Comparison On Mechanical Properties Of Microwave Cured Polypropylene Composites Reinforced With Hemp With Compression Moulding Technique.

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Abstract: In this research polypropylene was reinforced with short fibres of hemp. The composites were cured with microwave moulding technique and compression moulding. The parameters considered were different fibre content in both the manufacturing technique. In case of microwave technique power output was also considered as a parameter to observe the mechanical properties at different power output. After the composites were manufactured tensile and compressive strength were conducted on the samples cured by both the technique. The improvement in the mechanical properties of compression moulding samples were better than the microwave cured samples but time of manufacturing was much reduced in case of microwave technique. FESEM tests were conducted to know the reason of failure. It was observed that the bonding between the hemp and polypropylene was better in case of compression moulding technique and the blowholes were more in microwave cured samples. The results are discussed in the paper and it concludes.

1. Introduction

In the modern manufacturing system various products are made out of composites i.e. a heterogeneous mixture of two components. Composites have resulted in better mechanical, thermal and other properties from the parent material that is made of. Nowadays composites are reinforced with basically two types of fibres one being the natural fibres and the second being the synthetic fibres. The synthetic fibres are very costly which increases the cost of the production and the product. So researchers are trying to use natural fibres for the reinforcement material for the composites which will reduce the cost of production and the raw materials.

Various machines are developed in this modern era for obtaining composites materials with an accurate and précised shape. The machines that are commonly used for making composites are known as conventional machines or thermal machines which are categorized into injection moulding machines, compression moulding machine, transfer moulding machine, etc. The main drawback of using these machines is that these machines are very costly which increases the cost of the whole manufacturing unit. So to reduce the cost and the time of manufacturing researchers are working on various advanced techniques to create composites. One of the techniques is known as “microwave processing” which used microwaves for processing of materials.

The current manufacturing system has led to efficient utilisation of time and resources. In this recent era, The use of microwaves are generally used to cook foods but the use of microwaves to convert raw materials into finished products is a very new concept of development in the Indian technology. Microwave energy brings a lot of changes in the properties of the materials in a better way or vice versa.

Although all materials like metals cannot be processed in the microwave oven but still it brought an improvement in properties of various other materials.

The main motive to use microwaves oven in processing of material is to reduce the processing time of materials, the heat is transferred in the form of conduction, convection or through radiation. In case of microwave processing the electromagnetic energy is converted to thermal energy for the processing of material. Thus the principle of microwave processing becomes different from the conventional ones because in microwave processing heat conversion takes place rather than heat transfer.

As microwaves can penetrate within a materials thus volumetric heating can be achieved. Thick materials can be uniformly heated with the help of microwaves. Thus these are the advantages over conventional processing. Thus we can achieve volumetric heating with the help of microwave processing.
Rather than volumetric heating discriminating heating of materials is also possible in discriminating heating the materials with different dielectric properties are attached together. The microwaves will selectively pair with the materials which are likely to have high loss. Thus discriminating heating can be used in various applications.

In multistage materials some stages pair with microwaves to a greater extent than the other stages. So materials’ with different properties and microstructures can be obtained by discriminating heating of different stages of the material. Microwaves can cause chemical reactions which are a drawback in the conventional processing. Thus we can get new materials.

In spite of various advantages, microwave processing have faced various challenges too. If energy is transferred in the form of electromagnetic field then uniform heating cannot be achieved. If the material is a good absorber of microwave then it may get burnt prior to proper finishing of the process that is required. Thus “microwave interaction with the materials” gives the principle of microwave processing of materials.

