Malaysian Journal of Analytical Sciences, Vol 20 No 5 (2016): 1138 - 1144
DOI: http://dx.doi.org/10.17576/mjas-2016-2005-20

MALAYSIAN JOURNAL OF ANALYTICAL SCIENCES
Published by The Malaysian Analytical Sciences Society
ISSN
1394 - 2506

VIBRATION EXPOSURE ANALYSIS OF POLYDIMETHYLSILOXANE REINFORCED SILICA DERIVED RICE HUSK ASH

(Kajian Pendedahan Getaran Terhadap Polidimetilsiloksana yang Diperkuat Silika Dari Abu Sekam Padi)

Mohd Azham Azmi*, Mohd Syahmi Muin @ Marsayid, Shahruddin Mahzan, Sufizar Ahmad, Hariati Taib

Faculty of Mechanical and Manufacturing Engineering,
Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia

**Corresponding author: azham@uthm.edu.my*

Received: 10 June 2015; Accepted: 21 July 2016

Abstract

The study investigates the vibration and mechanical properties of rice husk silica (RHS) in enhancing the properties of Polydimethylsiloxane (PDMS). The PDMS/RHS composites panel were fabricated by using casting technique and cured at room temperature. PDMS panels were filled with 2 – 12 wt% of RHS. Vibration analysis of PDMS/RHS composites panel were guided by ISO 8662 standard in evaluation of hand arm vibration for hand grinder machine. The vibration exposure analysis showed that application of PDMS/RHS as a vibration absorber successfully decreased the vibration exposure to 46%. Tensile properties analysis conducted using ASTM D412 standard showed that the PDMS/10 wt% RHS properties increased to 9.6% compared to PDMS without RHS. Thus it is concluded that the addition of RHS had improved both properties of PDMS. RHS has successfully acts as a reinforcement when load is applied to the panel and during vibration exposure, RHS has acts as an absorber and distributed the vibration.

Keywords: polydimethylsiloxane, vibration exposure, rice husk silica, tensile properties

Abstrak

Kajian ini dijalankan untuk mengenalpasti sifat – sifat getaran dan tegangan silika sekam padi (RHS) yang digunakan untuk meningkatkan sifat – sifat polidimetilsiloksana (PDMS). Panel komposit PDMS/RHS dihasilkan menggunakan kaedah tuangan dan dirawat pada suhu bilik. Panel PDMS di isi dengan RHS sebanyak 2 – 12 wt%. Analisa getaran panel komposit PDMS/RHS dikendalikan menurut piawaian ISO 8662 bertujuan menilai pendedahan getaran pada tangan bagi penggunaan mesin canai tangan. Keputusan analisa terhadap pendedahan getaran menunjukkan bahawa penggunaan PDMS/RHS sebagai penyerap getaran telah berjaya menurunkan pendedahan getaran sebanyak 46%. Analisa sifat – sifat tegangan yang dijalankan berpandukan piawaian ASTM D412 menunjukkan sifat - sifat PDMS/10 wt% RHS telah meningkat sebanyak 9.6% jika dibandingkan dengan PDMS tanpa RHS. Ini menunjukkan bahawa penambahan RHS telah meningkatkan kedua – dua sifat PDMS. RHS telah berjaya bertindak sebagai penguat apabila beban dikenakan pada panel dan bertindak sebagai penyerap dan penyebar apabila getaran dikenakan.

Kata kunci: polidimetilsiloksana, pendedahan getaran, silika sekam padi, sifat terikan

Introduction

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 [1].

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 [2]. The importance of filler addition on polymer is to modify latter properties, either mechanical properties for example stiffness, modulus, etc. or physical properties for conductivity or density or rheological properties such as viscoelasticity or viscosity [3]. 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 [4].

Materials and Methods

RHS derivation

The derivation of the RHS starts by cleaning the rice husk using tap water to remove impurities. Next, wet rice husk was dried in the sun. Dried rice husk converts to RHS by burning process at 700˚C using furnace.

Composites fabrication

PDMS (Dow Jones Xiameter, USA) was applied as matrices and RHS as the reinforcement. Closed mold casting technique had been used to fabricate the composites panel. The PDMS/RHS composites panels were cured at room temperature.

