Vibration and Damping Characteristic of biopolymer upon UV exposure

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Abstract. Biopolymer Flexible Compress (Bio-PC) were prepared by the reaction of polyol based on waste vegetable oil with commercial Polymethane Polyphenyl Isocyanate (Modified Polymeric-MDI) with different percentages of Titanium dioxide (TiO_2) loading and then compress by using hot compression moulding technique at 90^{o}C. In this study, Bio-PC was examined the transmissibility and damping characteristic after UV exposure. It was found that the damping characteristic of Bio-PC was increase with increasing of the UV exposure and decrease with increasing of TiO_2 loading at displacement (1mm, 1.5mm) and acceleration (0.1G and 0.15G) base excitation according to ASTM D3580-9. The increasing of UV exposure of Bio-PC system will decrease the transmissibility of system and increased the damping of the system at low frequency ranges. However, the damping of Bio-PC increase with increasing of the UV exposure and decrease with increasing of TiO_2 loading.

Keyword: Biopolymer foam; UV exposure; Damping characteristic; Transmissibility

Introduction

Worldwide, more and more attention is being focused on polyurethane recycling due to under way changes in both regulatory and environmental issues. Increasing landfill costs and decreasing landfill space are forcing consideration of alternative option for the disposal material. Polyurethane successfully recycled from a variety of consumer product including appliances, automobiles, bedding, carpet cushion, upholstered furniture. Since 1990, the polyurethane recycle and recovery council (PURRC) sponsored major investigation into the recycling process including full-scale foam trials (Herman Stone 2000).

Recycling of polymer waste materials is a one way to overcome the disposal problem of polyurethane become economically and environmental viable. The four major categories, are mechanical recycling, advanced chemical and thermo chemical recycling, energy recovery and product recycling (KM Zia et al 2007). Mechanical recycling process by regrinding polyurethane foam into the powder and lead to be reused in the production of new foam as filler by the compression molding method. In this paper was discussed the development of a new method for converting polyurethane waste materials and used polyurethanes into reusable products which can be used in the preparation of polymer using mechanical recycling by hot compression moulding technique.

Damping characterization of the Biopolymer Compress (Bio-PC) was study to propose the reliability of Bio-PC transmitted of the vibration at low frequency after UV exposure. The transmissibility test was conducted followed ASTM D3580-95. The vibration characteristics, such as resonance peak, resonance frequency and attenuation frequency of Bio-PC inserted to system were determined and discussed based on the transmissibility results measured. The vibration damping of Bio-PC clearly noticed from the damping ratio (ζ) calculated using the formula of transmissibility and experimental data. According to White et al (2000) was reported that some of the amplitudes were absorbed by Bio-PC due to its damping effects occur during the transmissibility.

The modelled as a mass-spring damper system of measured vibration transmissibility of Bio-PC followed by previous researchers such as White *et al.*, (2000),Guo *et al.*, (2009) and Joshi *et al.*, (2010) as refer Figure 1. According to Guo *et al.*, (2009) was reported inserted the paperboard pads as nonlinear elastic but according to White *et al.*, (2000) and Joshi *et al.*, (2010) the foam cube inserted was modelled as nonlinear elastic and linear viscoelastic. In this study, the Bio-PC was modelled as nonlinear equivalent stiffness (K) and nonlinear equivalent damping (C) according to the difference characteristics and the damping effects of Bio-PC with TiO_2 loading and UV irradiation.

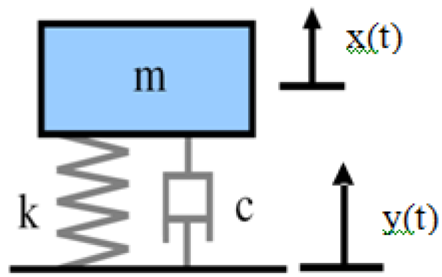

Figure 1: Mass-spring damper system was modeled as Bio-PC system

This method was proposed by Wang and Low (2005) to analyze the damped response of nonlinear of cushion. In this study, this method was selected to analyze of Bio-PC as long as the foam blocks system for sample testing. In mechanical vibrations study, there has a equation of motion when the Bio-PC system facing a vertical excitation and it shown as equation 1, where M = total mass applied on moveable top plate, C = damping coefficient = $2\zeta\ [(\sigma AM)/\ (\varepsilon d)]^{1/2}$, K = stiffness at local working point = $(\sigma A)\ /\ (\varepsilon d)$, x = motion in moveable plate, y = motion in base, and z = (x – y).

