**Acoustical and Mechanical Properties of Thermoplastic Composites from
Discarded Carpets**

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ABSTRACT

Without additional matrix or reinforcement, compression molded composites from waste polypropylene (PP) carpets/nylon (PA) carpets or PP carpets/polyester (PET) carpets have higher mechanical properties and sound absorption than traditional jute/PP composites. Large amount of carpets have been discarded every year, leading to waste of petro-based materials and serious environmental pollution. Fabrication of composites from discarded carpets via compression molding could save petroleum resources and alleviate environmental pressure. In this research, the compression molded composites from waste PP/PA carpets or PP/PET carpets showed good mechanical properties, sound absorption and water stability. Compared to the jute/PP composites, nylon 6,6 (PA66)/PP carpet composites had 37% and 9% higher flexural strength and impact resistance, as well as 45% and 10% higher sound absorption and water stability, indicating their potential for transportation and construction industries.

Keywords: E. carpets reuse; A. Thermoplastic composites; B. Sound absorption; A. Styrene-butadiene-rubber (SBR)

1. Introduction

Currently, more and more attention has been paid to recycling of petro-based materials due to shortage of oil resources and large demand for petroleum based materials [1]. Lv et al. used waste nylon 6/spandex blended fabrics to make plastics by compression molding [2]; Zou et al. used discarded polyester (PET)/cotton blend fabric for the fabrication of compression molded composites [3]; Petrucci et al. reported that polypropylene matrix were reinforced by cotton flocks from waste jeans fabric via injection molding [4]; Ashori and Nourbakhsh reported that high density polypropylene (PP), PP and old newspaper fiber could reuse and fabricate into composite panels [5]; Jayaraman and Halliwell reported that post-consumer waste plastics and Harakeke fibers could be compounded into composites using the screwless extruder [6].

Carpets are widely used for interior architecture, automobile and aircraft [7]. Currently, almost 4-6 million tons of carpets have been discarded and become one of the largest amounts of solid wastes [8-10]. However, only 2% waste carpets have been recycled [11]. Waste carpets contain non-degradable petro-based materials and thus cause serious environmental pollution. Usage of petro-based materials in discarded carpets is beneficial to environment and could alleviate high pressure from shortage of oil resources. Carpet reusing methods mainly include depolymerization [12], polyamide extraction [13], melt blending [14] and burning for heat energy [15]. Among the above methods, both of depolymerization and polyamide extraction are high cost, although high-quality chemical raw materials could be obtained by the

1 methods. Melt blending is low cost, easy preparation and has no requirement for the
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3 separation of carpet compositions. However, high temperature of melt blending
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5 probably damage SBR and decrease mechanical properties of subsequent products.
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7 Burning method is easy operation. However, high amount of toxic gases are usually
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9 released. In addition, some new methods for recycling carpets have been proposed.
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11 Wang et al. have used waste carpets to reinforce concrete and increased toughness of
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13 concrete composites [16, 17]. Schmidt and Cieslak have found there is strong
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15 adhesion of carpets to concrete [18]. However, carpets are required to be smashed for
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17 preparation of carpet-concrete composites, leading to more energy consumption and
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19 high processing cost. Jain et al. have fabricated composites using waste carpet and
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21 thermoset resins via vacuum- assisted resin transfer molding (VARTM) [11].
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23 However, carpet composites produced by VARTM cannot be reused again. Pan et al.
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25 reported that thermoplastic composites from waste nylon carpets or PP carpets were
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27 fabricated [19, 20].
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39 Fabrication of thermoplastic composites from discarded carpets is a high efficiency
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41 approach. The advantages include their reusability and 100% recycle efficiency. The
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43 carpet with high-melting-temperature surface fibers could serve as reinforcement
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45 materials, while the carpet with low-melting-temperature surface fibers could serve as
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47 matrix. According to the types of surface fibers, carpets are mainly classified into
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49 nylon 6 (PA6), nylon 6,6 (PA66), PP, PET carpets. Besides surface fiber, carpets
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51 mainly contain backing fibers (PP), binders (SBR), fillers (CaCO₃). In this research,
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53 composites have been developed from PP/PA6, PP/PA66 and PP/PET carpets, which
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1 were compression molded at melt temperature of PP. This temperature could protect
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3 SBR from heat damage [21]. PP yarns in PP carpets served as matrix, while PA66,
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5 PA6, PET carpets and SBR/CaCO₃ in PP carpets served as reinforcements. This
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7 research studied the potential of fabricating compression molded composites from two
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9 types of waste carpets. Effects of ratio of reinforcement, types of fiber reinforcement,
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11 SBR and CaCO₃ on mechanical properties, water absorption and sound absorption of
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13 the carpet composites have also been studied.
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20 **2. Experimental**

