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Selection of teak sawdust polypropylene composite's composition for outdoor applications using TOPSIS analysis

ANIL KUMAR YADAV* and RAJEEV SRIVASTAVA

Department of Mechanical Engineering, MNNIT Allahabad, Allahabad 211004, India
e-mail: anilhbtik@gmail.com; rajmnnit@mnnit.ac.in

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Abstract. Selection of a material for their end use in engineering applications depends on the properties of materials. In this paper, physical and mechanical properties of teak sawdust-polypropylene composite are evaluated and most suitable composition for outdoor applications have been determined by using TOPSIS technique of optimization. Virgin and recycled polypropylene are mixed with teak sawdust to fabricate the composite with and without maleated polypropylene (MAPP) using compression molding method. TOPSIS technique of optimization involves prioritizing the performance indicators. Important properties such as tensile strength, flexural strength, impact strength, hardness, melt flow index, water absorption and thickness of swell are selected for the study. The composition 50% recycled polypropylene, 45% wood sawdust and 5% MAPP by weight is found to be most suitable for outdoor applications.

Keywords. TOPSIS; wood plastic composite; water absorption; MAPP; teak sawdust; eco-friendly materials.

1. Introduction

The increasing concern towards environmental issues related to disposal of plastics has resulted in the use of eco-friendly materials such as natural fiber or wood particles with polymers. Polymer filled with natural fiber or wood particles are known as wood plastic composite or green composites. Wood plastics composites are attractive as they are biodegradable, recyclable and cost-effective. They also have high specific strength, stiffness and durability [1]. The use of natural fillers in the polymer matrix reduces the cost and increases the biodegradability of the composite. However natural filler have disadvantages of water absorption and degraded in presence of ultraviolet rays. These disadvantages can be overcome by using the additives and ultraviolet stabilizer [2]. Reuse of polymeric waste reduces the use of virgin polymeric materials and it also reduces the carbon foot print of plastics. WPCs are generally the mixture of wood and plastics having a ratio 50:50 by weight polypropylene (PP), Polystyrene (PS), polyvinyl chloride (PVC), polyethylene (PE), and polyethylene terephthalate (PET) are important thermoplastics utilized for fabrication of WPCs. Thermoplastics are easily recyclable which makes WPCs recyclable[3, 4]. Bonding between wood particles and polymers is poor due to their chemical properties which affects the properties of the WPCs [5]. The adhesion of polymers with wood particles can be enhanced by use of coupling agents in small amount 0 to 5%. Coupling agents improve the performance of wood plastic composites. The maleic anhydride grafted polypropylene (MAPP), methyl amino propyltrimethoxysilane (MAP), polyethylene based epolene G-2608, and Polypropylene based epolene E-43 are generally used as coupling agents in the fabrication of WPCs to increase the interfacial adhesion between wood and polymers [6–8]. Physical and mechanical properties of WPCs attract the researcher as they are suitable for indoor and outdoor applications. Selection of material for a particular application is done according to properties of material. The success of any product can be evaluated by its lifespan, performance and cost associated with it.

Teak wood availability is more in India and its sawdust is generated during the processing of it. Teak sawdust and high density poly ethylene (HDPE) composite is fabricated and properties are explored in the literature [9]. Teak saw dust and epoxy composite is also fabricated in the literature but polypropylene and teak saw dust composite is not available in the literature. Propylene and teak saw dust composite is new composite and its properties are also new thus this novel composite and its properties attract us. Teak sawdust and virgin/recycled polypropylene composites have been fabricated. Wood content varied from 20% to 50% by weight in the polymer matrix. The specimens with 40% and 50% wood content are prepared with and without MAPP, six different types of compositions of virgin and recycled polypropylene composites are prepared. The composite should be strength full, weatherproof and posses no biological decay. It has been found that mechanical

*For correspondence
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properties of the WPC degrade due to water absorption. Water intake by the composites changes according to temperature [10]. The composite for outdoor applications composite should have minimum water absorption and good mechanical properties.

Selection of materials in design and development of any product is a challenging issue for the engineers. Material selection process is conventionally done by hit and trial method. A logical and systematic approach is required to select the most suitable material among the available alternatives and eliminate all incompatible alternatives [11].

In this paper, selection of the most suitable composite composition for outdoor application is determined using TOPSIS technique. TOPSIS technique is a multi-criteria decision analysis which provides more realistic solution on the basis of ranking. It can be applied in several fields like supply chain management, marketing, material selection, nuclear power, human resource management and business management, etc. Properties of composites like tensile strength, flexural strength, impact strength, hardness, melt flow index, water absorption and thickness of swell have been considered as important performance indicators for selection of most suitable composition for outdoor applications.

2. Materials and methods

2.1 *Materials*

Virgin polypropylene (VPP) has been procured from Repole dealer M/s Durga Polymers and recycled polypropylene (RPP) is arranged from a local recycling plant in the form of granules. These granules are dried at 65°C for 12 hours. Teak wood sawdust is used as filler, it was arranged from a local sawmill and dried at 110°C for 24 hours. The wood particles size of 200–250 μm have been used in the fabrication of composites. Maleated polypropylene (MAPP) is used as a coupling agent in the fabrication of the composites.

2.2 *Composite preparation*

Virgin PP/recycled PP and wood particles are compounded by a twin screw extruder. The extruder is programmable logic controlled (PLC) and has four temperature zone of 160°C, 170°C, 180°C and 190°C, respectively. The screw speed is 90 r.p.m. at barrel pressure of 40 bar [figure 1a]. The materials are compounded in a batch of one kilogram as given in table 1.

The compounded materials come in the form of wire through a bath tub and cut in small granules by a cutting machine as shown in figure 1b and c (Tables 2, 3, 4, 5).