1.1 Natural Fibres

Natural fibres are easily available in the nature. Nowadays various origins of natural fibres are used for making polymer composites. These natural fibres are obtained either from plants or from animals. In contrast to the synthetic fibres the natural fibres have a very low cost and are biodegradable. The main applications of plant fibres are in the composite factory. Plant fibres mainly constitutes of cellulose, lignin, micro fibril angle. The bonding between the fibre and the polymer matrix depends on the lignin constituent and the micro fibril angle. The animal fibres mainly constitutes of protein. The animal fibres are not much strong as plant fibres so plant fibres are more preferred for making composites. According to the fibre origin, plant fibres can be classified as follows:

a) Grass fibre- These fibres are obtained from the stem of the plant like bamboo and sugarcane.

b) Leaf fibre- These fibres are obtained from the leaves. These fibres run along the length of the leaves like sisal, abaca.

c) Bast fibres- These fibres are extracted from the stem’s inner bark which is also known as the plant’s phloem like hemp, jute, flax, etc.

d) Fruit and seed hairs- These fibres are the hairs around the seed or fruit like, coconut fibre.

1.2 Microwave-Material relationship

The interaction of the material with the microwaves depends on the dielectric properties of the materials to bind with. It is based on principle of dielectric losses of polar molecules.

There are mainly two elements stated below:

a) The dielectric consistency

b) The loss element

These above factors can be derived as

\[
\tan \delta = \frac{\varepsilon''}{\varepsilon'} \tag{1}
\]

\[
\varepsilon^* = \varepsilon' - i\varepsilon'' \tag{2}
\]

Here \( \varepsilon' \) is the dielectric constant which denotes the entry of microwave inside the material. \( \varepsilon'' \) is the loss factor which denote the energy storing capacity of the material. \( \tan \delta \) is the tangent loss which denotes the heat conversion from the electromagnetic waves.

Classification of materials in terms of dielectric effects:

1. Permeable - In this the microwaves can pass through very easily without any energy loss thus they have a very less dielectric deficiency.

Example- Teflon

2. Non-permeable – These materials do not allow the entry of microwaves.

Example- Metals

3. Absorbing- They have very high dielectric loss. They can absorb electromagnetic waves.

Example- Silicon carbide (SiC)

4. Mixed Absorber- Two phase elements are present which absorb microwaves in respect to their dielectric effects.

Example- Composites
1.3 Heating technique of microwave
As compared to the conventional processing of materials the microwave processing is not alike. It depends on the magnetic and dielectric phases of the material to be processed. Microwaves can only penetrate through materials with the help of polarization or ionic conduction. Polarization requires very short range transfer of the charge through circulation of dipoles of a magnet (electric dipoles). The ionic conduction method involves a very long transfer of charge. The superiority of the ionic conduction at low frequencies leads to the dielectric losses and immersion losses. The more is the frequency the less is the ionic conduction. The charge transfer time reduces with the increase in the frequency. The relevant elements necessary for processing of material through microwave are:
1. Power required (I)
2. Penetration capacity (C)

1.4 Polymer Matrix Composite
Polymer matrix composites (PMC) constitutes of a collection of short-end or consecutive fibres attached together by a biotic polymer matrix. In a ceramic composite the reinforcement is used only to extend the fracture toughness but in polymer matrix composite both the strength and stiffness increases by the addition of the reinforcement. The PMC are arranged in such a way that the mechanical weight of the structure that is taken into account is given support by the reinforcement. The main work of the matrix is to bind the fibres together and load distribution among the fibres. Categorization of the PMCs is mainly done into two parts: reinforced plastics, and “advanced composites”. The categorization is based on the mechanical attributes. There is no apparent line distinguishing the two. Reinforced plastics are not too much expensive, they mainly constitutes of polyester resins reinforced with glass fibres having minor-stiffness. Advanced composites, were basically used in the aerospace manufactory. They are very costly but have exceeding strength and firmness. The basic characteristic of PMCs is their low density paired with superior firmness and strength in the reinforcement’s direction. For the above characteristics PMCs are used in aircraft, automobiles, and other affective constructions. Other attributes of PMC are high corrosion and fatigue resistance unlike metals. PMCs are bound to temperatures below about 305°C because they decompose at a high temperature.