21 *2.1 Materials*

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23 PP, PA6, PA66 and PET loop pile carpets were purchased from Carpet Land Inc.,
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25 Lincoln, NE. Hydrochloric acid (HCl) (37%) was purchased from EMD Chemicals
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27 Inc., Gibbstown, NJ. Jute fibers were purchased from Bast Fibers LLC (Cresskill, NJ)
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29 and had an average fineness of 32 denier, tensile strength of 312 MPa, breaking
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31 elongation of 1.4% and Young's modulus of 24.3 GPa.
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39 *2.2 Composition analysis of carpets*

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41 Chemical structures of surface yarns and backing yarns of the carpets were
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43 measured using Fourier Transform Infrared Spectrometry (FTIR). Measurements were
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45 taken on a Nicolet 380 (Thermo-Nicolet, Waltham, MA) spectrophotometer through
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47 the diffuse reflectance technique from 400 to 4000 cm⁻¹ with a resolution of 4 cm⁻¹
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49 and 64 scans. The FTIR spectra obtained were analyzed using OMNIC software
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51 (Thermo Electron Corp., Waltham, MA). Surface yarns and backing yarns were
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53 disconnected from the carpets. Adhesives of SBR/CaCO₃ particles were separated
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1 from surface yarns on a Louet laboratory scale carding machine. To remove CaCO_3 ,
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3 carpets were soaked in 1% HCl for 24 h and then rinsed in distilled water for 2 h.
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5 After dried at 50 °C for 12 h and balanced in a sealed desiccator for 2 h, calcium-free
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7 carpets were weighted. The weight ratio of components in the PP, PA6, PA66 and PET
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9 carpets is: CaCO_3 : SBR: PP = 40:10:50; PA6: CaCO_3 : SBR: PP = 38:40:12:10; PA66:
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11 CaCO_3 : SBR: PP = 40:40:12:8; PET: CaCO_3 : SBR: PP = 42:38:10:10.
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17 *2.3 Thermal analysis*

20 Thermal properties of the PA6, PA66, PET, surface PP yarns and backing PP yarns
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22 were measured using a differential scanning calorimetry (DSC). About 10 mg of each
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24 type of yarns were placed in aluminum pans and the DSC Mettler Toledo D822^e
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26 (Mettler Toledo Inc., Columbus, OH) was operated at a heating rate of 10 °C/min
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28 from 25 °C to 200 °C or 280 °C under nitrogen atmosphere. The obtained DSC
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30 thermogram was analyzed to determine the melting temperature of PA6, PA66, PET
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32 and PP filaments. SBR and calcium carbonate do not have melting temperature due to
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34 their non-thermoplasticity. The DSC curve as shown in Fig. 1, melting point of the
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36 PA6, PA66, PET and PP were around 225, 260, 260 and 165 °C, respectively.
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45 *2.4 Fabrication of compression molded composites*