Molecular analysis

Fourier transform infrared spectroscopy (FTIR) was conducted by using Perkin Elmer FTIR Spectrum 100 Spectrometer, USA to analyze the molecular in PDMS/RHS composite panels. 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, modulus was determined via tensile testing as per ASTM D412 standard test methods for vulcanized rubber and thermoplastic elastomers. Shimadzu AG-1 10kn, Japan was used to conduct the testing. Figure 3.15 shows the Shimadzu AG 10kn universal testing machine attached with tensile jig.

Vibration Test

The vibration properties of PDMS/RHS composite panels were evaluated under 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 hand grinder to operator. Figure 1. shows the PDMS/RHS composite panels and accelerometer were attached to hand grinder grip. Human vibration meter of Larson Davis's HVM100 were used to measure the hand arm vibration.

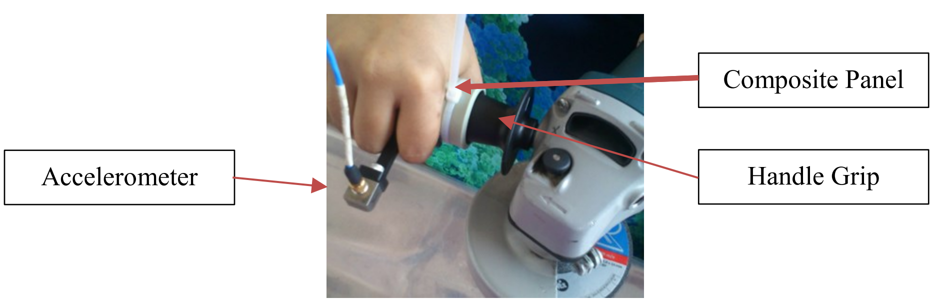

Figure 1. Hand grinder grip attached with composite panels and accelerometer

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 Figure 2. It was found that the range of wavelength observed referring to presence of PDMS and RHS is from 2963 cm^{-1} to 788 cm^{-1}. The four main peaks have a wavelength of 2968 cm^{-1}, 1260 cm^{-1}, 1012 cm^{-1} and 791 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 cm^{-1}, 1258 cm^{-1}, 1008 cm^{-1} and 788cm^{-1} which almost similar to previous studies [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 –CH_3 in first peak (2968 cm^{-1}) and second peak (1260 cm^{-1}) indicated that the reaction between hydroxyl groups on the surface of RHS and PDMS has occurred. The presence of Si in third (1012 cm^{-1}) and fourth peak (791 cm^{-1}) corresponding to silanol groups on the surface of silica decreases after curing [7].