These granules are kept at 75°C for 4 hours to remove the moisture using an air circulatory oven. Composite sheets are fabricated using compression molding process. The granules are pressed in a die of dimension 180 mm × 150 mm × 3 mm with a pressure of 5 ton at 200°C for 4–5 min [see figure 1d].

3. Experiments

3.1 *Tensile test*

Tensile tests are conducted using TINIUS OLSEN Universal Testing Machine of 10 kN capacity according to ASTM D638-14 standard [12]. The standard test specimens of dumb-bell shape are cut from the fabricated sheets as shown in figure 2. The computerized machine is supported by Q MAT software. Three specimens of each composition are tested at crosshead speed of 5 mm/min with a load of 5 kN load cell at room temperature 24°C. The fractured specimen is shown in Figure 3. Average values of tensile strength are reported in this paper.

3.2 *Flexural test*

Flexural tests are conducted on the same machine at crosshead speed of 2.8 mm/min with a load of 2.5 kN using ASTM standard D790-03 for three-point bending test [13]. Test specimens of dimensions 76.2 mm × 25.4 mm × 3.2 mm are cut from the fabricated composite sheets. Three specimens of each composition are tested at 24°C with the relative humidity of 50 ± 5%.

3.3 *Impact test*

The experiments are performed on Presto Impact Testing Machine according to ASTM D256-10 standards [14]. Three specimens of size 63.5 mm × 12.5 mm × 3.2 mm are cut from the sheets and a notch of 42°C is cut in every specimen by notch cutting machine and tested according to given standard.

3.4 *Hardness test*

Hardness test of the specimens has been performed according to ASTM D-2240 standards [15]. All tests are performed by digital Presto Shore-D testing machine. Three points are randomly tested and average value of three different points data has been recorded for every specimen.

3.5 *Melt flow index test*

Melt flow index test has been performed according to ASTM D1238-12 standard [16] by following the procedure of time flow rate measurement. It is defined as the mass

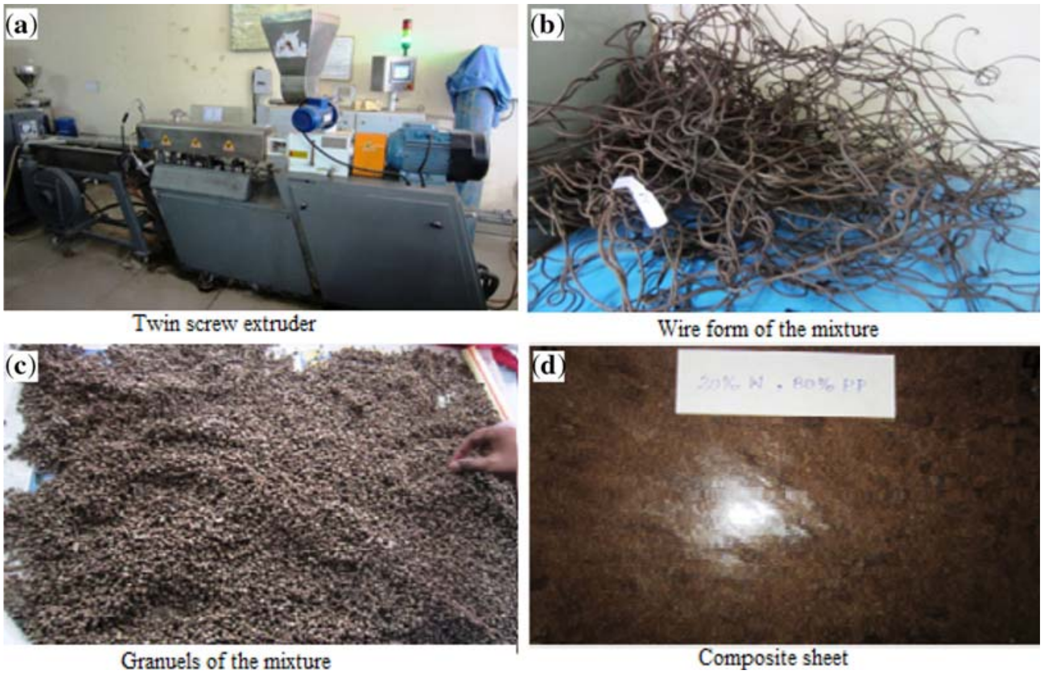

Figure 1. Manufacturing process of composites.

Table 1. Formulations and specimens code.

	Composite code				
S. no.	Virgin polypropylene	Recycled polypropylene	Wood sawdust (%wt)	Polypropylene (%wt)	Coupling agent (%wt)
1	V1	R1	00	00	00
2	V2	R2	20	80	00
3	V3	R3	30	70	00
4	V4	R4	40	60	00
5	V5	R5	50	50	00
6	V6	R6	50	47	03
7	V7	R7	50	45	05

flow rate of polymer (in grams) through a capillary of specified diameter and length in 10 minutes by an applied gravimetric pressure of 2.16 Kilogram at the prescribed temperature of 230°C.

3.6 *Water absorption test*

Water absorption test is conducted according to ASTM D570-98 standards [17]. The specimens are heated in air circulatory oven for 24 hours at 105°C to remove the moisture content and cooled in desiccators. The test specimens are placed in the container of distilled water at a maintained temperature of 24°C for 24 hours. Specimens are wiped properly and weigh at the interval of 24 hours with an accuracy of 0.001 gm. Water absorption has been recorded using the following equation:

$$WA(\%) = \frac{W_f - W_i}{W_i} \times 100 \quad (1)$$

where W_i and W_f are the initial and final weight of the specimen before and after immersion in the water. Three specimen of each composition have been tested and average value of them is reported in this paper.