47 Carpets were placed alternatively between two aluminum sheets and pressed in a
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49 laboratory-scale press (Carver, Inc., Wabash, IN) preheated to desired temperatures.
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51 Since melting temperature of PP was around 165 °C, the carpets composites (except
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53 for 100% PA6 carpets composites) were pressed at 180 °C for 10 min. SBR particles
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55 in the carpets could be prevented from damaging or decomposing when compression
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1 molded at the temperature of 180 °C. 100% PA6 carpets composites were pressed at
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3 220 °C for 10 min. Different numbers of PA6 carpet and PP carpet layers were
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5 prepared to obtain final composites with different ratios of reinforcement and matrix.
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7 Different carpets (PA6, PA66 or PET carpets) as reinforcement and PP carpet as
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9 matrix were prepared to study the effect of reinforcement on the properties of
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11 composites. PA6/PP carpet composites were prepared with PA6 carpets and PP carpets;
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13 PA66/PP carpet composites were prepared with PA66 carpets and PP carpets; PET/PP
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15 carpet composites were prepared with PET carpets and PP carpets. Thickness of the
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17 obtained composites was 4.0 ± 0.08 mm.
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25 To investigate effect of CaCO_3 in the compression molded composites from carpets,
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27 carpets were treated in 1% HCl for 24 h and rinsed in water to remove calcium
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29 carbonate. After dried at 50 °C for 12 h, carpets without CaCO_3 were obtained. To
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31 study SBR effect, SBR was removed from calcium free carpets, while the separated
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33 carpet yarns were prepared for 0 wt.% SBR samples as controls.
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39 Jute/PP composites containing 40 wt.% of jute fibers had good mechanical
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41 properties [22]. Thus, jute/PP (40/60) composites were compression molded at 180 °C
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43 for 10 min as a control with the same density and thickness as carpet composites. PP
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45 carpets were also compression molded at 180 °C for 10 min as another control with
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47 the same density. Types of compression molded composites, temperature and time of
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49 compression molding and thickness of the compression molded composites were
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51 listed in Table 1.
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58 *2.5 Mechanical properties of compression molded composites*

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1 Tensile tests were performed on an MTS machine QTest10 (MTS Corporation,
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3 Eden Prairie, MN) according to procedure ASTM D638-03. Length of the samples
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5 was 165 mm, width of the sample was 19 mm, and gage length was 115 mm.
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7 Crosshead speed was 5 mm/min. Flexural tests were carried out in an MTS QTest10
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9 tester following procedure of ASTM D790-03, sample size was 7.6 cm x 20.3 cm with
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11 15.2 cm support length, load cell was 500 N, and the crosshead speed was 10 mm/min.
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13 Offset yield load was recorded at 2.0 mm. Impact resistance test was performed on a
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15 Plastic Impact Tester by Tinius Olsen model 66 (Tinius Olsen, Horsham, PA) using
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17 procedure ASTM D256-03. Sample size was 63.5 mm x 10.2 mm. The notch was cut
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19 perpendicular to the cross section.
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27 *2.6 Dynamic mechanical analysis*

31 The viscoelastic properties of the composites were measured by a dynamic
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33 mechanical analyzer DMA Q800 (TA Instrument Inc., New Castle, DE) according to
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35 ASTM D4065 standard. The test was carried out by heating the samples from 25 to
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37 145 °C at a rate of 5 °C/min. The samples were tested in a dual cantilever mode at an
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39 oscillating amplitude of 15 mm and frequency of 1 Hz.
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44 *2.7 Morphology*

47 A variable pressure scanning electron microscope (VPSEM) Hitachi S3000N
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49 (Hitachi, Tarrytown, NY) was used for observing the cross-sections of the
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51 compression molded composites from carpets. Samples were sputter coated with gold
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53 palladium before observing under the SEM. Magnification of SEM images was 150×.
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58 *2.8 Water Stability*

1 The swelling and water absorption were conducted according to ASTM D 570.
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3 Swelling was measured in the thickness direction of the composites [23]. A piece of
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5 carpet with dimension of about 3 cm x 3 cm was immersed in 20 °C and 50 °C water
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7 for 1, 3, 5, 7 and 9 days. After removal from the water, the samples were dried by
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9 patting with a towel before measuring thickness and weight. The data reported are
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11 average values obtained from five separate samples.
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16 2.9 Sound absorption

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18 Sound absorption of the composites were determined according to ASTM standard
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20 E1050-98 on a Bruel & Kjaer impedance tube (type 4206 A) (Bruel & Kjaer, Norcross,
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22 GA) at 0-3 kHz. Three samples with diameter of 63 mm from different composites
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24 were tested for the sound absorption and the average readings were used to plot the
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26 absorption coefficient curves.
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33 2.10 Statistical analysis