$$M\ddot{x} + C\dot{z} + Kz = 0 \qquad (1)$$

The transmissibility is defined ad ratio of base transmitted to moveable top plate with 2 blocks loaded at different frequency of this research were determined as equation 2 (Guo *et al.*, 2010), where r = frequency ratio of base frequency to natural frequency of system = $(\omega_b/\ \omega_n)$, ζ = damping ratio, x = motion at mass, y = motion at base.

$$\text{Transmissibility, } T_r = \frac{X}{Y} = \omega_n\Big[\frac{\omega_n{}^2 + (2\zeta\omega_b)^2}{\sqrt{(\omega_n{}^2 - \omega_b{}^2)^2 + (2\zeta\omega_n\omega_b)^2}}\Big]^{\frac{1}{2}}$$

$$T_r = \Big[\frac{1+(2\zeta r)^2}{\sqrt{(1-r^2)^2 + (2\zeta r)^2}}\Big]^{\frac{1}{2}} \qquad (2)$$

By using equation 3, the total damping ratio (ξ_{total}) occurred in Bio-PC system can be calculated from experimental data obtained in transmissibility test. As noted in description of FFC system, the total damping occurred in system was generated from damping effect from Bio-PC (ξ foam) and friction losses ($\xi_{\text{frictional losses}}$) found in Bio-PC system during mechanical vibration (Liang and Freeny, 1998).

$$\zeta = \frac{1}{2}\sqrt{\frac{1}{Tr^2 - 1}} \qquad (3)$$

The frictional loss was occurred of Bio-PC system due to vibration transmitted from base to the moveable top plate may dissipated by resistance to uniaxial motion of top plate of foam block system.

In this study, this friction loss were measured in order to accurately analysis the damping effects caused by Bio-PC to vibration absorption.

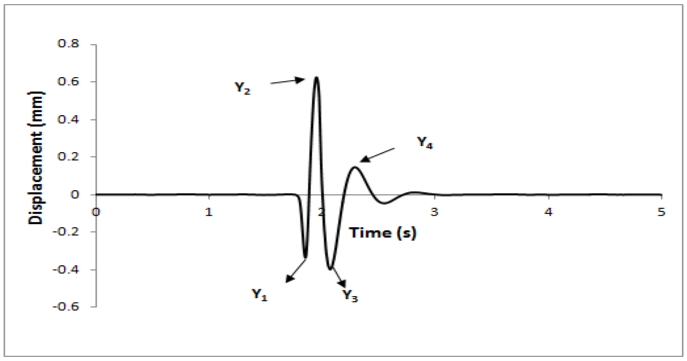

Figure 2 : Displacement response of foam-block system in free-vibration test.

The friction losses were determined due to the displacement response of moveable top plate of foam block system by a free-vibration test. Figure 4 shows the beginning motion of top plate with two blocks loaded is vibrate with decaying amplitude very fast, after an initial forced applied. This situation was occurred due to the frictional loss in four linear bearing of the foam block system. Liang & Feeny (1998) were mentioned the frictional losses or damping can be calculated through a logarithmic decrement method generate based on free vibration test.

According to Liang & Feeny (1998), the main formula to calculate the damping to the displacement response measured, where Y = y(t) = displacement, i = 1, 2, ..., n-1, and β = logarithmic decrement = $\xi/(1-\xi^2)^{1/2}$. Based on this formula (Equation 3), the β can be calculated by having 4 data from the resulting curve referred Figure 4.

$$\text{Log}\left(-\frac{Y_{i+1}-Y_{i-1}}{Y_i+Y_{i-2}}\right) = -e^{-\beta\pi} \tag{4}$$

The damping ratio generated by 4 bearing linear system in foam block system can be determined by filled the β value to $\beta = \xi/(1-\xi^2)^{1/2}$. According to Liang and Freeny, (1998) was mentioned the total damping ratio (ξ_{total}) = damping foam (ξ foam) - friction losses ($\xi_{\text{frictional losses}}$).