2. Experimental Setup

2.1 The Experimental Procedure of microwave moulding process:
Step 1- The volume of the mould is measured first with the help of vernier calliper. The density of PP is known. So now the mass of PP is found out for the specific volume by the formula.

\[
\text{Mass} = \text{volume} \times \text{density}
\]

Fig 2. Mould (B10)

Step 2- Now from the total mass 5% (according to the research) of the mass is subtracted. This 5% mass of PP subtracted is replaced by the fibre.

Step 3- The 5% fibre and the 95% PP is mixed uniformly and poured into the mould. For this research short fibre of hemp of 5-6 mm length is taken into consideration.

Step4- Floor tiles are used as the pressure plate for applying force from the top. Floor tiles have the same dimension as the mould area from the open side with approx.± 1mm clearance from each side so that the pressure plate can be easily taken out after the solidification of the composite.

Step 5- Now the whole setup of the mould along with the pressure plate is put into Teflon clamps. The screws are tightened to apply pressure on the pressure plate.
Step 6- Now the role of fire bricks come into play. Some pieces of fire bricks are cut so that a flat base is obtained for the whole setup, especially for putting the silicon carbide on it. Some small pieces are also cut to adjust the mould height from the susceptor otherwise the PP will not melt properly but the fibre will get burnt.

Step 7 - Before the height adjustment is done, the SiC powder is poured at the centre of the base for evenly heating of the mould and samples are made and observed, and accordingly the optimum height is achieved.

Step 8 - The whole moulding unit held by the fixture (Teflon clamps) is mounted on the base of fire bricks along with the susceptor at the centre of the base. Now the whole setup is put inside the microwave oven.

Step 9 - The power knob is kept at the top level (4th) i.e. 700 Watt (according to this research) and a random time is set. When the time is over both the mould’s and the pressure plate’s temperature is measured with the help of infrared thermometer. Now the composite is let to cool down.

Step 10 - After the solidification the pressure plate is removed and the composite is taken out and necessary observations are made.

Step 11 - If the sample is not perfect the processing time is increased or decreased according to the observation to the optimum temperature of manufacturing. The optimum temperature for this research is 170-190°C. The optimum temperature for 700 W was found out to be 8 min and in case of 595 W the processing time was 9 min.

Limitations

- More than 15% fibre cannot be added as the mould according to this research is very small so during the processing the fibres ejects out along with the plastic which becomes waste.
- Time optimisation is very important as a little increment in the time increases the in heat inside the microwave which may burn the fibre and proper sample cannot be achieved.
- After processing of one sample the microwave should be left to cool down otherwise the magnetron inside the microwave might get damaged and the plate rotator might melt.

If the microwave doesn’t cool properly the sample will be pre-processed which will mislead to time optimisation and the actual optimised time cannot be achieved.
2.2 The Experiment Procedure for compression moulding process-

**Step 1** - First the granules are spread over a two roll mill where the granules come in molten state as the rolls get heated up. According to this experiment the melting temperature was taken as 190°C and roll rpm was 40.

**Step 2** - Now in this molten plastic the required amount of fibres (in this case 5%, 10% and 15 % of hemp) are added from top to get a proper coupling between the plastic and the fibre. This sample is let to cool down. In this case the mixture is a circular bulk of the composite which needs to be flattened for performing various tests.

**Step 3** - The above technique is known as compounding and each compounding takes about 10-25 minutes depending on the sample to be made.

**Step 4** - After obtaining the circular bulks of polymer fibre composite of different fibre composition these sheets are carried forward for compression moulding. For this experiment a hand compression moulding was used.

**Step 5** - In this technique there are two metal plates which covers the mould from top and bottom in which silicon spray is applied for proper extraction of the sample from the mould.

**Step 6** - Now the lump of composites obtained from compounding are put into the mould and it is pressed at a pressure of 50kgf/cm² and at a temperature set of 190°C for 30 seconds. This is known as the breathing pressure which is applied to evacuate the air to prevent blow holes. Now the apparent compression pressure is applied which varies from 180-200 kgf/cm². This pressure is applied for 10 minutes for proper forming of the composites.