3.7 *Thickness of swell test*

Thickness swelling of the composites is measured with micrometer having least count of 0.01 mm. The thickness

Table 2. Criterion data.

S. no.	Composite	Tensile strength (MPa)	Flexural strength (MPa)	Impact strength (MPa)	Hardness Shore-D	Melt flow index (10 g/min)	Water absorption (%)	Thickness of swell (%)
1	V2	30.25	42.65	329.01	61.6	10.96	0.28	0.24
2	V3	28.46	38.44	240.43	63.3	8.68	1.90	1.76
3	V4	26.85	34.17	198.76	66.8	7.05	3.25	3.04
4	V5	24.45	29.47	168.33	68.7	5.87	5.17	4.94
5	V6	32.08	51.41	196.84	70.2	5.95	1.66	1.45
6	V7	34.18	53.64	222.50	73.4	6.02	1.32	1.21
7	R2	31.34	44.23	267.50	63.5	8.02	0.25	0.21
8	R3	29.35	40.77	198.68	66.0	6.21	1.65	1.45
9	R4	27.67	36.84	165.70	68.2	5.02	2.95	2.75
10	R5	25.88	32.75	132.89	70.7	4.32	4.68	4.35
11	R6	33.21	52.41	178.90	72.6	4.42	1.27	1.13
12	R7	35.4	54.15	188.78	76.5	4.48	1.15	1.05
Ideal solution		35.4	54.15	329.01	76.50	10.96	0.25	0.21
Worst solution		24.45	29.47	165.70	66.00	4.32	5.17	4.94

Table 3. Decision matrix.

S. no.	Composite	Tensile strength (MPa)	Flexural strength (MPa)	Impact strength (MPa)	Hardness Shore-D	Melt flow index (10 g/min)	Water absorption (%)	Thickness of swell (%)
1	V2	7	7	9	5	9	9	9
2	V3	5	6	7	4	8	8	8
3	V4	4	4	5	5	7	5	5
4	V5	3	4	4	6	3	3	4
5	V6	6	6	5	7	6	6	6
6	V7	8	8	8	8	5	7	7
7	R2	7	7	8	3	8	8	8
8	R3	6	6	6	4	6	7	7
9	R4	5	4	5	5	5	5	5
10	R5	4	3	3	5	4	4	3
11	R6	8	8	6	8	4	6	6
12	R7	9	9	7	9	5	7	7

swell (TS) of specimens are measured by using the following equation:

$$TS(\%) = \frac{\delta_f - \delta_i}{\delta_i} \times 100 \qquad (2)$$

where $\delta_i$and δ_f are the initial and final thickness of the specimen before and after immersion in the water. Three specimen of each compound have been tested and average value of them is reported in this paper.

3.8 *Microstructure examination*

The microstructure of the tensile fracture surface is analyzed using ZEISS Scanning Electron Microscope. Each specimen is coated with gold and analyzed at 300X and 500X magnifications at 15 kV.

3.9 *TOPSIS technique*

TOPSIS was first introduced by Yoon in 1980 and modified by Hwang and Yoon in 1981. This is a multi-criteria decision making (MCDM) problem-solving technique based on the selected alternatives which should have a minimum Euclidian distance from positive ideal solution (PIS) and maximum from negative ideal solutions (NIS). TOPSIS analysis determines the rank of the available alternatives. The best or ideal solution gets the highest rank and the worst solution is given least preference.

3.9a *Selection methodology*: TOPSIS analysis technique provides rank base selection solution of a problem among the available choices. Selection of best composite composition in the available compositions has been shown in figure 4.

Table 4. Normalised matrix.

S. no.	Composite	Tensile strength (MPa)	Flexural strength (MPa)	Impact strength (MPa)	Hardness shore-D	Melt flow Index (10 g/min)	Water absorption (%)	Thickness of swell (%)
1	V2	0.3229	0.3222	0.41122	0.23973	0.4262	0.40129	0.4012902
2	V3	0.2306	0.2762	0.31984	0.19179	0.3788	0.356702	0.3567024
3	V4	0.1845	0.1841	0.22846	0.23973	0.3315	0.222939	0.222939
4	V5	0.1384	0.1841	0.18276	0.28768	0.1421	0.133763	0.1783512
5	V6	0.2768	0.2762	0.22846	0.33562	0.2841	0.267527	0.2675268
6	V7	0.369	0.3682	0.36553	0.38357	0.2368	0.312115	0.3121146
7	R2	0.3229	0.3222	0.36553	0.14384	0.3788	0.356702	0.3567024
8	R3	0.2768	0.2762	0.27415	0.19179	0.2841	0.312115	0.3121146
9	R4	0.2306	0.1841	0.22846	0.23973	0.2368	0.222939	0.222939
10	R5	0.1845	0.1381	0.13707	0.23973	0.1894	0.178351	0.1337634
11	R6	0.369	0.3682	0.27415	0.38357	0.1894	0.267527	0.2675268
12	R7	0.4151	0.4143	0.31984	0.43152	0.2368	0.312115	0.3121146

Table 5. Weighted normalised matrix.