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35 Data generated was analyzed using Tukey's multiple-pair wise comparison using
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37 SAS program (SAS Institute, Raleigh, NC). A significance level of $\alpha=0.05$ was
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39 considered as statistically significant. In each figure, data points without significant
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41 differences were marked with same letters, numbers or symbols.
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47 3. Results and discussion

48 3.1 Effect of PA6 carpets on the mechanical properties of PA6/PP carpet composites

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50 As shown in Fig. 2, the PA6/PP carpet composites have higher mechanical
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52 properties as compared with the compression molded composites from PP carpets or
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54 PA6 carpets, individually. Increasing weight percentage of PA6 carpets to 33%
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substantially increased flexural strength, flexural modulus, impact resistance of PA6/PP carpet composites; slightly increased tensile strength but slightly decreased tensile modulus. Further increasing weight percentage of PA6 carpets to 66% increased flexural strength, flexural modulus and impact resistance, although tensile strength and tensile modulus of the compression molded composites were not increased. Comparatively poor mechanical properties of the compression molded composites from single PP or PA6 carpets were mainly due to lack of fiber reinforcement under 180 or 220 °C. It was also proved in Fig. 3a and 3d. Adding PA6 carpets increased the amount of fiber reinforcement in the compression molded PA6/PP carpet composites under 180 °C, and therefore improved mechanical properties of the compression molded composites. As shown in Fig. 3b, the compression molded composites with 33% PA6 carpets have good interface. It is probably because melted PP could wrap unmelted PA6 yarns in the compression molded composites. However, the compression molded composites with 66% PA6 carpets show poor interface in Fig. 3c. It is mainly because low amount of melted PP fail to glue PA6 yarns together. As a result, the compression molded composites with 33% PA6 carpets show comparatively higher mechanical properties.

3.2 Effect of SBR and CaCO₃ in carpets on the mechanical properties of PA6/PP carpet composites

As shown in Fig. 4, SBR in carpets has capability to improve impact resistance of PA6/ PP carpet composites, although has no influence on their tensile and flexural properties. CaCO₃ could substantially increase flexural strength and modulus of the

1 compression molded composites, slightly increased tensile modulus, but almost no
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3 influence on their tensile strength. Solid SBR has high toughness and could absorb
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5 high amount of impact energy [24, 25], and thus endow composites with high impact
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7 resistance. CaCO₃ powder reinforcement has high hardness and could improve
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9 flexural strength and modulus of composites This is in accordance with the results
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11 reported from Herrera-Franco et al. [26], Yang et al. [27] and Leong et al [28].
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16 17 *3.3 Effect of SBR in carpet on the sound adsorption of PA6/PP carpet composites* 18 19

20 SBR in carpets has capability to enhance sound adsorption of the compression
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22 molded carpet composites. As seen in Fig. 5, the compression molded composites
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24 from PA6 yarn/PP yarn (PA6/PP yarn), PA6 yarn/PP yarn/SBR (PA6/PP/SBR), and
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26 PA6/PP carpets show similar sound adsorption coefficient at frequency ranging from
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28 0.3 to 2 KHz. However, the compression molded composites from PA6/PP/SBR and
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30 PA6/PP carpets show obviously higher sound adsorption coefficient at frequency
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32 ranging from 2 to 3 KHz. It is mainly because of the existence of SBR in the
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34 compression molded composites from PA6/PP/SBR and PA6/PP carpets. SBR has
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36 high damping property, indicating its molecular structure with complex network. Thus
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38 higher energy is required for stress variation of SBR based materials [29]. When
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40 sound waves go through the compression molded carpet composites, sound energy
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42 will be consumed by heat energy due to motion and friction of molecular chains as
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44 well as destruction and reconstruction of physical bonding between SBR and other
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46 molecular chains, leading to increased attenuation of sound waves [30]. When
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48 low-frequency sound waves spread, movement of SBR molecular chains could
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completely response excitation frequency of sound waves, leading to less energy loss and low coefficient of sound absorption. When high-frequency sound waves spread, movement of SBR molecular chains will lag behind excitation frequency of sound waves, leading to hysteresis loss and high coefficient of sound absorption.

