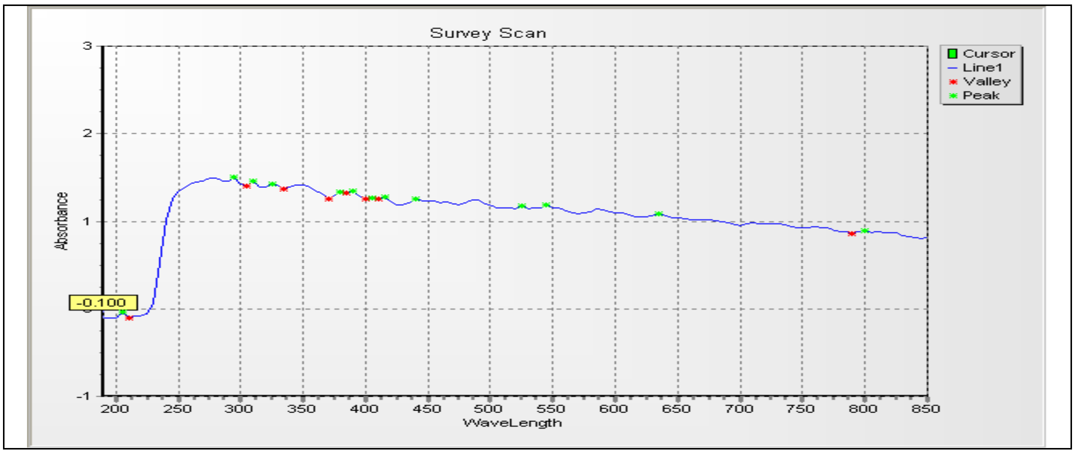


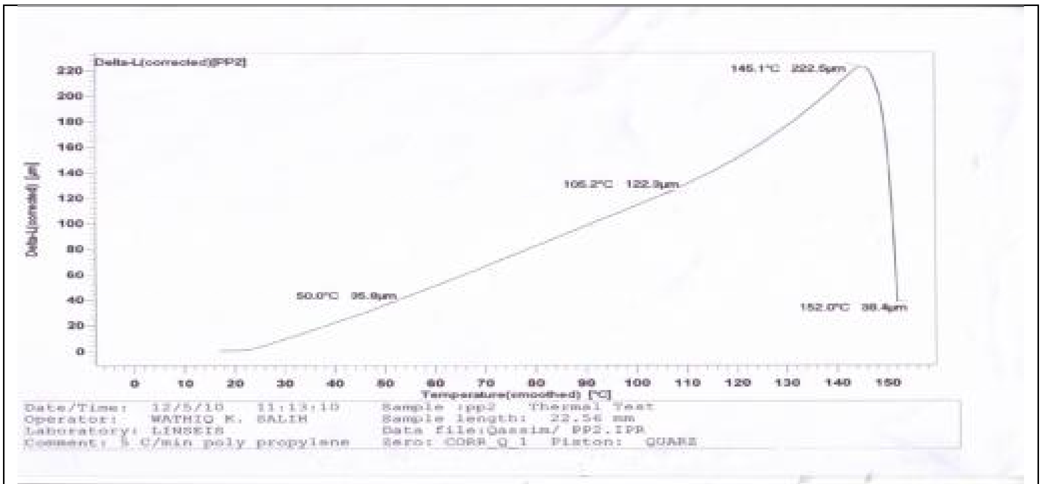
Figure (4). Illustrate the absorption spectrum of the ultraviolet rays of the Lignin

Table 3 represents the specifications of the used polypropylene with the mechanical and thermal tests results for the final prepared sample of 56% of rice husks.

Table (3). Represents the mechanical and thermal tests results.

Composite		poly propylene	56% Rice Husks +7additaive+37% PP
Density	g/cm³	0.9	1.08
Tensile	Strength (MPa)	28.5	21.47
	Modulus (GPa)	1.53	1.35
	Elongation	5.90	4.80
Flexural	Strength (MPa)	38.3	33.21
	Modulus (GPa)	1.19	1.16
Compression	(MPa)	40.0	37.75
Hardness	Shore D	72.0	81.50
Charpy impact Energy	Unnoticed (J/m)	656	38.0
Heat	Deflection Temperature	57. ºC	145. ºC

Figure 5 reveals the improvement of thermal and some mechanical properties depending on thermal- mechanical analysis system TMA results. The increase in heat deflection from 57 °C of the matrix material (poly propylene) to 145 °C for the prepared composite. This is due to milled rice husk up to 300 µm (with high contained Lignin) as reinforcement material with poly propylene. In addition, the small particles increase linking between the polymeric chains (increase the crosslink of polymer) which leads to improve the mechanical properties[6]. That means rice husks may be bonded with poly propylene by physical and chemical bonds, where hydroxyl groups of the rice husk bond with carbon of the poly propylene through malice anhydride coupling agent [6] .



Figure(5). Shows the thermal endurance of the composite.

The objective of this study were confirmed by the results of thermal and some mechanical tests declared in the above results. It shows the possibilities of using these composites materials as non-traditional building materials.

CONCLUSIONS

The possibilities of using these composites outside door much more real able because of its resistant to high temperature compared to the matrix material (polypropylene) as well as fixed mechanical properties over wide temperature range. This increase in rice husks ratio lead to reduce the costs of non-traditional building materials and make it economically feasible.

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