S. no.	Composite	Tensile strength (MPa)	Flexural strength (MPa)	Impact strength (MPa)	Hardness shore-D	Melt flow index (10 g/min)	Water absorption (%)	Thickness of swell (%)
1	V2	0.0872	0.0633	0.08586	0.01846	0.0325	0.010942	0.008017
2	V3	0.0623	0.0542	0.06678	0.01477	0.0289	0.009726	0.007126
3	V4	0.0499	0.0361	0.0477	0.01846	0.0253	0.006079	0.004454
4	V5	0.0374	0.0361	0.03816	0.02215	0.0108	0.003647	0.003563
5	V6	0.0748	0.0542	0.0477	0.02584	0.0217	0.007295	0.005344
6	V7	0.0997	0.0723	0.07632	0.02954	0.0181	0.008511	0.006235
7	R2	0.0872	0.0633	0.07632	0.01108	0.0289	0.009726	0.007126
8	R3	0.0748	0.0542	0.05724	0.01477	0.0217	0.008511	0.006235
9	R4	0.0623	0.0361	0.0477	0.01846	0.0181	0.006079	0.004454
10	R5	0.0499	0.0271	0.02862	0.01846	0.0145	0.004863	0.002672
11	R6	0.0997	0.0723	0.05724	0.02954	0.0145	0.007295	0.005344
12	R7	0.1122	0.0813	0.06678	0.03323	0.0181	0.008511	0.006235

Figure 2. Standard tensile specimen of the composite.

Figure 3. Fractured tensile specimen of the composite.

Step 1: Construction of decision matrix according to the available data,

$$\begin{array}{c} \\ l_1 \\ l_2 \\ \vdots \\ l_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \dots & Cn \end{array} \\ \begin{bmatrix} X_{11} & X_{12} & \dots & X_{1n} \\ X_{21} & X_{22} & \dots & X_{2n} \\ \vdots & \vdots & \dots & \dots \\ X_{m1} & X_{m2} & \dots & X_{mn} \end{bmatrix} \end{array} \quad (3)$$

where i is criteria index (i = 1…m), m is number of potential sites and J is number of alternatives index (J…n). The elements l_1, $l_2 \ldots l_m$ are alternatives and $C_1 \quad C_2 \quad \ldots \quad C_n$ are criteria. The elements of matrix are related with criteria i with respect to alternatives J.

Step 2: Calculation of normalise matrix by the given equation:

$$R_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{i=m} X_{ij}^2}} \quad (4)$$

Normalised decision matrix represents the relative performance of the design alternatives.

Step 3: Calculate the weighted normalised matrix by AHP (Analytical Hierarchy Process) to quantify the relative importance of the different selection criteria. The weight are introduce by AHP method and weight were multiplied with every column element of normalised matrix

$$V = V_{ij} = W_i \times R_{ij} \quad (5)$$

Step 4: Identify the ideal positive and negative solution. The Positive ideal solution (A+) and ideal negative solution according to decision matrix via equation is given below:

$$A^{\div} = \left\{V_1^{\div} V_2^{\div} \ldots V_n^{\div}\right\} where V_j^{\div} = \left\{\left(\max\left(V_{ij}\right) if\ J \in J\right); \left(\min\left(V_{ij}\right) if\ J \in J'\right)\right\} \quad (6)$$

$$A^{-} = \left\{V_1^{-} V_2^{-} \ldots V_n^{-}\right\} where V_j^{-} = \left\{\left(\min\left(V_{ij}\right) if\ J \in J\right); \left(\max\left(V_{ij}\right) if\ J \in J'\right)\right\} \quad (7)$$

where J is associated with the beneficial attributes and J' is associated with the non beneficial attributes.

Step 5: Calculation of separation distance of each competitive alternatives from the ideal and non ideal solution.

$$S^{+} = \sqrt{\sum_{j=1}^{n} \left(V^{+} - V_{ij}\right)^2} \quad i = 1, 2 \ldots m \quad (8)$$

$$S^{+} = \sqrt{\sum_{j=1}^{n} \left(V^{-} - V_{ij}\right)^2} \quad i = 1, 2 \ldots m \quad (9)$$

where i = criteria, J-alternatives index.

Step 6: Calculate the relative closeness of each location from ideal solution using given equation:

$$C_i = \frac{S_i^{-}}{\left(S_i^{+} + S_i^{-}\right)} \quad (10)$$

Step 7: The higher value of the closeness refers to higher ranking of the alternatives. Ranking of the alternatives represents the comparative better and worst solutions [18, 19].

4. Results and discussion

4.1 *Tensile test analysis*

Tensile strength of all composites has been shown in figure 5. Tensile strength of neat RPP and VPP is 32.95 MPa and 31.75 MPa, respectively. Tensile strength of composites V2 and R2 is 30.25 MPa and 31.24 MPa. The composites V5 and R5 have minimum tensile strength of 24.40 MPa and 25.88 MPa, respectively. Increase of wood

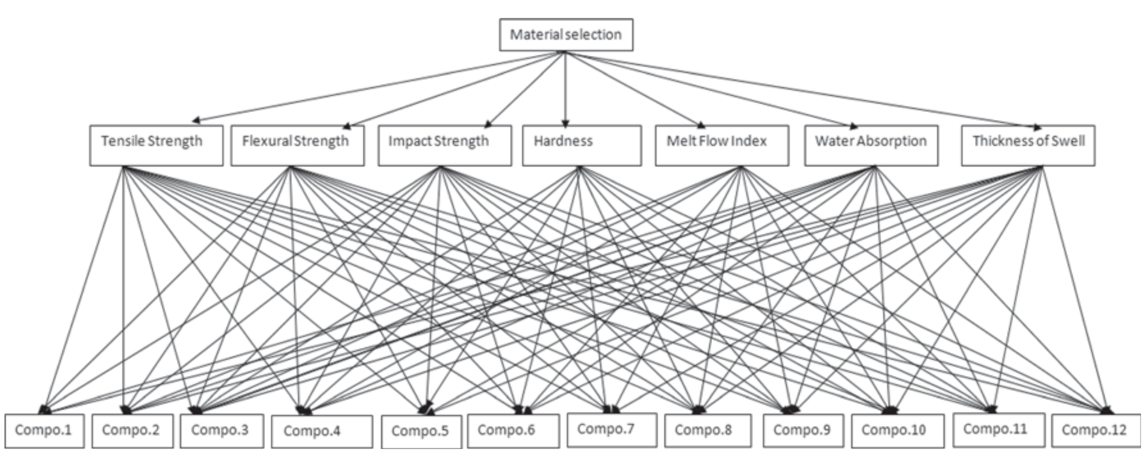

Figure 4. Materials selection process by TOPSIS technique.

content in the polymer matrix reduces the tensile strength of the composites.

