Investigation on Mechanical Properties of Various Microwave Cured Natural Fibre Reinforced Polymer Composites

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Abstract

The development of natural fibre reinforced polymer composites has received widespread attention due to their environment friendly characteristics over the synthetic fibre based polymer composites. Although, different categories of natural fibre reinforced composites have been developed, their joining has not been explored extensively. In the present research initiative, natural fiber reinforced polypropylene composites have been prepared by microwave curing. The advantage of microwave processing is that it leads to significantly faster curing times compared to thermal processing. The fast heating rate encountered using microwave energy can thus lead to reduced processing time and consequent energy efficiency. In order to distinguish the effect of various fibres in the polymer matrix which is cured by microwave curing, a number of experiments were performed. Details of the experiments conducted along with the results were discussed in the paper and it concludes.
Keywords—Polymers, Composites, Microwaves Material Processing, Natural fibres

1. Introduction

The emerging trend towards development of new composites and processes which are not only cost effective but also environmentally sustainable has been observed globally. In these sense, natural fibres reinforced polymer composites has received widespread attention due to their environment friendly characteristics over the synthetic fibre based polymer composites. The present scenario has presented scientists and engineers with a challenge to replace non-biodegradable petroleum-based resins and synthetic fibres with fully bio-degradable environmentally friendly natural fibres and bio-polymers. Due to their high specific strength and modulus, natural fibre reinforced polymer composites are receiving widespread attention. Keeping these things in mind, this paper is focused on microwave processing of partially and fully bio-degradable composites. The advantage of microwave processing is that, it leads to significantly faster curing times compared to thermal processing. Natural fibres like coir, rattan and bamboo are experimented as reinforcement [1]-[4].

Significance of microwave processing

Microwaves have some special properties in material interaction energy transfer which makes it useful in processing different types of materials. Microwave heating is basically different from conventional radiation and/or convection heating. In conventional heating thermal energy is delivered to the surface of the material and transferred to the bulk of the material via conduction. Microwave energy is delivered directly to the material through molecular interaction with the electromagnetic field [5], [6].

The conventional heating results temperature gradient along the thickness direction but microwaves can penetrate and supply energy throughout the material and heat the material uniformly so that it can be called as a volumetric heating process. Therefore microwave heating helps to achieve rapid and uniform heating of thick materials. The thermal gradient in microwave processed materials is the reverse of that in materials processed by conventional heating. In conventional heating, slow heating rates are selected to reduce steep thermal gradients that lead to process-induced stresses. Likewise, in microwave heating, there is a relationship between processing time and product quality. When microwave energy is in contact with materials having different dielectric properties, it will selectively couple with the higher loss tangent material. Therefore, with microwaves, the joint interface can be heated by incorporating a higher loss material at the interface [5]-[8].

Microwaves are electromagnetic waves in the frequency band from 300 MHz (3×10^8cycles/second) to 300 GHz (3 × 1011 cycles/second). Not all materials can be successfully processed by microwave. The material properties requiring greatest consideration in microwave processing of a dielectric are the complex relative Permittivity and loss tangent. Loss tangent, dielectric loss predicts the ability of the material to convert incoming energy into heat [8],[9].

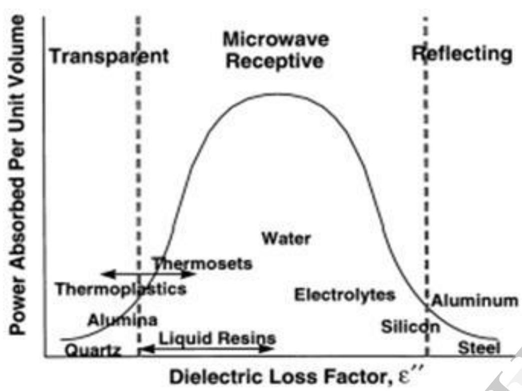


Fig.1 Relationship between the dielectric loss factor and ability to absorb microwave power for some common materials [2]

Sl. No	***Characteristic***	***Conventional processing***	***Microwave processing***
1	Heat transfer mode	Heat transfer by Conduction	Molecular interaction with the EM waves and it is energy conversion rather than heat transfer.
2	Temperature Gradient	Present; so slow heating is done to reduce steep thermal gradient.	Uniform volumetric heating and hence temperature gradient not present.
3	Selective heating of materials	Not possible	Present cause absorption of microwaves depends on the dielectric constant of materials
4	Feasibility	Every material	Not all materials
5	Time of processing	High	Low
6	Energy efficiency	Low	High

Table1.0 Comparison of microwave processing with conventional processing [8]

From the above mentioned facts, it is clear that Microwave processing results in materials with unique microstructure and properties and also aids improved product yield, time saving, energy savings, reduction in manufacturing cost and synthesis of new materials. So Microwave processing has been emerging as an innovative sintering method for many traditional ceramics, advanced ceramics, specialty ceramics and ceramic composites as well as polymer and polymer matrix composites.

