Investigation on the mechanical and physical properties of TPU/PVC blend as potential material of bedpan

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Abstract. The purpose of this study is to determine the impact properties, chemical resistance and morphology of TPU/PVC blend in order to be used as potential material to fabricate bedpan. TPU and incorporation of PVC in TPU was done by melt-mixing method. The blends of TPU/PVC from melt mixing were then undergoing hot press compression moulding to produce sample with 3mm thickness. The blend sample was subjected to drop weight impact test, chemical resistance test and SEM test. Results from impact test showed that 30/70 TPU/PVC has recorded the maximum velocity impacted by 6 J of 1.8 m/s at 97ms while 50/50 TPU/PVC has the highest force (impact strength) of 0.95kN compared with other samples. The result also found that 50/50 TPU/PVC blend has lowest weight change, indicated that the blend has good resistance toward NaOH. HCl has a stronger effect on TPU/PVC blend compared to NaOH for all blend composition where 10/90 TPU/PVC showed highest resistance towards HCl. The micrograph shows that 50/50 TPU/PVC exhibited both smooth surface, indicating the brittleness of PVC and rough and the plasticity fractured surface, indicating the ductility of TPU features.

1. Introduction
In recent years, the utilization of polymers in production of medical product are being increases. The advantages of these materials consist of a low cost manufacturing processes which can led to many products of polymer materials in medical application [1]. Polymers also can be mixed or copolymerized with or without any chemical bonding between them that also called polymer blend. Polymer blending is done to achieve commercially variable products through either superior properties or lower cost as compared to the virgin material. Various advantages accomplished by developing polymer blending such as improvement of the properties, reduction of the material cost, improved processability of polymer and extended service temperature range [2]. One example of polymer blend is blending of thermoplastic polyurethane (TPU) and polyvinylchloride (PVC) which can be obtained by melt-blending the materials that have been used as a coated wire, cable, tubing, hoses, upholstery, apparel fabric, film, and others. Soft grades of TPU are often used as polymeric plasticizers in PVC. On the other hand Polyurethanes (PU) exhibit excellent mechanical properties and good low
temperature properties. Thus, the versatility of PU chemistry allows thermoplastic polyurethanes (TPU) to be tailor made for various polymer blends [3].

Shashidhara et al. (2010) compared the mechanical and thermal properties PVC/TPU blends with variable weight ratio prepared using single and twin screw extruder. Two grades of TPU’s different in hardness (Shore A hardness 66 and 85) were used in making the blends. The tensile strength of PVC/TPU-1 and PVC/TPU-2 blends obtained from twin screw extruder is higher than that obtained from single screw extruder. The effect of addition of TPU to PVC which is already plasticized with DOP was expected to decrease the modulus of the blends [4]. Study by Hernandez et al. (2002) showed that the PVC plasticized with common Dioctyl phthalate (DOP) shows a considerable higher elongation at break and lower Young modulus than PVC mixed with TPU. A remarkable reduction in the viscosity of the polymer blends observed by these authors indicates that these compounds worthy of attention from a technological point of view [5]. Pita et al studied the influence of processing condition on the mechanical properties of plasticized PVC and PVC/TPU blend. It is suggested that the structure of TPU/PVC mixtures could be maintained efficiently up to 50 phr TPU content. Processing of the corresponding melts is obviously very interesting and promising in the study of polymeric materials [6].

Pielichowski et al. (2000) has examined the thermal behaviours of compatible polyvinyl chloride (PVC)/chlorinated polyurethane (CPU) blends. Decomposition route was found to be of a two-step process; the decisive degradation stage was found to be a result of parallel reactions of PVC and CPU decomposition. The enhanced thermal stability of several PVC/CPU blends can be explained in terms of specific dipole-dipole interactions whose intensity may, however, be lowered by diffusion conditions of volatile products through the polymer matrix [7].

The purpose of this research is to determine the potential of TPU/PVC blend as material for fabricating bedpan. The effect of TPU loading percentages on the impact properties, chemical resistance and morphology of TPU/PVC blend will be determined. The drop weight impact test can give the information on impact properties of the TPU/PVC blend from the graph of force against displacement, and velocity against time. Chemical resistance testing were using sodium hydroxide (NaOH) and hydrochloric acid (HCl) as chemical reagent to get the information of the effect of chemical to dimensions or weight of the TPU/PVC blend. The morphology of the TPU/PVC blend was study using Scanning electron microscopy (SEM).