Addition of MAPP in the polymer matrix increases the tensile strength of VPP and RPP composites. Composite V6 (33.08 MPa) and R6 (33.21 MPa) shows better strength than V5 and R5 after addition of 3%MAPP in 47%wt polymer matrix. Similarly, composite V7 (34.18 MPa) and R7 (35.40 MPa) shows better strength than V6 and R6 after addition of 5%wt MAPP in 45% wt polymer matrix [20].

4.2 *Flexural strength test analysis*

Flexural strengths of the composites are recorded and shown in figure 6. The VPP and RPP polymer show the flexural strength of 48.50 MPa and 50.59 MPa, respectively. The composites V5 and R5 have minimum flexural strength 29.47 MPa and 32.75 MPa respectively while composites V2 and R2 have maximum flexural strength of 42.65 MPa and 44.23 MPa respectively. Increase of wood content in the matrix reduces flexural strength of the composites. Brittleness of the composites increases as well as wood content increases in the polymer matrix. The results of flexural test show that recycled polypropylene based composite have higher flexural strength than virgin matrix based composite at the same composition.

Addition of 3%wt MAPP in the matrix of 47%wt VPP/RPP composites V6 (51.41 MPa) and R6 (52.41 MPa) show better strength than V5 (29.47 MPa) and R5 (32.75 MPa). Composites V7 (53.64MPa) and R7 (54.15MPa) show better flexural strength than V6 (51.41 MPa) and R6 (52.41 MPa) after addition of 5% wt MAPP in 45%wt polymer matrix. MAPP increases the interfacial adhesion between wood and polymer which show the positive effect on the flexural strength of the composite [20].

4.3 *Impact test analysis*

The impact strength of the composites is shown in figure 7. The VPP (376.54 J/m) has higher impact strength than RPP (323.76 J/m). The impact strength of the composite made by VPP decrease continuously from 329.01 J/m (V2) to 168.33 J/m (V5) due to loading of wood content in the polymer matrix. Similarly, impact strength of RPP matrix composites decreases from 267.5 J/m (R2) to 132.89 J/m (R5).

Impact strength of composites increases after addition of 3%wt MAPP in the matrix from V5 (168.33 J/m) to V6 (196.84 J/m) and R5 (132.89 J/m) to R6 (178.9 J/m). The Composites V7 (222.5 J/m) and R7 (188.78 J/m) have better impact strength than V6 (196.84 J/m) and R6 (178.9 J/m) after addition of 5%wt MAPP in 45%wt the polymer matrix. The coupling agent improves the impact strength of the composite, while recycling produces negative effect on impact strength of the composite [20].

4.4 *Hardness test analysis*

The results of hardness (Shore-D) test have been tabulated in figure 8. The hardness of VPP and RPP polymer are 60 and 62.1, respectively and RPP matrix based composites have maximum hardness of 70.7(R5) and VPP matrix composite have maximum hardness of 68.7(V5). The minimum hardness of recycled and virgin PP matrix composites are 63.5(V2) and 61.6(R2), respectively. It has been observed that hardness of the material increases with the increase of wood content in the polymer matrix.

Addition of MAPP in the polymer matrix increases the hardness of composites, composite having 3%wt MAPP in V6 and R6 matrix recorded hardness of 70.2 and 72.6, respectively. Similarly, composite V7 and R7 have hardness 73.4 and 76.5 with 5%wt MAPP in the 45%wt polymer matrix [20].

4.5 *Melt flow index test analysis*

Melt flow index (MFI) of the compounded materials are given in figure 9. The maximum MFI of virgin and recycled polypropylene is 13.5 g/10 min and 10.32 g/10 min,

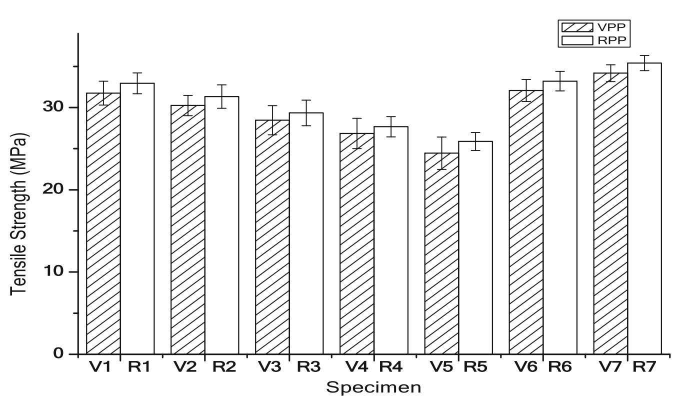

Figure 5. Tensile test.

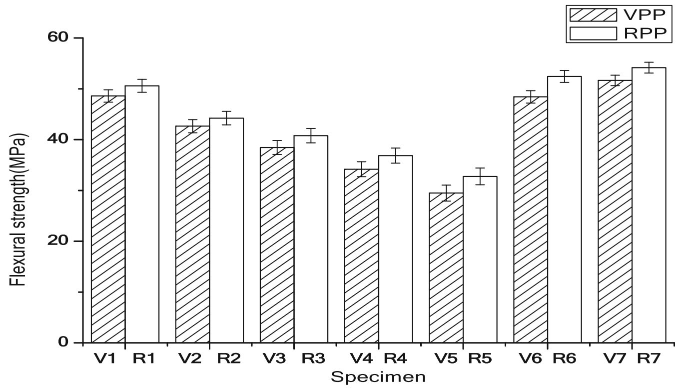

Figure 6. Flexural test.

