Experimental Analysis over Natural Fibre (Sisal) Reinforced Composite, With Microwave and Compression Moulding

Kunal Chopra¹, Prag Sharma² & Abhishek Singh Jatav³
Suresh GyanVihar University ¹, IIT Roorkee², Rajasthan Technical University³

Abstract: The research deals with reinforcement of polypropylene with sisal short fibres. The composites were processed with microwave moulding and compression moulding. The parameters considered were varying amount of fibre percentage for either technique. In microwave moulding, power output parameter was also entertained specifically, justifying mechanical properties at different levels of power. Composites once ready, by both manufacturing technique were introduced with tensile and compressive strength testing. Though the compression moulding won the case of enhancing mechanical properties, but time of manufacturing in microwave was much less than conventional. Optical microscope test was conducted to paper to have better look around of failures. The respective comparison, theory, and conclusion is discussed in the thesis.

Introduction

We now live in a world that is changing and growing at constant rate. Every other day we are introduced with latest innovations which are two steps further than the previous. Feasibility and effective techniques are the major keywords. Vision through new eyes has led to the development of latest and desired technologies in the world of manufacturing.

We are only aware of microwave as a household device, and are only known with its application in food industries. But its boundaries are far widespread than just what we know if we see it technically. It is used to enhance properties of material, change the state of substance and is economically sound and procedurally very effective in manufacturing.

Conventional methods like Injection moulding, Compression moulding, Open moulding etc. Has transfer of heat taking place which creates direct impact over the molecules of the material and that results in release of energy from the surface of the material, while in microwave technology energy is delivered directly to the material by molecular interaction, it is basically transition from one form of energy to the other.

Certain materials like metals cannot be worked within a microwave but properties of other materials like resins, plastics can be improved.

In comparison to other thermal processing methods microwave has resulted in reducing the manufacturing time and cost of production. In the process of microwave manufacturing technique the heat can be transferred by either conduction convection or radiation. In this type of processing the electromagnetic energy is changed to heat energy which is further used for the material processing. This characteristic of microwave technique makes it different from the other conventional technique as heat conversion takes place in the former case where as heat transfer takes place in the later processing technique.

In case of microwave technique volumetric heating of materials can be achieved as the microwaves can enter the materials and heat the whole volume of the material. Microwave technique has certain disadvantages too as a material being a good microwave absorber can get burnt before the processing time.

1. Microwave Heating Mechanism

The heating and processing done through microwave process is entirely different from that of conventional one. It majorly depends over the magnetic and dielectric properties of the material under subject.

To ingest microwave, it basically has two paths, either through polarization or ionic conduction processes. Polarization involves short-range displacement of the charge through formation and rotation of electric dipoles (or magnetic dipoles). While the latter deals with the long range travel of charges. Both boil down to absorption losses in some frequency ranges. Ionic conduction being dominant at low frequencies results in absorption losses, ε˝ , while at higher frequencies rotation of permanent dipoles are likely. As we know that our
ions flow at very high velocities, so when they interact with the other material they incur ionic conduction losses, the phenomenon also termed as ohmic losses. As time allowed for transport in the direction of fields is indirectly proportional to rising frequencies so hence Ionic conduction also decreases with increasing frequencies. The relation is simple, increase in temperature leads to increase in kinetic energy of dipoles, in this way the system responds quickly to the oscillating fields and shifts the curving curves to the upper frequencies.

Fig 1: Mechanism of microwave heating [4].

Two important factors for microwave processing are power absorbed (P) and depth of microwave penetration (D). The power absorbed per unit volume, P(W/mm³) is

$$P = 2\pi f_0 \varepsilon' \tan \delta |E|^2$$

$$D = \frac{3\lambda}{6.686 \tan \lambda (\varepsilon' / \varepsilon_\circ)^{1/2}}$$

Where E is magnitude of internal field, $\varepsilon_0$ is permittivity of free space, f is the microwave frequency, $\varepsilon'$ is dielectric constant, $\tan \delta$ is loss tangent, D is depth of penetration at which incident power is reduced to one half and $\lambda$, is the incident wavelength.

1.1 Microwave Hybrid Heating

Transparent materials as we know are pretty much difficult to heat by microwave, but it is seen that some of them respond to elevated temperatures and heating can take place. So by some source of heat, preheating up to a critical temperature can be done for these materials. This methodology of heating is named as “Hybrid Heating”. In this way additional amount of heat could be supplied to our subject, which helps in reducing processing time and proper heating.