2. Experimental Details

2.1. Materials

The materials used in this studied are commercial polyvinyl chloride (PVC) and thermoplastic polyurethane (TPU). PVC grade Kane vinyl PSM 31 (Degree of polymerization 1230 to 1430 and density 1.4 g/cm3) was obtained from Kaneka (Malaysia) Sdn. Bhd., and TPU grade Estane 58887 (hardness 87 Shore A and density 1.12 g/cm3) acquired from Lubrizol Advanced Material Malaysia Sdn. Bhd. company.

2.2. Sample preparation

TPU and incorporation of PVC in TPU was done by melt-mixing method using Brabender Internal Mixer Plastograph EC machine at different ratios of 10/90 %wt, 30/70 %wt and 50/50 %wt. of TPU/PVC at temperature of 180ºC and speed of 60 rpm. Firstly TPU was charged to start the melt mixing. After 2 min PVC was added and mixing was continued for another 6 minutes. At the end of 8 min, the blend was taken out and the sample was obtained. The blends of TPU/PVC sample from melt mixing were then undergoing hot press compression moulding to produce sample with 3mm thickness. The hot press compression machine GT-7014-H model was used for compaction a sample for test. The
temperature was set at 180°C and the pressure was set at 15 ton. The mould was preheated for 2 minutes before compression to remove air trapped in the sample. The compression process was done for 5 minutes and then, the sample was cool down for 5 minutes. The hollow rectangular mould was used in the compression moulding has the dimension of 170 mm x 135 mm with thickness 3 mm. The samples were then cut according to the America Society for Testing and Materials (ASTM) standard dimensions for mechanical and physical testing [8].

2.3. Drop weight impact test
A model IM10 drop weight impact testers manufactured by IMATEK was used to produce the instrumented impact loading. For this experiment, the impactor surface was hemispherical with a radius of 12.7 mm and the total mass including impactor and carriage was 9.6209 kg. The test was performed at room temperature with 6 J impact energy level. Five specimens for each of the blend were tested and mean values were calculated. The test specimen size is 150mm x 100mm flat rectangular with thickness of 3mm.

2.4. Chemical resistance test
The chemical resistance test was performed by following ASTM standard test method D543[9]. Two chemical reagents were used in this study; which are sodium hydroxide (NaOH) and hydrochloric acid (HCl). The chemical resistance towards NaOH and HCl was measured through swelling effect and weight loss. The specimens were immered in the appropriate reagent for a specified time under the room temperature. For the swelling effect, changes in mass were reported for time duration of 24, 72 and 168 hours which represent short, intermediate and long period of the tests. Three sample tests were carried out for each blend sample.

2.5. Scanning electron microscopy(SEM) test
The morphology of the surface of samples was examined by scanning electron microscope (SEM) JEOL JSM-6460LA. The impact fractured sample was cut into small rectangular shape, so the sample can be mounted with the tape on the sample holder.

3. Result and discussion
3.1. Drop weight impact
The impact properties of TPU, PVC and TPU/PVC blend with a ratio of 10/90, 30/70, and 50/50 are used to compare the mechanical properties of TPU, PVC and their blends. Figure 1 shows the peak of velocity against time behaviour at impact energy of 6J. The results showed that the velocity was increased with increasing of time at the beginning of the test before significantly dropped after 10ms and increase back for all samples. TPU sharp drop was noted at 20ms while PVC was noted at 50ms. 50/50 TPU/PVC blend has exhibited intermediate drop between TPU and PVC at 25ms. The maximum velocity has occurred at 97 second where the maximum velocity was recorded by 30/70 TPU/PVC by 1.8 m/s.