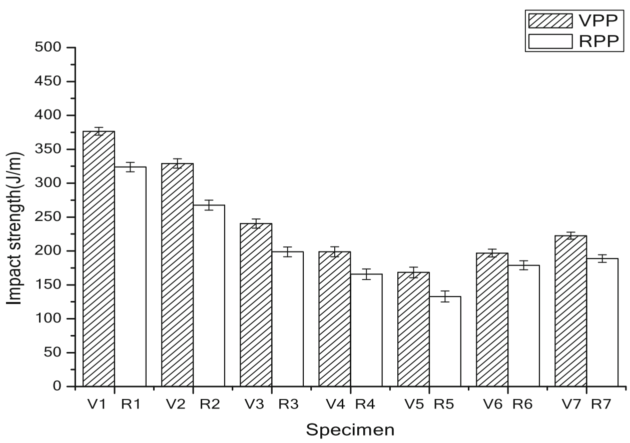

Figure 7. Impact test.

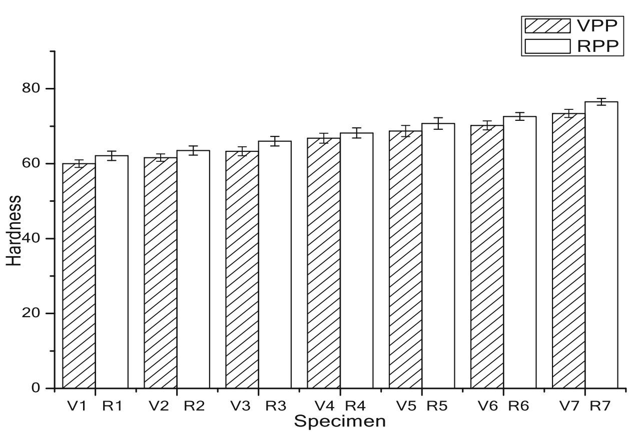

Figure 8. Hardness test.

respectively. Minimum MFI of compounds V5 and R5 are 5.87 g/10 min and 4.32 g/10 min, respectively. The maximum MFI of compound V2 and R2 are 10.96 g/10 min and 8.02 g/10 min have been recorded.

MFI of compounds decreases as wood content increases in the matrix. The reduction in MFI of compounded material confirms that viscosity of the material increases as wood sawdust percentage increases in the mixture. Addition of MAPP in the matrix increases the MFI of the compounds as shown in Table 6, composition V6 (5.95 g/10 min) and R6 (4.42 g/10 min) have higher MFI than V5 (5.87 g/10) min and R5 (4.32 g/10) min with 3%wt MAPP in the polymer matrix. MFI increases from 5.87 g/10 min (V5) to 6.02 g/10 min (V7) and 4.329 g/10 min (R5) to 4.48 g/10 min (R7) after addition of 5%wt MAPP in the 45%wt polymer matrix. The mobility of molecules decreases and viscosity increases due to cross-linking or molecular chain enlargement of the polymer which attributes to reduction in MFI of compositions [20].

4.6 *Water absorption test analysis*

Adhesion between wood and polymers is poor as wood and plastics are not compatible with each other. Poor adhesion of wood and polymer promotes water absorption at the interface of wood and plastic. Water absorption test for all compositions of composites with and without MAPP are conducted. The water absorption by the composites has been calculated by using equation (1). The outcomes of 24 hours experiments are given in figure 10.

The water uptake of the composites increases with increase of wood filler in the matrix. The water absorbed by VPP and RPP during this experiment is 0.06% and 0.05% in 24 hours. The water absorption of VPP matrix composite varies from 0.28% to 5.17% for 24 hours period. Similarly, water uptake by RPP matrix based composite varies for 24 hours period from 0.25 to 4.68%. Water absorption 5.17% is maximum for the composite V5. The RPP based composites show low water absorption than VPP based composite at the same wood content. Recycling of polymer also improves the adhesion between wood and plastics. Addition of 3% to 5% MAPP in the polymer matrix reduces the water absorption [20, 21] (Tables 7, 8).

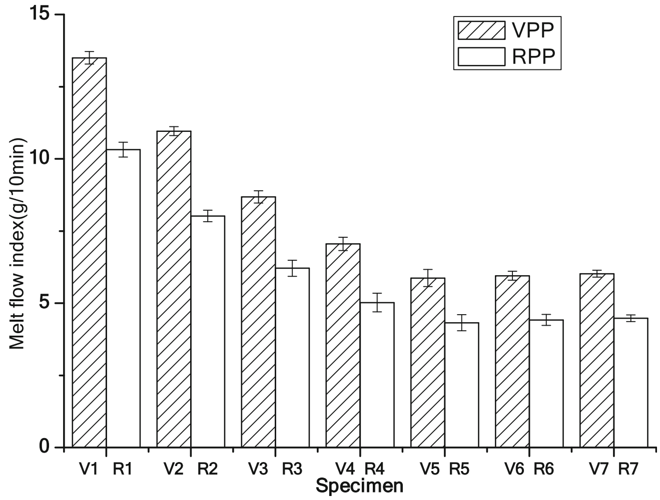

Figure 9. Melt flow index test.

Table 6. Ideal positive and negative solution.

S. no.	Tensile strength (MPa)	Flexural strength (MPa)	Impact strength (MPa)	Hardness Shore-D	Melt flow index (10 g/min)	Water absorption (%)	Thickness of swell (%)
A^+	0.1122	0.0813	0.08586	0.03323	0.0325	0.003647	0.0026702
A^-	0.0374	0.0271	0.02862	0.01108	0.0108	0.010942	0.0080107

4.7 *Thickness of swell test analysis*

Thickness of swelling (TS) corresponds to water absorption of the composite due to poor encapsulation of wood particles by the polymer matrix. Thicknesses of the swell of all compositions are given in figure 11 for 24 hours experiments.

