Mechanical Properties of Polydimethylsiloxanes (PDMS) Reinforced Silica Derived Rice Husk Ash

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Abstract. Additional filler in polydimethylsiloxane (PDMS) has successfully enhanced the properties of the composites. This paper highlights the role of rice husk silica (RHS) in improving the vibration and tensile properties of PDMS. The PDMS/RHS composite panels were fabricated via casting technique and cured at 100 °C. PDMS/RHS composites were analyzed for hand arm vibration exposure analysis using ISO 8662 standard and tensile properties conducted using ASTM D412 standard. In vibration exposure study, addition of RHS in PDMS had decreased the vibration exposure to 47%. The tensile properties of PDMS/RHS panels showed improvement in the tensile strength with 15% increment compared to unfilled PDMS. Both analyses had proven that RHS plays a vital role as a filler and reinforcement to improve the properties of PDMS. In tension mode, RHS act as reinforcement to bear and transmit the load efficiently to matrix and in terms of vibration exposure, significantly decreased the vibration acceleration value.

Introduction

Particulate polymer composites offer interesting mechanical, physical, mixing process and rheological properties resulting from polymer matrix and filler dispersed phase interaction. Polymer matrix and filler requires specific equipment in order to achieve uniform dispersion of fillers in the polymer matrix [1]. The importance of filler addition on polymer is to modify latter properties, either mechanical properties in example stiffness, modulus, etc. or physical properties for conductivity or density or rheological properties such as viscoelasticity or viscosity [2]. This study focuses on improving PDMS properties by usage of silica filler. PDMS or so called as silicone rubber will be filled with naturally derived silica produced via rice husk burning. Several
Previous studies have shown that filling PDMS with reinforced filler will enhance PDMS in terms of its vibration absorption, mechanical and chemical properties [3].

The importance of improving the PDMS vibration properties is to offer a new invention or solution in decreasing the transmitted vibration to human body. Powered tools such as hand powered tools will expose the operators to hand arm vibration syndrome (HAVS) which lead to neurological and/or vascular disorders separately or simultaneously. Exposure to hand-transmitted vibration can also occur from vibrating work pieces held in the hands of the operator, and from hand-held vibrating controls such as hand grinder [4].

**Materials and Methods**

**RHS Derivation**

RHS were derived from the rice husk. The impurities in the rice husk were removed by cleaning it using tap water. The cleaned rice husk are then dried at room temperature. The rice husk is further fired in the furnace at 700°C for 8 hours.

**Composites Fabrication.**

PDMS (Dow Jones, USA) were used as a matrix and RHS (Muar, Malaysia) were used as a reinforcement. Closed mold casting technique had been used to fabricate the composites panel. The PDMS/RHS composites panels were cured at 100°C.

**Molecular Analysis**

Molecular analysis of PDMS/RHS panels was performed using Fourier transform infrared spectroscopy (FTIR) Spectrum 100 Spectrometer, Perkin Elmer, USA. Testing specimen preparation and procedures were conducted as per ASTM D2702 - Standard practice for rubber chemicals - determination of infrared absorption characteristics.

**Tensile Test**

Tensile properties as tensile strength and modulus of elasticity was determined via tensile testing as per ASTM D412 standard test methods for vulcanized rubber and thermoplastic elastomer using Universal Testing Machine, AG-1 10kn, Shimadzu, Japan.

**Vibration Test**

The vibration properties of PDMS/RHS composite panels were evaluated as according to BS ISO EN 8622 for testing procedure and BS ISO EN 5349 for Hand Arm Vibration (HAV) measurement. This test method used to determine the average sum frequency weighted acceleration of X, Y, and Z axis and measure the limit of daily vibration exposure of Bosch GWS 8-1 100CE, Germany hand grinder to operator. Fig. 1. shows the PDMS/RHS composite panels and accelerometer were attached to hand grinder grip. Human vibration meter HVM 100, Larson Davis, USA were used to measure the hand arm vibration.
Results and Discussion

Molecular Analysis

Molecular analysis via FTIR used to determine and confirm the existence of molecular bonding in the PDMS/RHS composite. The infrared spectra according to the RHS content ranged from 0 to 12% is shown in Fig. 2. It was found that the range of wavelength observed referring to presence of PDMS and RHS is from $2968\text{cm}^{-1}$ to $791\text{cm}^{-1}$. The four main peaks have a wavelength of $2968\text{cm}^{-1}$, $1260\text{cm}^{-1}$, $1012\text{cm}^{-1}$, and $791\text{cm}^{-1}$. The bonds corresponding to the peaks are C-CH$_3$, Si-CH$_3$, Si-O-Si and SiO$_4$ bond respectively similar to observation by Shah et al and Duo et al. [5, 6]. Those four main peaks have a wavelength of $2968\text{cm}^{-1}$, $1260\text{cm}^{-1}$, $1012\text{cm}^{-1}$ and $791\text{cm}^{-1}$ which almost similar to the studies conducted by Shah et al and Duo et al. [5, 6].