**Step 7** - After 10 minutes the compression pressure is released and the mould is let to cool down. After cooling the sample is extracted out from the mould. This is the final sample achieved.

3. Results and Discussion

The actual tensile strength of PP is - 28MPa.

The actual compressive strength of PP is - 24MPa

The tensile strength and compressive strength at different power outputs by microwave moulding technique are stated below:

<table>
<thead>
<tr>
<th>Test parameters</th>
<th>5% hemp</th>
<th>10% hemp</th>
<th>15% Hemp</th>
</tr>
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<tbody>
<tr>
<td>Tensile strength</td>
<td>45</td>
<td>51.7</td>
<td>62.4</td>
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<tr>
<td>Compressive strength</td>
<td>24.8</td>
<td>32.7</td>
<td>39.1</td>
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<table>
<thead>
<tr>
<th>Test parameters</th>
<th>5% hemp</th>
<th>10% hemp</th>
<th>15% Hemp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength</td>
<td>53.8</td>
<td>59.9</td>
<td>64.2</td>
</tr>
<tr>
<td>Compressive strength</td>
<td>30</td>
<td>35.5</td>
<td>40.7</td>
</tr>
</tbody>
</table>

The tensile strength and compressive strength by compression moulding at different fibre content are stated below:

<table>
<thead>
<tr>
<th>Test parameters</th>
<th>5% hemp</th>
<th>10% hemp</th>
<th>15% Hemp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength</td>
<td>55.4</td>
<td>61.2</td>
<td>67.7</td>
</tr>
<tr>
<td>Compressive strength</td>
<td>74.9</td>
<td>75.8</td>
<td>79.3</td>
</tr>
</tbody>
</table>

Fig 6_Comparison between 595 W and 700 W of hemp based on tensile strength in microwave technique
Fig 7. Comparison between 595 W and 700 W of hemp based on compressive strength in microwave technique

Fig 8. Comparison between microwave molding and compression molding on the basis of tensile strength

Fig 9. Comparison between microwave molding and compression molding on the basis of compressive strength

Fig 10. Pores in compression moulding
4. Conclusion

- It can be concluded that the tensile and compressive strength has increased from the parent polymer's strength in case of microwave moulding on increasing the fibre content.
- In case of compression moulding the tensile strength has also increased from the apparent value of strength of the polymer and also the compressive strength has increased to a large extent in contrast to the microwave moulding technique.
- The content of blowholes and other manufacturing defects are observed more in microwave moulded samples rather than compression moulded samples as microwave technique is not much precised yet.
- The overall betterment of strength is achieved in compression moulded samples.
- To produce better samples within a cheap rate of manufacturing, microwave process can be preferred.
- The more is the power output the lesser is the manufacturing time in case of microwave moulding technique and better results can be achieved.
- In case of compression moulding, the power consumption is very high as compared to microwave moulding technique as for producing bulk moulded compound in compression moulding technique two machines are required, one for compounding and the other for compressing which consumes high power individually.
- Both the tensile and compressive strength has increased in both the manufacturing technique with the increase in fibre content.
4.1 Recommendations

- After performing this research, compression moulding technique is recommended as the overall mechanical properties are better than microwave moulding technique.
- The setup cost and power consumption is less as compared to compression moulding, thus microwave technique is recommended.
- The production time is very less in case of microwave moulding technique rather than compression moulding, thus microwave technique must be preferred much for faster production rate.
- If power output can be increased then better composites can be achieved at lesser time in case of microwave technique.

4.2 Future scope

- This research can be carried out on various fibres like sisal, grewia optiva, coir, abaca, etc.
- Various length of fibres can be considered like short fibres, long fibres, mat-form fibres to compare with.
- Various other moulding techniques can be used like Injection moulding, transfer moulding for comparison.

5. References