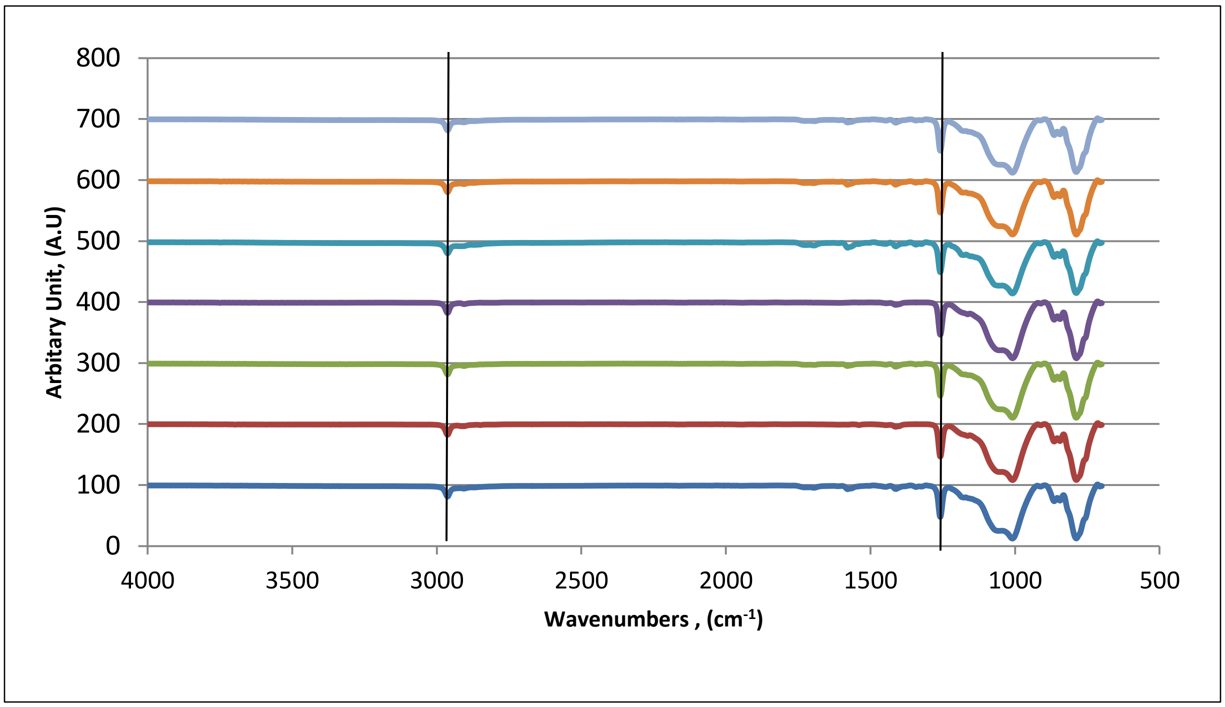

Figure 2. Infrared spectra of PDMS/RHS composite panels

Tensile properties

Tensile properties of PDMS/RHS composites were analyzed in terms of the tensile strength and modulus of elasticity. Figure 3 and Figure 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 5.311 MPa to 5.819 MPa and 1.408 MPa to 2.842 MPa respectively.

Tensile strength and modulus elasticity of composites tend to increase with increment of RHS loading up to 10 wt%. 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 12 wt%. This may be due to formation of large SiO_2 aggregates caused by agglomeration of the high SiO_2 content. Subsequently these aggregates contribute to poor an inhomogeneous distribution of SiO_2 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].