The trend of peaks and bonds shows the presence of hydroxyl and silanol group bonding which refer to PDMS and silica bonding respectively. The existence of $-\text{CH}_3$ in first peak and second peak indicated that the reaction between hydroxyl groups on the surface of RHS and PDMS has occurred. The presence of Si in third and fourth peak corresponding to silanol groups on the surface of silica decreases after curing [7].
Tensile Properties

Tensile properties of PDMS/RHS composites were analyzed in terms of the tensile strength and modulus of elasticity. Fig. 3 and Fig. 4 shows the results of tensile strength and modulus of PDMS/RHS composites modulus gradually increase with increasing RHS loading. The addition of RHS had increased the tensile strength and modulus properties of PDMS from 4.069 MPa to 4.536 MPa and 2.947 MPa to 3.473 MPa respectively.

Tensile strength and modulus elasticity of composites tend to increase with increment of RHS loading up to 10wt%. This is ascribed to the greater reinforcing ability by the RHS that may be due to excellent bonding adhesion between matrix and filler [8]. However a decline in tensile behavior was observed as the RHS content reaches 12wt%. This may be due to formation of large SiO₂ aggregates caused by agglomeration of the high SiO₂ content. Subsequently these aggregates contributes to poor an inhomogeneous distribution of SiO₂ in PDMS [9].

The tensile strength and modulus shows a similar trend because of the increment of the RHS loading increased the tensile strength. The elasticity of the composites are indeed proportional to the tensile strength value. Higher tensile strength yields higher modulus of elasticity. However, the strain rate of the composites did not much improve as the addition of RHS caused the composites become stiffer [10].
Fig. 3. Tensile strength of PDMS/RHS composites

Fig. 4. Modulus of elasticity PDMS/RHS composites

Vibration Properties
Frequency weighted acceleration and vibration exposure time were observed in hand grinder’s hand arm vibration measurement. Each measurements used different type of composite panels
attachments which ranged from 0wt% to 12wt%. The measurement without composite panels attachment also had been studied as a references. Fig. 5 and Fig. 6 shows the results of sum average frequency weighted acceleration and vibration exposure time respectively.

The frequency weighted acceleration values were present the amount of vibration generated during measurement. From the Fig. 5 the frequency weighted acceleration were progressively decreased as the filler loading increase. Maximum frequency weighted acceleration decrement occurred at PDMS/4wt%RHS. However, the frequency weighted acceleration tend to increase at PDMS/6wt%RHS.

Results showed that the use of PDMS composite panels had significantly decreased the frequency weighted acceleration or vibration of hand arm. The attachment of PDMS without RHS filler hand decreased the frequency weighted acceleration from 8.770 ms\(^{-2}\) to 7.700 ms\(^{-2}\). This is due to PDMS properties itself which able to absorb the transmitted vibration [11]. The used of RHS as a filler had improve further the vibration absorption. RHS act as a filler in order to help to distribute the transmitted vibration to every surface in the composite panels body [12]. Compared to unfilled PDMS, the vibration localized at the vibration source, this lead to weak vibration distribution [13]. However, when the used of RHS exceed its limitation and above, 6wt% for this study, its turn out to be insignificant in reducing the vibration due to agglomeration and distribution of filler in the composite panels.

The decrement in frequency weighted acceleration lead to lower hand arm vibration of hand grinder during operation. The lower vibration rate will helps the operator to work at longer time with less hazardous effect. Fig. 6 shows the vibration exposure time as per measured during HAV measurement. Without an attachment to hand grinder grip, in 8 hours working duration per day, the operator only allowed to expose with hand grinder vibration for only 0.65 hour. By applying the PDMS/RHS composites panel the vibration exposure time had increased. The maximum vibration exposure time achieved was 2.3 hours with addition 4wt% of RHS. This enhancement will allow the operator to working or expose to the hand grinder vibration in longer duration and improve the productivity.
Fig. 5. Sum average frequency weighted acceleration

Fig. 6. Vibration exposure time
Conclusion

PDMS filled with RHS were successfully fabricated via casting method and cured at 100°C. Tensile tests revealed that RHS had improve the tensile strength and modulus with the significant enhancement at 10wt% RHS addition. PDMS/4wt%RHS composite panels also improved the productivity of hand grinder operator working hours up to 2.3hours by reduce the vibration transmitted. This improvement had decreased health effects to the hands-transmitted vibration.

References