3.4 Reinforcement effect of different carpets on the mechanical properties of composites using PP carpets as matrix

As shown in Fig. 6a, compared to the compression molded composites from PP carpets, the PA6/PP carpet composites, PA66/PP carpet composites and PET/PP carpet composites show about 60%, 88% and 40% increased flexural strength, flexural modulus and impact resistance, respectively, although no difference on tensile strength and modulus. It is mainly because fiber reinforcement in the PA6/PP carpet composites, PA66/PP carpet composites and PET/PP carpet composites enhance their mechanical properties. However, reinforced PA6, PA66 or PET yarns with loop piles were not aligned straightly in the composites, and thus cannot substantially strengthen tensile strength of the compression molded composites. Among the three types of combined carpet composites, PA66/PP carpet composites have higher mechanical properties compared to other two. As compared with the jute/PP composites, PA66/PP carpets composites had 37% higher flexural strength, 2% higher elastic modulus and 9% higher impact resistance, respectively. It is mainly because PA6, PA66 and PET yarns have higher tensile strength than jute fibers, and PA66 yarns have comparatively higher tensile strength [31]. In addition, CaCO_3 powders and SBR in carpets are beneficial to increase flexural properties and impact resistance of the compression

1 molded composites, respectively. Therefore, using PA6, PA66 or PET carpets as
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3 reinforcement of compression molded PP carpet composites could enhance flexural
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5 properties and impact resistance of the compression molded composites from PP
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7 carpets.
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11 Fig. 6b shows the tensile stress-strain curves of the compression molded
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13 composites from PP carpets, PA6/PP carpets, PA66/PP carpets, PET/PP carpets and
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15 jute/PP. All the carpet composites have very similar characteristics: initial linear
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17 elasticity becomes non-linear up to peak stress followed by a plateau stress. However,
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19 jute/PP composites display linear behavior before entering the plastic region. Then the
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21 jute/PP composites break abruptly [32, 33]. It is clearly shown that the tensile strength
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23 and tensile modulus of carpet composites were lower than that of jute/PP composites.
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31 *3.5 Reinforcement effect of different carpets on the sound absorption properties of* 32 33 *composites using PP carpets as matrix* 34 35

36 As shown in Fig. 7, compared to jute/PP composites, the compression molded
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38 composites from PP carpets, PA6/PP carpets, PA66/PP carpets and PET/PP carpets
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40 have higher sound adsorption at frequency ranging from 0.3-3 KHz. The sound waves
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42 are more likely to be weakened by transmitting through multiple phases of materials
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44 than single or double phases of materials [34-36]. Thus, the compression molded
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46 carpet composites reinforced by SBR, CaCO₃ and surface yarns had good capability
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48 of absorbing sound wave. PA66/PP carpet composites had 45% higher sound
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50 absorption at medium frequency comparing to jute/PP composites. Moreover,
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52 PA66/PP carpet composites show higher sound adsorption compared to PA6/PP carpet
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1 composites, PET/PP carpet composites and PP carpet composites. It is probably
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3 because PA66 has higher damping property than PA6, PET and PP. Sound absorption
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5 at low frequency is desired for some transportation and construction composites
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7 because this frequency zone corresponds with noise from wind, road, conversation
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9 and running engine [37-39]. Therefore, the compression molded composites from
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11 combined carpets have potential for transportation and construction applications.
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16 3.6 Dynamic mechanical analysis