Figure 2 shows the peak of force against displacement at impact energy of 6J. The force against displacement curves give information about the impact response of composite materials tested [10]. The displacement of impact test was conducted to determine the ability of the blend to withstand the forces applied vertically from a specified height in the drop load method [11]. The peak of force against displacement shows that the 50/50 TPU/PVC have the highest force (impact strength) by 0.95kN as compared to other samples. There are no perfect rebounding type curve was occurring of the diagram after reaching a maximum force for the test at impact energy of 6J. For 10/90 TPU/PVC and 30/70 TPU/PVC blend, the scattered peak was observed that possibly due to the damage of both specimens. This affects significantly showed that 10/90 TPU/PVC and 30/70 TPU/PVC blends have lower impact strength.
3.2. Chemical resistance

The chemical resistance of TPU/PVC blends against NaOH and HCl are shown in Figure 3 and 4. The chemical resistance effect is determined by the percentage of weight change after immersion. The chemical resistance of the TPU/PVC blends after 24 hours, 72 hours and 168 hours of immersion in NaOH as shown in Figure 3. It was found that a TPU has the highest weight gains which are 0.19% after 24 hours, 0.39% after 72 hours and 0.57% 168 hours followed by PVC for all immersion period. This implies that TPU has lower resistant ability to resist the absorption of NaOH. While, the lowest weight change is found by 50/50 TPU/PVC blend where only 0.19% weight gained over 168 hours of immersion, which indicated that 50/50 TPU/PVC has a good resistance toward NaOH.

Figure 4 representing the chemical resistance effect of the blend after immersion in HCl for 24 hours, 72 hours and 168 hours. PVC showed the highest percentage of 0.93% than other samples followed by TPU with 0.85% and 50/50 TPU/PVC blend with 0.83% of weight gained after immersion for 168 hours. Blend of 10/90 TPU/PVC has highest resistance towards HCl with only 0.69% weight increase after 168 hours. Even though the 50/50 TPU/PVC blend showed a high gain during longer immersion period (168 hours), it has displayed good properties in 24 hours immersion with the lowest value of gain with only 0.15%. The 30/70 TPU/PVC blend showed the highest weight gain recorded at 0.23% after immersing for 24 hours as compared to the other blends. The result shows that the chemical resistance of the TPU/PVC blend has lessened with increasing of TPU content after long exposure. Strong interaction between the plastic material and chemical are preferred when the chemical nature of the materials are similar. For example, if the solvent is highly polar and plastic materials also have polar groups, the plastic material may be influenced by the chemical [12]. Therefore in this case there will be a strong interaction between PVC and HCl, which are both non-polar.
3.3. Scanning electron microscopy (SEM)

Scanning electron microscope (SEM) is used to observe the fracture surface of the TPU/PVC blend sample in order to evaluate the morphology of the polymer blends. The fracture specimens were acquired from impact test. Figure 5 shows scanning electron micrographs of TPU, PVC and 50/50 TPU/PVC blends at magnification of x2000. PVC displayed smooth surface, indicating the brittle fracture has occurred as shown in Figure 5 (a). The surface of TPU was rough with small particle surface which signifies the ductile fracture while 50/50 TPU/PVC exhibited the mixture of both features with smooth cut with smaller particulate of agglomeration and pores on its surface that indicate in Figure 5 (b) and (c). From the result, it is assured certainly that by adding TPU resulted in reduction of PVC brittle fracture [13]. This suggests the good compatibility between TPU and PVC that could achieve good performance.
4. Conclusion
Impact test showed the maximum velocity has occurred at 97 ms by 1.8 m/s that was recorded by 30/70 TPU/PVC. The peak of force against displacement shows that the 50/50 TPU/PVC have the highest force by 0.95kN as compared to other samples. The immersion of TPU/PVC blend in NaOH found that the 50TPU has lowest weight change of only 0.07 % after being immersed for 168 hours. The highest weight change after immersion in NaOH for 72 hours of immersion was TPU by 0.39% of weight gain. The weight increased for 50/50 TPU/PVC after complete immersion in NaOH for 24
hours is 0.06 % and after immersion for 168 hours is only 0.18% as compared to other blends which
indicated that 50/50 TPU/PVC blend has a good resistance toward NaOH. HCl had a stronger effect
on TPU/PVC blend compared to NaOH where the weight change occurred above 0.6% for all blend
composition. The SEM micrographs showed that the fracture surface of the blend of 50/50 TPU and
PVC sample resulted in the adaption of both PVC brittleness and TPU ductility features. The results of
this blend showed promising potential to be used to fabricate bedpan.

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