Sample preparation

Bio-monomer based on waste cooking oil from Small Medium Entrepreneur (SME's) was prepared by using in-house catalyst preparation to generate the epoxides from unsaturated fatty compound which comprises the acid-catalyst ring opening of the epoxides to form polyols (Anika Zafiah, 2008 &2009 ; M.H.N. Normunira et al, 2013). The bio-monomer is mixed with diisocyanate-diphenylmethane (MDI) with different percentages of TiO_2 which is 0%, 2.5%, 5.0%, 7.5% and 10.0% were prepared by simple open casting method to produce the biopolymer foam and was removed from the mold after 12 hours. After that, the samples were prepared with 160g of biopolymer foam was weighted to fill into the mould with internal core size of 180 * 180* 15mm to produce Bio-PC by using hot compression technique. The parameter of the compression machine was set at 90°C of temperature, under 26 tonnes of pressure within 1 hour. Sample of Bio-PC were exposed to the UV light in UV Lamp Test Chamber Model HD-703 (Haida International Equipment Co., LTD) at different exposure time at 250h, 500h, 750h, and 1000h at 50°C. The UV exposure of the samples was carried out using an array of UV fluorescent lamps emitting light in the region from 280 to 320 nm with a tail extending to 400 nm.

Vibration transmissibility and damping characteristic

The vibration transmissibility test was developed to determine the effectiveness of Bio-PC on reducing the unwanted base vibration. The transmissibility test was generated at various based excitation levels that is 1mm and 1.5 mm for displacement, 0.1G and 0.15G for acceleration in frequency range 2-30 Hz at 10mm, 15mm and 20mm of thickness. Damping characterization of the Bio-PC was study by modelled a mass-spring damper system at the range low frequency by following ASTM D3580-95.

Result and Discussion

The photo degradation effect of damping characteristic for Bio-PC with TiO_2 loading was investigated in this study from 0h to 1000h UV exposure. TiO_2 used as an additive of polymer due to the unique features including non toxicity and chemical stability under both high temperatures, the excellent UV screener to reflect the light away from the material surface (James Robinson et al, 2011). Furthermore, TiO_2 has been selected in this study cause the most important photocatalyst for the degradation of many organic pollutants. The value of (ξ_{foam}) was calculated using equation (3) and (4) in which damping foam (ξ foam) = damping total (ξ_{total}) - friction losses ($\xi_{frictional\ losses}$) in which the value of damping of friction losses ($\xi_{friction\ losses}$) is 0.37363 was calculated.

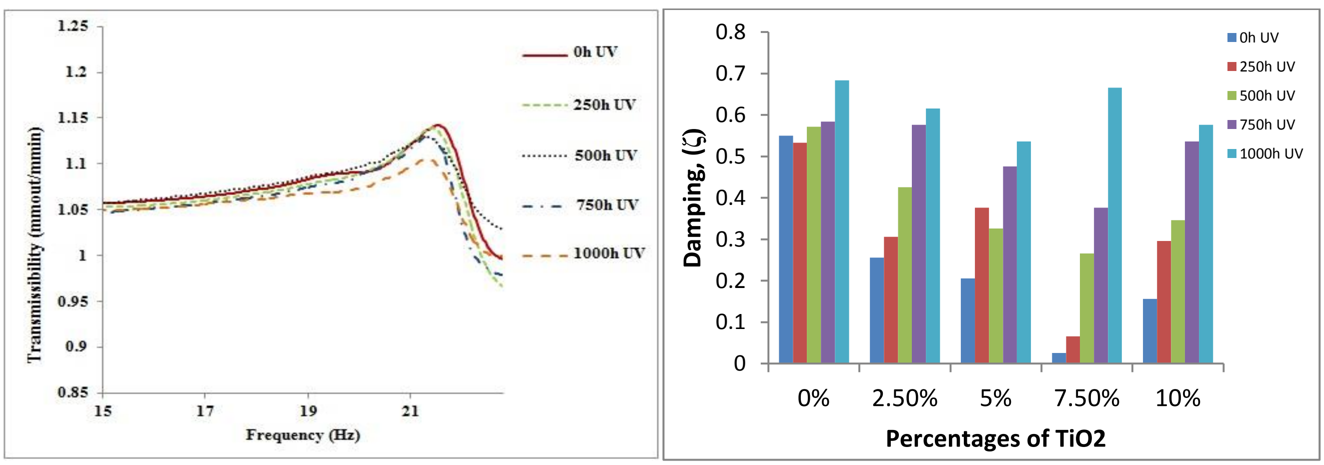

Figure 3: Transmissibility (neat Bio-PC) and damping of Bio-PC with TiO_2 loading for displacement 1mm excitation after UV exposure