Now apart from this, another method of hybrid heating also comes into play. We use susceptors like SiC powder, or Carbon powder which we place inside the microwave along with our subject. Being a good absorber and radiator, they initially absorb heat from microwave and once heated they release energy and supply heat to our specimen.

2. Compression Moulding

In the modern age compression moulding technique has been considered for producing plastics and polymer composite products. Various products can be generated with the help of compression moulding technique ranging from simpler structures like fuse box, pot handles, automotive parts, aircraft parts etc. The machining cost of compression moulding is very less compared to injection moulding and transfer moulding. In a compression moulding the plastic is in a molten state which is pressed into the mould by high pressure and heated to get the desired shape.

3. Polymer Matrix Composite

The constituents of polymer matrix composites are a collection of short-end or consecutive fibres bonded to each other by a biotic polymer matrix. To extend the fracture toughness in case of ceramic composite the reinforcement is used. But in polymer matrix composite both the strength and stiffness increases by the adding reinforcement. The PMC are arranged in such a way that the whole weight of the structure that is considered is supported by the reinforcement. The main motive of the matrix is fibre binding and load distribution among the fibres.

PMC’s are classified into two parts: reinforced plastics, and “advanced composites”. The classification is done on the basis of mechanical attributes. There is no specific line differentiating the two. Reinforced plastics are not too costly, the basic constituent are of polyester resins reinforced with glass fibres having low-stiffness. Advanced composites, were mainly used in the aeronautic industry. They are very costly but have high mechanical strength and firmness.

The main property of PMCs is their low density coupled with high mechanical firmness and strength in the direction of the reinforcement. For the above properties PMCs are used in aircraft, automobiles, and other affective constructions. Other characteristics of PMC are high corrosion resistant and fatigue resistant unlike metals. PMCs decompose at a high temperature so they are bound to temperatures below about 305°C.

The Experimental Procedure of microwave moulding process:

Step 1- The capacity of the mould is calculated by the help of vernier calliper. The density of PP is identified. Now the quantity of PP is established out for the definite capacity by using the formula.

$$\text{Mass} = \text{volume} \times \text{density}$$
Step 2- Now 5% (according to the research) of the total mass is deducted. This 5% mass of PP deducted is substituted by the specific fibre.

Step 3- The fibre and the PP is mixed homogeneously and decanted into the mould. According to this study short fibre of sisal of 20-30 mm long is considered.

Step 4- Floor tiles are used as a compression plate for smearing force from the topmost. Floor tiles should have almost the same measurement as the mould area from the open half with approx.±1mm allowance from all side so that the compression plate can be easily ejected out next to the hardening of the composite.

Step 5- Next the entire arrangement of the mould along with the compression plate is placed inside the Teflon clamps. Now the screws are constricted to smear pressure on the compression plate.

Step 6- Henceforth the part of fire bricks are taken into consideration. Selected portions of fire bricks are cut so that a flat base can be made for the whole setup, particularly for placing the silicon carbide. Certain small pieces are also cut for adjusting the mould’s height from the susceptor or else the PP will not liquefy appropriately instead the fibre will get burnt.

Step 7- Prior to the height adjustment, the SiC powder is placed at the middle of the base for uniformly heating of the mould and then models are prepared and detected, and therefore the finest height is attained.

Step 8- The entire moulding element is held by the fixture (Teflon clamps) and is placed on the base made of fire bricks, with the susceptor at the middle of the the fire brick. Next the entire arrangement is put within the microwave oven.

Step 9- Now the power control knob is set at the highest level (4th) i.e. 700 Watt (according to this experiment) and a haphazard time is fixed. After the time is over both the mould’s and the pressure plate’s temperature is determined by the use of infrared thermometer. Currently the composite is left to cool down.

Step 10- After the composites gets solidified, the compression plate is detached and the composite is extracted out and essential interpretations are prepared.

Step 11- If perfect samples are not attained then the treating time is amplified or diminished according to the observation till the optimum temperature of manufacturing is attained. The optimum temperature for this research is 170-190°C. The optimal time for 700 W was established out to be 6 min and 40 secs and in case of 595 W the manufacturing time was 7 min and 50 secs.

Step 12- The above process is conducted again in case of 700 Watt with 10% and 15% of sisal fibre and 595 W with 5%, 10% and 15% of sisal fibre correspondingly.

Fig 2. The whole setup of microwave Technique

Fig 3. Composite processed by microwave

The Experiment Procedure carried out for compression moulding technique-

Steps 1- Initially the pellets of PP are spread over the two roll mill where the pellet changes its phase to liquefied state as the rolls gets heated up. For this experimentation the melting temperature was considered as 190°C and roll speed was 40 rpm.