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18 PA6, PA66 and PET yarns, as fiber reinforcement, could increase elastic modulus
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20 and damping property of the compression molded composites from waste carpets.
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22 Viscoelastic properties of the compression molded composites from carpets were
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24 studied by DMA. The temperature dependence of storage modulus (E') and loss factor
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26 ($\tan \delta$) are depicted in Fig. 8. The compression molded composites from carpets have
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28 higher storage modulus than jute/PP composites, indicating higher viscoelastic
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30 properties of the compression molded carpet composites. It is probably due to the
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32 existence of PA6, PA66 and PET yarn reinforcement in the composites. Increasing
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34 temperature decreased storage modulus of all the carpet composites and jute/PP
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36 composites. It is mainly because molecular chain mobility of the polymers in the
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38 compression molded composites increases as temperatures increase [40, 41]. Due to
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40 higher glass-transition temperature (T_g) of PA66 and PET fibers than that of PA6
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42 fibers, storage modulus of PA66 and PET carpet reinforced composites decreased at
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44 higher temperature, indicating better thermal stability of PA66/PP carpet composites
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46 and PET/PP carpet composites.
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Higher value of $\tan \delta$ indicates better damping property. As shown in Fig. 8b, carpet composites have higher $\tan \delta$ than jute/PP composites. SBR in the compression molded carpet composites has flexible molecular chain and could consume mechanical energy by transforming them into heat, leading to higher damping property of the final composites. The PA6/PP carpet composites, PA66/PP carpet composites and PET/PP carpet composites have higher value of $\tan \delta$ compared to that of PP carpet composites, due to interfacial friction between PP matrix and fiber reinforcements. In addition, as shown in Fig. 8b, PA6, PA66 and PET has T_g of 50, 62 and 58 °C, which is higher than that of PP (-10 °C) [42]. Due to the existence of PA6, PA66 and PET yarn reinforcement in final composites, PA6/PP carpet composites, PA66/PP carpet composites and PET/PP carpet composites have higher T_g compared to the composites from PP carpets.

3.7 Water stability

PA6/PP, PA66/PP and PET/PP carpet composites had higher water stability than jute/PP composites, but lower water stability than PP carpet composites at room temperature and high temperature. Moreover, PA66/PP and PET/PP carpet composites had higher water stability than PA6/PP carpet composites. As shown in Fig. 9, PA6/PP, PA66/PP and PET/PP carpet composites had lower water absorption and increment of thickness than jute/PP composites, as immersed in 20 °C and 50 °C water for 1 day to 9 days. As shown in Fig. 9a and 9b, PA66/PP carpet composites had almost 5.3% higher dimensional stability and 4.9% lower water absorption comparing to jute/PP composites after 9 days at 20 °C. As shown in Fig. 9c and 9d, prolonging immersing

day in 50 °C water bath for 9 days deteriorated water stability of the compression molded composites, although PA6/PP, PA66/PP and PET/PP carpet composites have lower increment of thickness and water absorption than jute/PP composites. PA66/PP carpet composites had almost 10% higher dimensional stability and 8.4% lower water absorption comparing to jute/PP composites. Jute fibers are hydrophilic and swell easily in wet condition [43], leading to increased water absorption and increment of thickness of jute reinforced PP composites. Synthetic yarns in the compression molded composites, including PA6, PA66 and PET, have comparatively lower water absorption than jute fibers. Due to hydrophilic property, CaCO_3 particles could absorb moisture [44]. However, in the compression molded carpet composites, CaCO_3 particles were discontinued and mixed with hydrophobic SBR, and thus were not affected by water. Therefore, compression molded composites from combined carpets had satisfactory water stability under room temperature and high temperature.

4. Conclusions

Without additional matrix or reinforcement, compression molded composites from waste PP carpets and PA or PET carpets have higher mechanical properties and sound absorption than jute/PP composites. Compared to the compression molded composites from PP carpets, PA6, PA66 or PET as fiber reinforcement increased the flexural strength, flexural modulus and impact resistance of PP carpets composites. Among the three types of carpets reinforcement, PA66 carpets as reinforcement showed higher mechanical properties compared to other two. Compared to the compression molded composites from PP carpets, PA66/PP carpet composites had 60%, 88% and 40%

1 higher flexural strength, flexural modulus and impact resistance, respectively. SBR
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3 had capability to improve sound adsorption and impact resistance of carpets
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5 composites, although no influence on their tensile and flexural properties. CaCO_3
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7 could substantially increase flexural strength and modulus of the compression molded
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9 composites, slightly increase tensile modulus, but almost no influence on their tensile
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11 strength. PA66/PP carpet composites had 37% higher flexural strength, 2% higher
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13 elastic modulus, 9% higher impact resistance, 45% higher sound absorption at
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15 medium frequency, 10% higher water stability at 50 °C and better damping property
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17 compared to jute/PP composites commonly used in transportation and construction
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19 industries. Therefore, compression molded composites from discarded carpets have
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21 good composites performances and show potential for transportation and construction
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23 industries.
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Figure Captions

Fig. 1. DSC curves of PP backing fiber, PP face fiber, PA6 fiber, PA66 fiber and PET fiber of carpets.