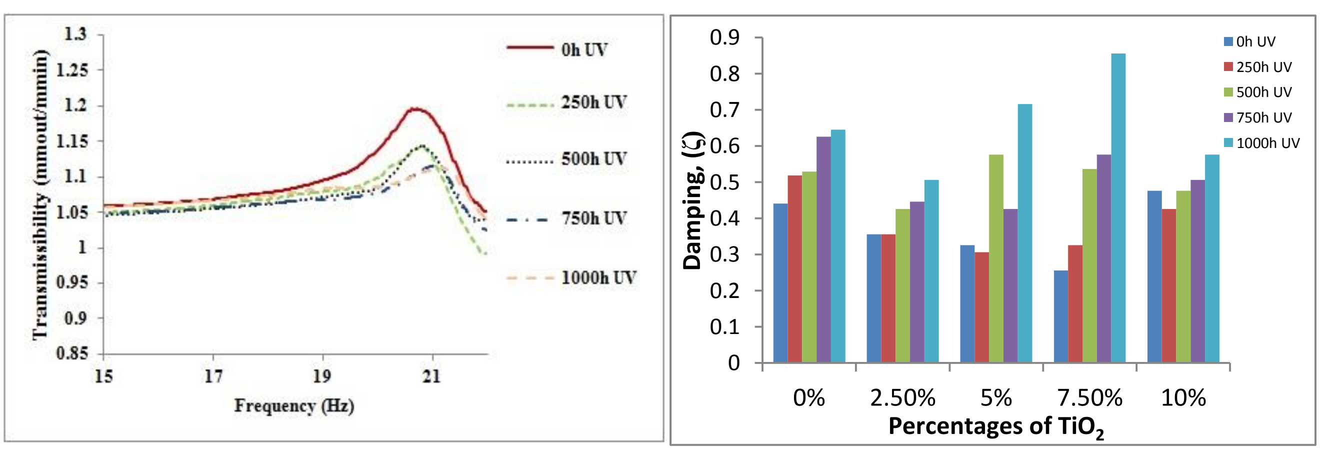

Figure 4: Transmissibility (neat Bio-PC) and damping of Bio-PC with TiO_2 loading for displacement 1.5mm excitation after UV exposure

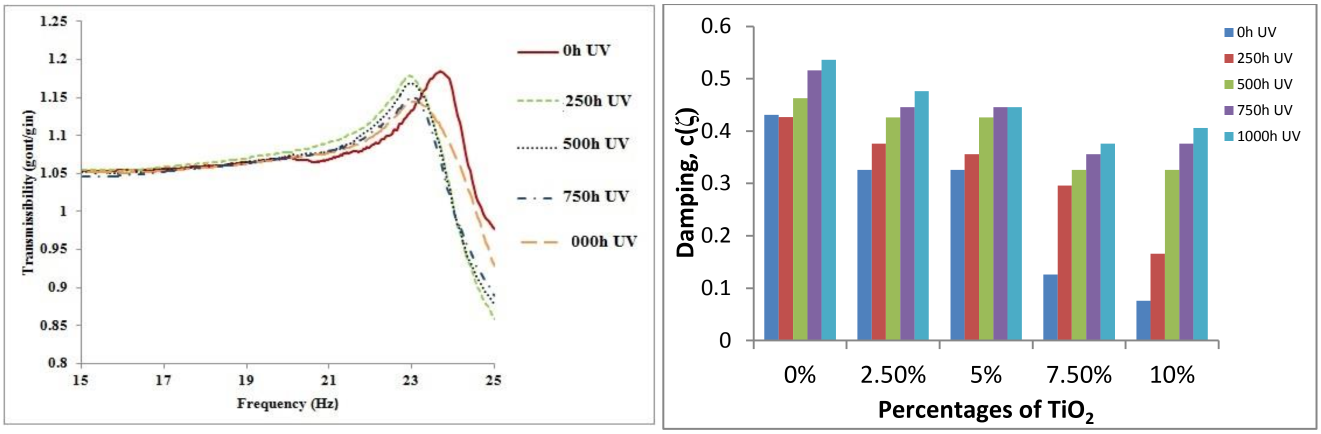

Figure 5: Transmissibility (neat Bio-PC) and damping of Bio-PC with TiO_2 loading for acceleration 0.1G excitation after UV exposure