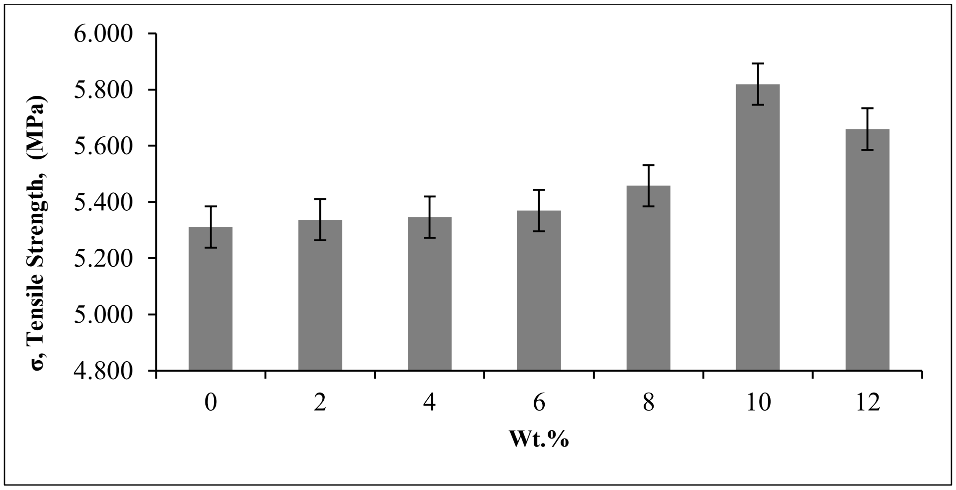

Figure 3. Tensile strength of PDMS/RHS composites

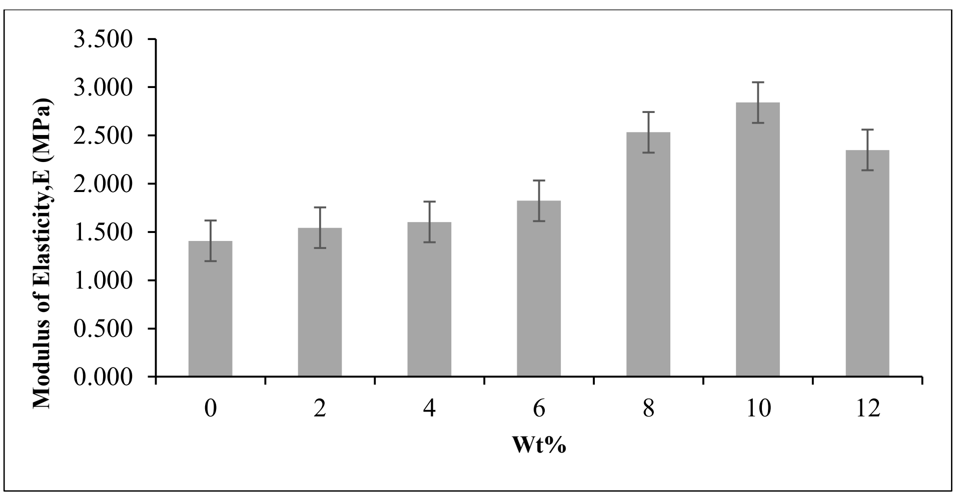

Figure 4. Modulus of PDMS/RHS composites

Vibration properties

Frequency weighted acceleration and vibration exposure time were observed in hand grinder's hand arm vibration measurement. Each measurement used different type of composite panels attachments which ranged from 0 wt% to

12 wt%. The measurement without composite panels attachment also had been studied as a reference. Fig. 5 and Fig. 6 show 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 Figure 5 the frequency weighted acceleration were progressively decreased as the filler loading increase. Maximum frequency weighted acceleration decrement occurred at PDMS/4 wt% RHS. However, the frequency weighted acceleration tends to increase at PDMS/6 wt% 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 11.700 ms^{-2} to 6.360 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.

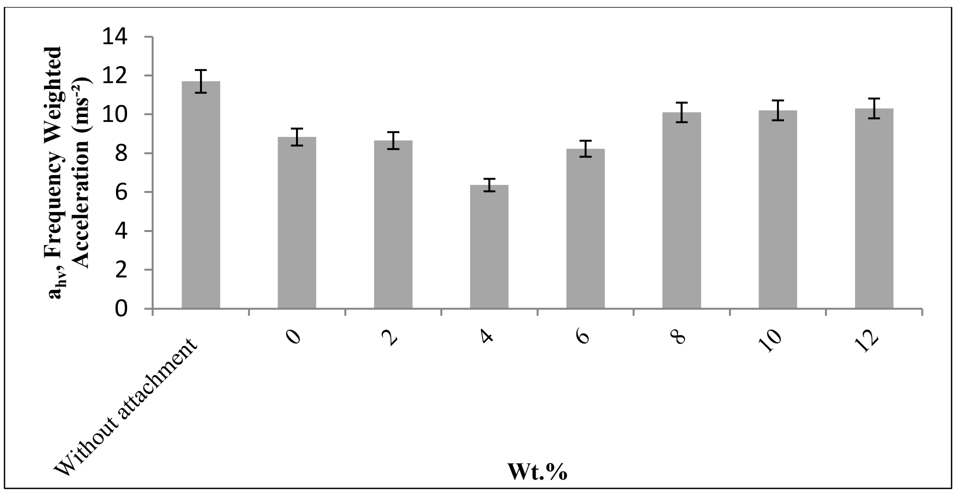

Figure 5. Sum average frequency weighted acceleration

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. Figure 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 0.46 hour. By applying the PDMS/RHS composites panel the vibration exposure time had increased. The maximum vibration exposure time achieved was 1.55 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.