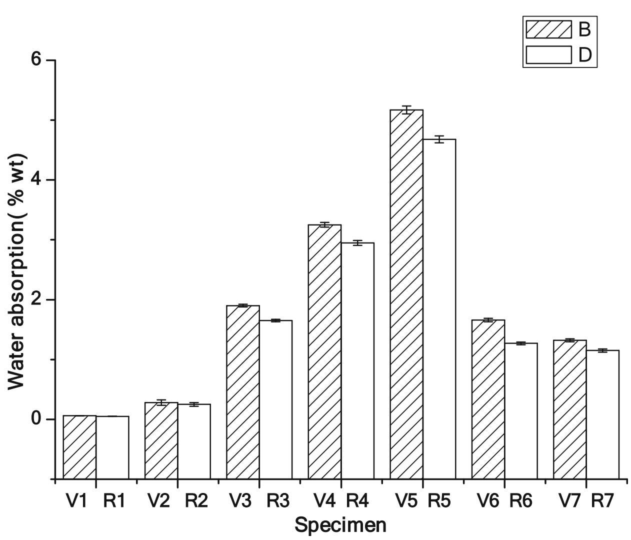

Figure 10. Water absorption test.

Thickness swelling of wood-Polypropylene composites is determined by using the equation (2). The results show that 50:50 wt% wood sawdust-VPP composite specimen V5 exhibit higher thickness of swelling which corresponds to the highest water absorption. The thickness of swell of composites increases with increase of wood content in the matrix. The thickness of swelling in 24 hours of RPP matrix composite varies from 0.21% to 4.35% and 0.24% to 4.94% for VPP matrix composites. The experiments confirm that RPP matrix based composite exhibit low thickness of swell

Table 7. Separation measure.

S. no.	Composite	S+	S−
1	V2	0.0353	0.0871
2	V3	0.0632	0.0562
3	V4	0.0875	0.03
4	V5	0.1025	0.0192
5	V6	0.0615	0.0534
6	V7	0.0242	0.0927
7	R2	0.04	0.08
8	R3	0.0587	0.0556
9	R4	0.0801	0.0348
10	R5	0.1032	0.017
11	R6	0.0376	0.0844
12	R7	0.0247	0.1027

Table 8. Relative closeness value and ranking.

S. no.	Composite	Closeness	Rank
1	V2	0.71156	3
2	V3	0.47053	7
3	V4	0.25537	9
4	V5	0.15774	11
5	V6	0.46483	8
6	V7	0.79288	2
7	R2	0.66663	5
8	R3	0.48644	6
9	R4	0.30274	10
10	R5	0.14133	12
11	R6	0.69149	4
12	R7	0.80615	1

than VPP matrix based composites. The thickness of swelling of RPP and VPP matrix composite reduces from 4.35% (R5) to 1.13% (R6) and 4.94% (V5) with 3% MAPP. Similarly, it reduces from 4.35% (R5) to 1.05% (R7) and 4.94% (V5) to 1.21% (V7) for 24 hours with 5% MAPP.

4.8 *Microstructure analysis*

The microstructure of the fractured tensile test specimen has been examined at 500× and 300× magnifications.

Figure 12a is scan of V4 at 500× composite having 40% wood content it has been observed that wood particle are not properly encapsulated by the polymer due to poor adhesion between wood and polymer. Voids are present due to pulling of wood particles. These are cause of poor mechanical strength and high water uptake of the composite. Figure of R4, 12b at 300× having 40% wood content shows fine incorporation of wood and plastic in the composite. Distribution of wood particles in the recycled matrix composite is uniform in comparison to virgin PP matrix based composite in figure 12a.

Figures 12c of V6 having 60% sawdust and 12d of V7 having 70% sawdust at 500× magnification shows incorporation of MAPP in the composite improves the adhesion properties of wood particles with polymer. Coupling agent MAPP increases the interfacial bonding between wood and polymer by the formation of covalent bonds due to etherification mechanism. The improvement in the bonding of the wood and particle improves the properties of the composites. Figure 12e R4 and f R5 at 300× and 500× magnification shows that sawdust reduces the homogeneity of the composites without MAPP, improper dispersion of the wood particles in the composite reduces the mechanical, rheological and hygroscopic properties of the composites.

5. Ranking of material using TOPSIS analysis

Composites of VPP/RPP polymers are chosen for the analysis.

5.1 Criterion matrix
5.2 Decision matrix
5.3 Normalised matrix
5.4 Weighted normalised matrix
5.5 Ideal positive and negative solution
5.6 Separation measure
5.7 Relative closeness value and ranking

Tensile strength, flexural strength, impact strength, hardness, melt flow index, water absorption and thickness of swell have been considered for TOPSIS analysis as performance indicators. The composite R7 is very close to

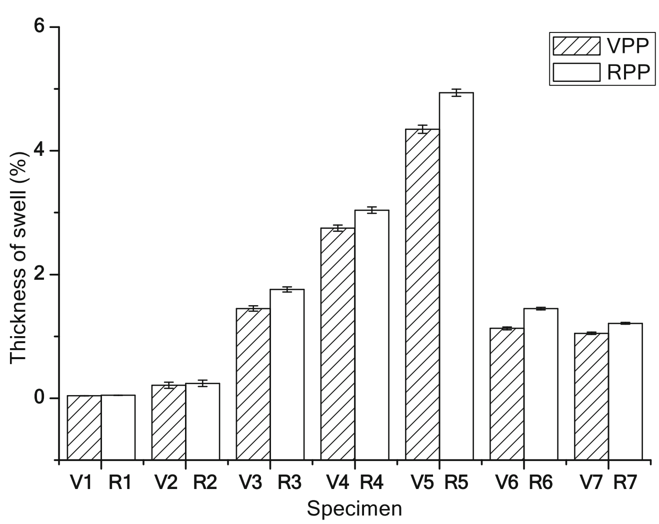

Figure 11. Thickness of swell test.