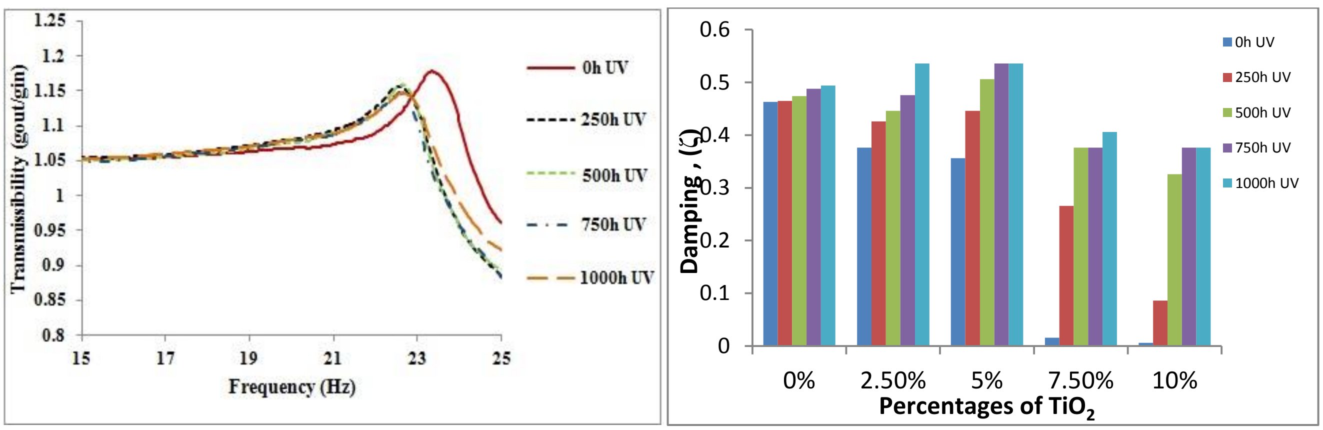

Figure 6: Transmissibility (neat Bio-PC) and damping of Bio-PC with TiO_2 loading for acceleration 0.15G excitation after UV exposure

Referring Figure 3 to Figure 6 indicated the damping of Bio-PC with different ratio of TiO_2 loading at excitation for displacement was 1mm and 1.5mm and acceleration 0.1G and 0.15G with 10mm of thickness respectively. The results show the damping of Bio-PC increase with increasing upon the UV exposure and decrease with increasing of TiO_2 loading. Obviously, the damping of Bio-PC with 7.5% TiO_2 loading gives decrease without UV exposure as compare to other concentration of TiO_2 loading at the 1mm and 1.5mm displacement based excitation. These results reported may the molecules of Bio-PC leads to the break (chain-scission), crosslink or suffer substitution reaction after UV exposure. The increasing of duration time of UV exposure up to 1000h of Bio-PC can cause the polymer breakdown and reduction of strength.

However, the increment time of UV exposure of Bio-PC system will gives the increment of damping of the system in whilst for acceleration and displacement. The damping significantly linearly increased at the maximum transmissibility at the range 15 to 25 Hz frequencies. The different concentration ratio of TiO_2 loading gives the deceasing of damping before UV exposure and started increment when exposure to UV. Hence, the damping characteristic of Bio-PC has become an important requirement in the design automotive and aerospace structures (Gibson and Finegan, 1999). However, for Bio-PC, the characteristic of damping is an important property of materials and damping capacity is usually employed to judge material ability to dissipate elastic strain energy when it is subjected to vibratory loads (Gu *et al.*, 2007). In this case, Bio-PC can dissipated the vibrations through expelled the fluid inside the particles when the moveable top plate vibrate (Gibson and Ashby, 1997).

Conclusion

The Biopolymer Flexible Compress (Bio-PC) is a renewable polymer based on waste vegetable oil is used to characterize the transmissibility and damping after UV exposure. The increasing of UV exposure of Bio-PC system will decrease the transmissibility of system and increased the damping of the system at low frequency ranges. However, the damping of Bio-PC increase with increasing of the UV exposure and decrease with increasing of TiO_2 loading. In this study was conclude that the system behavior of Bio-PC is under damping ($0<\zeta<1$) with UV exposure and TiO_2 loading.

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