Fig. 2. Effect of concentration of PA6 carpets on the mechanical properties of the compression molded composites from PA6/PP carpets. Compression molded composites from PP carpets, PA6/PP (33/67) carpets, PA6/PP (67/33) carpets and PA6 carpets were made at 180 °C, 180 °C, 180 °C and 220 °C for 10 min, respectively.

Data points with different numbers, letters, or symbols indicate statistically significant difference.

Fig. 3. SEM images of the cross sections of the composites from (a) PP carpets, (b) PA6/PP (33/67) carpets, (c) PA6/PP (67/33) carpets and (d) PA6 carpets compression molded at 180 °C, 180 °C, 180 °C and 220 °C for 10 min.

Fig. 4. Effects of SRB and CaCO₃ on the mechanical properties of the compression molded composites from PA6/PP carpets. PA6/PP (33/67) carpet yarns with or without SBR, PA6/PP (33/67) carpets with CaCO₃ were compression molded at 180 °C for 10 min. Data points with different numbers, letters, or symbols indicate statistically significant difference.

Fig. 5. Effects of SRB and CaCO₃ on the sound absorption of the compression molded composites from PA6/PP carpets. PA6/PP (33/67) carpet yarns with or without SBR, PA6/PP (33/67) carpets with CaCO₃ were compression molded at 180 °C for 10 min.

Fig. 6. Reinforcement effect of different carpets on the (a) mechanical properties and (b) tensile stress-strain curves of composites using PP carpets as matrix. Compression

1 molded composites from PP carpets, PA6/PP carpets, PA66/PP carpets, PET/PP
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3 carpets were made at 180 °C for 10 min. Jute/PP composites were also compression
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5 molded at 180 °C for 10 min. Data points with different numbers, letters, or symbols
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7 indicate statistically significant difference.
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11 **Fig. 7.** Reinforcement effect of different carpets on the sound absorption of
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13 composites using PP carpets as matrix. Compression molded composites from PP
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15 carpets, PA6/PP carpets, PA66/PP carpets, PET/PP carpets were made at 180 °C for 10
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17 min. Jute/PP composites were also compression molded at 180 °C for 10 min as a
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19 control sample.
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25 **Fig. 8.** Temperature dependence of (a) storage modulus (E') and (b) loss factor ($\tan \delta$)
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27 of compression molded composites from PP carpets, PA6/PP carpets, PA66/PP
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29 carpets, PET/PP carpets and jute/PP. All composites were compression molded at
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31 180 °C for 10 min.
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36 **Fig. 9.** Water absorption and thickness increment of the compression molded
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38 composites from PP carpets, PA6/PP carpets, PA66/PP carpets, PET/PP carpets and
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40 jute/PP immersed in 20 °C water for 1 - 9 days a) increment of thickness, b) water
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42 absorption; In 50 °C water for 1 - 9 days c) increment of thickness, d) water
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44 absorption. Compression molded composites from PP carpets, PA6/PP carpets,
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46 PA66/PP carpets and PET/PP carpets were made at 180 °C for 10 min. Jute/PP
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48 composites were also compression molded at 180 °C for 10 min.
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Table 1 List of the compression molded composites studied in this research.

Types of compression molded composites studied in this research	Compression molding		Thickness of compression molded composites (mm)
	Tempertaure (°C)	Time (min)	
Polypropylene (PP) carpets	180	10	4
PA6 carpets	220	10	4
PA6/PP carpets	180	10	4
PA66/PP carpets	180	10	4
PET/PP carpets	180	10	4
PA6/PP yarns	180	10	4
PA6/PP carpets without CaCO ₃	180	10	4
Jute/PP (40/60)	180	10	4

Figure 1

Figure 2

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