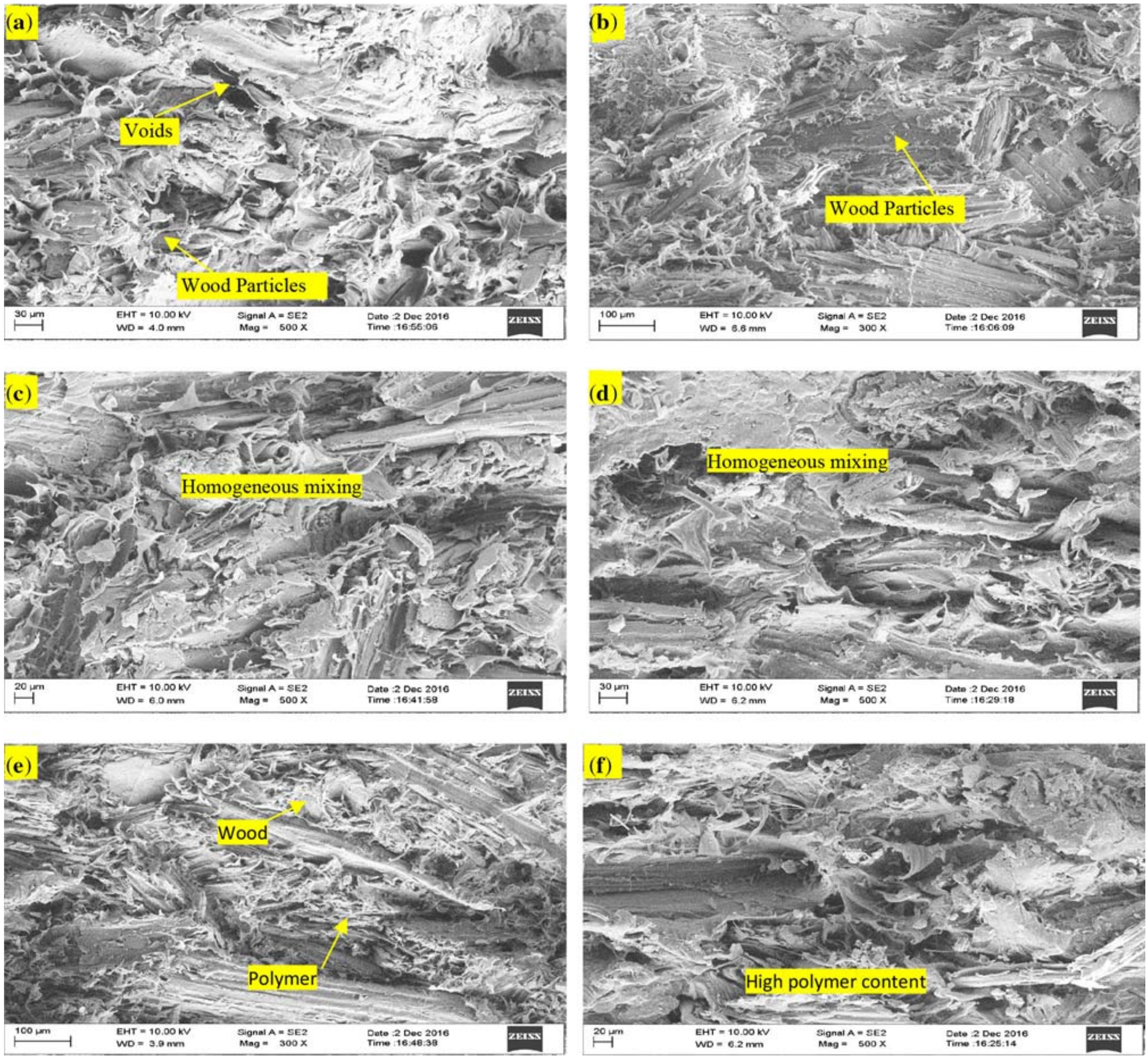

Figure 12. SEM images of fractures surfaces.

objective and it got 1st rank in the analysis. The composition of R7 is 50%wt recycled polypropylene, 45%wt wood sawdust and 5%wt MAPP by weight and has better mechanical, rheological properties with low water absorption and thickness of swell.

6. Conclusions

The mechanical rheological and hygroscopic properties of teak wood composites affect the rank of the composition in the analysis. Tensile, flexural, impact strength of the composites decreases with increase of wood content in the matrix. Increase of wood content in the matrix also increases the water absorption and thickness of the composites. Hardness of the composite increases with increase of wood content in the matrix but melt flow index decreases due to increase of viscosity of the compositions. Small size of wood particles leads to compacting of composite leading to increase in hardness of the composites. SEM scans confirms that mixing of the composite is homogeneous. Addition of MAPP in the polymer matrix increases the adhesion of wood and polypropylene. Tensile strength, flexural strength, impact strength, hardness, melt flow index, water absorption and thickness of swell have been considered for TOPSIS analysis as performance indicators. TOPSIS provides that R7 is better in all aspects. The composition of R7 is 50%wt recycled polypropylene, 45%wt wood sawdust and 5%wt MAPP by weight. Composite R7 have better mechanical, rheological properties with low water absorption and thickness of swell. Thus Composite R7 is most suitable composite for outdoor applications.

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