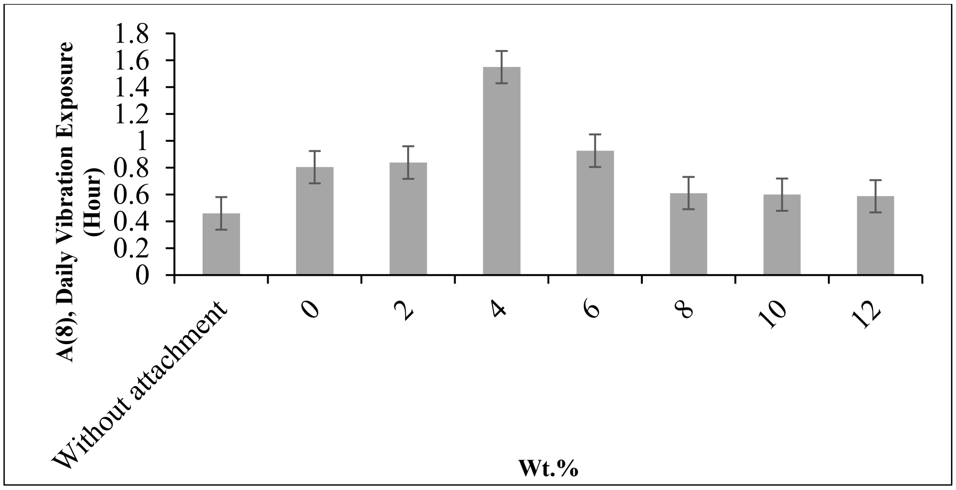

Figure 6. Vibration exposure time

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 10 wt% RHS addition. PDMS/4 wt% RHS composite panels also improved the productivity of hand grinder operator working hours up to 1.55 hours by reduce the vibration transmitted. This improvement had decreased health effects to the hands-transmitted vibration.

Acknowledgement

Authors are grateful for the KPT's MyBrain15 scholarship to Author 1, RAGS research grant's fund (Ref: R022) and UTHM's short term grant fund (Ref: 1273).

References

1. British Standards Institution (2001). *Mechanical vibration - Measurement and evaluation of human exposure to hand-transmitted vibration - Part 1: General requirements.* London: EN ISO 5349-1.
2. Pal, R. (2010). Rheology of Particulate Dispersions and Composites Surfactant Science. 1st ed. London: Taylor and Francis.
3. Leblanc, J. L. (2010). Filled Polymers: Science and Industrial Applications. 1st ed. Florida: CRC Press.
4. Ahmed, K., Nizami, S. S. and Riza, N.Z. (2014). Reinforcement of natural rubber hybrid composites based on marble sludge/Silica and marble sludge/rice husk derived silica. *Journal of Advanced Research*, 5(2): 165 – 173.
5. Shah, J., Yuan, Q. and Misra, R. D. K. (2009). Synthesis, structure and properties of a novel hybrid bimodal network elastomers with inorganic cross-links: The case of silicone-nanocrystalline titania. *Materials Science and Engineering A*, 523(1-2): 199 – 206.
6. Duo, S., Li, M., Zhu, M. and Zhou, Y. (2008). Polydimethylsiloxane/silica hybrid coatings protecting Kapton from atomic oxygen attack. *Materials Chemistry and Physics*. 112: 1093 – 1098.
7. Yingze, S., Jinhong, Y., Dan, D., Lixian, S. and Nan, J. (2014). Effect of silica particles modified by in-situ and ex-situ methods on the reinforcement of silicone rubber. *Materials and Design*. 64: 687 – 693.
8. Camenzind, A., Schweizer, T., Sztucki, M. and Pratsinis, S. E. (2010). Structure & strength of silica-PDMS nanocomposites*. Polymer*, 51(8): 1796 – 1804.
9. Prasertsri, S. and Rattanasom, N. (2012). Fumed and precipitated silica reinforced natural rubber composites prepared from latex system: Mechanical and dynamic properties. *Polymer Testing*, 31(5): 593 – 605.

10. Yan, Z., Yanwu, Z., Gui, L., Ruoff, R. S., Naiping H., Schaefer, D. W. and Mark, J. E. (2013). What factors control the mechanical properties of poly (dimethylsiloxane) reinforced with nanosheets of 3-aminopropyltriethoxysilane modified graphene oxide? *Polymer*, 54(14): 3605 – 3611.
11. Jones, R. G., Ando, W. and Chojnowski, J. (2001). *Silicon-Containing Polymers: The Science and Technology of Their Synthesis and Applications.* Dordrecht: Kluwer Academic
12. Carponcin, D., Dantras, E., Michon, G., Dandurand, J., Aridon, G., Levallois, F., Cadiergues, L. and Lacabanne, C. (2015). New hybrid polymer nanocomposites for passive vibration damping by incorporation of carbon nanotubes and lead zirconate titanate particles. *Journal of Non-Crystalline Solids*, 409: 20 – 26.
13. Sharma, S. K., Gaur, H., Kulkarni, M., Patil, G., Bhattacharya, B. and Sharma, A. (2013). PZT–PDMS composite for active damping of vibrations. *Composites Science and Technology*, 77: 42 – 51.