From large family of composites only a few have been investigated for microwave processing therefore research exploration is required for other composite materials in natural fibre reinforced polymer matrix composite family. The exploration of feasibility of microwave curing of natural fibre composite is required [8]-[11].

2. Experimental setup

A. Mould for Microwave Curing

A number of vitrified ceramic tiles were fabricated for the microwave curing. The dimensional details of the cavity are:

Length: 150mm, Width: 20cm, Depth: 7mm

Vitrified ceramic tile was used as the moulding material because it absorbs microwave energy and gets heated, it has significantly higher melting point than the polymers used. (Polypropylene, Polyester Resin) and it has very good surface finish.

Fig.2 Mould for microwave curing

B. Natural Fibres

1. Rattan (scientific name: calameae)

Rattan is the name for the roughly 600 species of palms in the tribe Calameae, native to tropical regions of Africa, Asia and Australasia.

Fig.3 Rattan Fibres

2. Bamboo (scientific name: Bambuseae)

Bamboo is a tribe of flowering perennial evergreen plants in the grass family Poaceae, subfamily Bambusoideae, tribe Bambuseae. Giant bamboos are the largest members of the grass family. In bamboos, the internodal regions of the stem are hollow and the vascular bundles in the cross section are scattered throughout the stem instead of in a cylindrical arrangement. Bamboos are some of the fastest-growing plants in the world due to a unique rhizome-dependent system. Bamboos are of notable economic and cultural significance in South Asia, Southeast Asia and East Asia, being used for building materials, as a food source, and as a versatile raw product

Fig.4 Bamboo Fibres

3. Coir *(scientific name: Cocos nucifera)*

Coir is a natural fibre extracted from the husk of coconut and used in products such as floor mats, doormats, brushes, mattresses, etc. Technically, coir is the fibrous material found between the hard, internal shell and the outer coat of a coconut. Other uses of brown coir (made from ripe coconut) are in upholstery padding, sacking and horticulture. White coir, harvested from unripe coconuts, is used for making finer brushes, string, rope and fishing nets. [4]

Fig.5 Coir Fibre

3. Experimental procedure

Step 1: Fill the mould cavity with alternating layers of polymer and reinforcement in the desired composition.

Step 2: Put the mould inside the microwave oven and set the predetermined time of exposure and power based on the feasibility study.

Step 3: Take the mould outside, apply some pressure if possible and let the mould cool down.

Step 4: Dissemble the mould and take out the cured composite specimen.

Ceramic mould was filled with alternating layers of matrix and reinforcement in desired composition. The mould was covered and it placed inside the microwave oven and the required curing temperature is applied for predetermined time. All experiments were initially conducted for a curing time of 12 minutes at 600W power. After that mould was taken out, some pressure was applied and it allowed to cooling down. The mould was dissembled and taken out the cured composite specimen.

Fig 6 Composites of Polyproylene & Rattan

Fig. 7 Composites of Polyproylene & Bamboo

Tensile strength of the composites obtained was tested using Universal testing machine. Impact strength was measured using Charpy – impact testing machine and flexural strength was tested on a three point bending test machine.

4. Results and discussion

Following mechanical tests were performed for the characterization of microwave cured composite specimens:

1. Tensile strength test

2. Impact strength test

3. Flexural strength test

All the results along with the values taken from previous literatures were summarized in table 2.

A. Comparison of Tensile Strength of Microwave Cured Composites

From the investigation, it is clear that there is no significant variation in tensile strength of polypropylene–Rattan, polypropylene–Coir and polypropylene–Bamboo. Poly propylene-sisal fibre shows comparatively good tensile strength than the other composites. EVA -Grewia optiva shows the least tensile strength. The results obtained are shown in fig:8