Step 2- Now in this liquefied state plastic the mandatory quantities of fibre (in this case 5%, 10% and 15 % of sisal) are spread from top to get a proper combination between the plastic and the sisal fibre. This sample is now left to cool down. In this technique the mixture is a globular bulk of the composite which needs to be flattened further for conducting various tests.
Step 3 - The above procedure is identified as compounding technique and each compounding takes about 10-25 minutes dependent on the sample to be prepared.

Step 4 - Subsequently attaining the globular bulks of polymer fibre composite of different fibre composition these mass is carried forward for compression technique. For this experimentation a hand compression moulding machine was used.

Step 5 - In the compression technique there are two metal square plates which acts as a concealment from the top and bottom of the mould in which silicon spray is applied for proper withdrawal of the sample from the mould.

Step 6 - Next the bulk of composites attained from compounding technique are put inside the mould and it is compressed at a pressure of 50kgf/cm² and at a temperature of 190°C for 30 seconds. This is recognized as the breathing pressure which is applied to vacate the air from the mould to avoid blow holes. Now the actual compression pressure is applied which fluctuates from 180-200 kgf/cm². This compression pressure is applied for min. 10 minutes for proper development of the composites.

Step 7 - After 10 mins the compression pressure is unconfined and the mould is left to cool. Next to cooling the sample is taken out from the mould. This is the ultimate sample attained.

4. Results and Discussion

The definite tensile strength of polypropylene is 28MPa.

The authentic compressive strength of polypropylene is 24MPa

Table 1. Mechanical properties of microwave produced composite at 700 W

<table>
<thead>
<tr>
<th>Test parameters (595 Watt)</th>
<th>5% sisal</th>
<th>10% sisal</th>
<th>15% Sisal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength</td>
<td>44.30</td>
<td>48.40</td>
<td>54.30</td>
</tr>
<tr>
<td>Compressive strength</td>
<td>27.70</td>
<td>32.70</td>
<td>40.20</td>
</tr>
</tbody>
</table>

Table 2. Mechanical properties of microwave produced composite at 595 W

<table>
<thead>
<tr>
<th>Test parameters (595 Watt)</th>
<th>5% sisal</th>
<th>10% sisal</th>
<th>15% Sisal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength</td>
<td>45.30</td>
<td>49.80</td>
<td>53.40</td>
</tr>
<tr>
<td>Compressive strength</td>
<td>35.10</td>
<td>37.80</td>
<td>40.70</td>
</tr>
</tbody>
</table>

Table 3. Mechanical properties of composites Produced by compression moulding

<table>
<thead>
<tr>
<th>Test parameters (595 Watt)</th>
<th>5% sisal</th>
<th>10% sisal</th>
<th>15% Sisal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength</td>
<td>55.80</td>
<td>59.50</td>
<td>62.70</td>
</tr>
<tr>
<td>Compressive strength</td>
<td>73</td>
<td>82.50</td>
<td>84.8</td>
</tr>
</tbody>
</table>

Fig 4. Comparison between 595 W and 700 W cured sisal based on compressive strength
Comparison between microwave moulding and compression moulding on the basis of tensile strength

Comparison between microwave molding and compression molding on the basis of compressive strength
5. Optical microscope images of sisal reinforced composites

6. Conclusion

- It can be determined that the tensile and compressive strength has improved from the base polymer’s asset in case of microwave technique on increasing the fiber percent.
- By using compression molding the tensile strength has also increased from the strength of the base polymer and the compressive strength has also increased to a great amount in comparison to the microwave technique.
- The count of blowholes and other imperfections are more in microwave molded samples relatively than compression molded samples as the microwave molding is not much accurate up till now.
- To create improved samples within an inexpensive rate of manufacturing, microwave process can be favored.
- The more is the power output the smaller is the time of manufacturing in case of microwave technique and improved results can be attained.
- The power consumption is very high in compression technique in contrast to microwave technique as for manufacturing the necessary samples in compression molding technique two machines are required, first one for compounding technique and the second one for compression technique which consumes a large amount of power individually.
- It has been observed that both the tensile and compressive strength has improved in both the manufacturing techniques with the addition of fiber content.

7. Future scope

- This examination can be carried out on several fibers like sisal, nettle, coir, abaca, etc.
- Various fiber lengths can be taken into account like short fibers, long fibers, mat-form fibers.
- Various other casting techniques can be taken into consideration like Injection molding, transfer molding, etc.

References

6. Titto John George, Nebu Jacob, Frenosh K Francis, Manu Joseph, “Investigation on