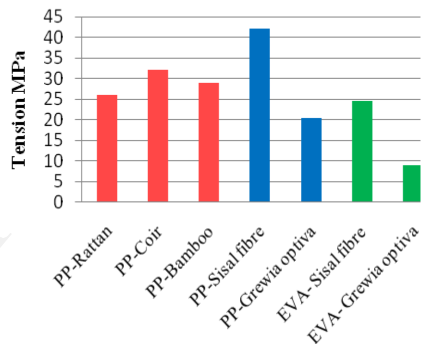
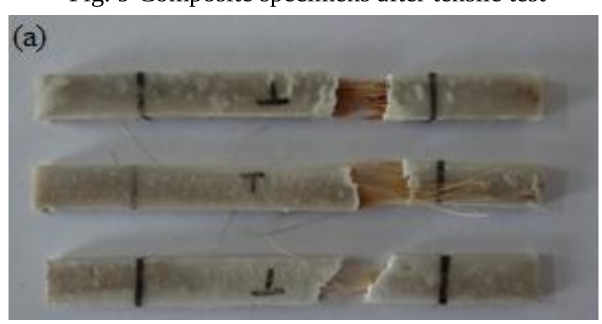


Fig. 8 Tensile strength comparison

Fig. 9 Composite specimens after tensile test



B. Comparison of Impact Strength of Microwave Cured Composites

Impact test on composites reveals that polypropylene- Bamboo and Polypropylene- Sisal fibre have equal impact strength and also the highest. There is drastic reduction in impact strength of EVA-Grewia optiva composite. The results obtained are shown in fig: 10

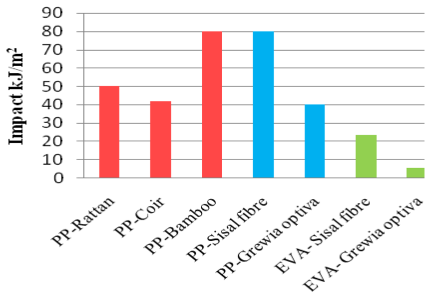


Fig. 10 Impact strength comparison

Fig 11 composite specimens after impact test

C. Comparison of flexural Strength of microwave cured composites

Test values indicate that Polypropylene –sisal fibre is having maximum flexural strength. It is also evident that Polypropylene –Coir and Polypropylene –bamboo gives higher flexural strength and is almost equivalent to that of EVA –sisal fibre.

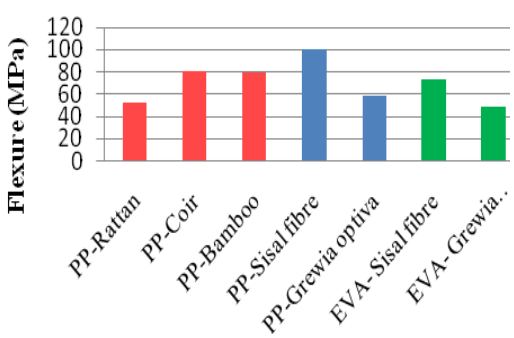


Fig 12 Flexural strength comparison

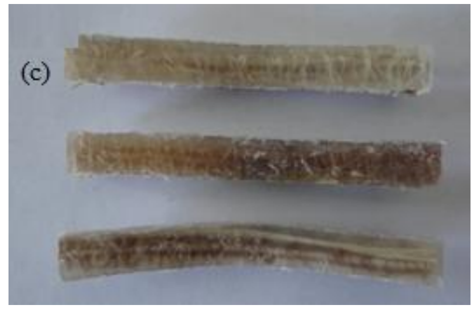


Fig. 13 Composite specimens after flexural strength test

Materials		Curing methods			
		Microwave			
Matrix	Fibre	Time (mins)	Test Values		
			Tension (MPa)	Impact (kJ/m^2)	Flexure (MPa)
Polypropylene	Rattan	12	26	50	52
Polypropylene	Coir	12	32	42	81
Polypropylene	Bamboo	12	29	80	80
Polypropylene	Sisal fibre	15	42.2	80	100.5
Polypropylene	Grewia optiva	15	20.5	40	59.3
EVA	Sisal fibre	12	24.5	23.3	73.5
EVA	Grewia optiva	12	8.9	5.5	48.9

5. CONCLUSION

Microwave processing is effective technique for curing polymer composites but there are lot of factors that have to be considered before employing microwave processing of materials. Not all the materials are suitable for microwave processing and one has to match the special characteristics of the process. Blind applications of the microwave processing may lead to production of inferior quality composites. On the basis of the present investigation, following conclusions can be drawn:

Strength of the processed polymers is slightly less than the properties of polymers shown in previous literature. This may be due to lack of application of pressure. Also, in the present set of experiments conducted inside the oven, it is not possible to apply pressure. Either pressure must be applied after curing or a mechanism to apply pressure while heating must be developed. Orientation of fibres is having very important role in the strength. Presently only layered fibres arranged in single direction was used. The strength values may improve if mesh type structure of fibres were used. The heating time and power of microwaves must be studied more and need to be optimized in future.

6. Aknoweledgment

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