Effect of 5-15% Carbon Black Reinforcement on Mechanical Properties and Resistivity of Polyurethane Composites

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Abstract. This research investigated the effects of carbon black-reinforced thermoplastic polyurethane matrix composite with variation of 5, 10, and 15 vol.% on mechanical properties and electrical resistance. The composites were produced using injection molding process with temperature of 193 °C, pressure of 30 bar and injection speed of 176 mm/sec. Characterization of composites were conducted by hardness and tensile testing, electrical resistivity measurement and SEM examinations. The results showed that the highest tensile strength of composite of 20.44 MPa is obtained with carbon black 10 vol.% reinforcement. The hardness improved with the increase of carbon black reinforcement, which the highest hardness was produced on carbon black 15 vol.% composite by 89.5 Shore A. The lowest resistivity was achieved in polyurethane composite reinforced with 15 vol.% carbon black of 8.20 x 10^5 Ω.

Keywords: Polyurethane composite, carbon black, mechanical properties, resistivity.

1. Introduction

Polymer composites are improved nowadays for many component, for instance as castor wheel of hospital bed. The polyurethane materials have insulated properties with resistivity values of 1.8 x 10^{12} Ω, which must be reduced to avoid electrostatic discharge (ESD) especially when the wheel moved on the carpets [1]. ESD could be very dangerous because it can harm electronic components related to human health [2]. Several studies have been conducted to decrease resistivity of the polymer materials, especially adding conductive reinforcement as carbon basis materials. Reinforcing 25 wt.% of carbon basis material on polymer improved antistatic properties, whereas decrease mechanical strength and process ability [3,4]. Islam, et al. [5] studied role of 30 wt.% carbon black reinforcement on PVC composite which resulting resistivity value of 9.92 x 10^3 Ω. Carbon black is one of the commercially produced Nano-particles which have three main characteristics of particle size, structure and chemical surface. Carbon black basically has element of carbon in the form of very fine particles that improve mechanical properties [6-8]. Carbon-filled fillers have recently emerged as one of the promising substitute materials because of their high aspect ratio, low cost, easy production of low resistance values, low density and high conductive values [9-10]. Ibrahim et al. [11] conducted a research by adding carbon black to the polyurethane matrix to improve mechanical properties. Therefore, this research studied carbon black-reinforced

polyurethane composite, which is expected to decrease electrical resistance value and improve mechanical properties.

2. Materials and Methods

The matrix materials used in this study are thermoplastic polyurethanes; consisting of Isothane and Desmopan with a mixture ratio of 2:1. The reinforcement material is carbon black with grade of N330, with variation of 5,10 and 15 vol.%. The composites were produced using injection-molding process, with temperature of 193 C, pressure of 30 bar and injection speed of 176 mm/sec. The instruments used in this research are a 215 kg mixing machine; a 16.6 kW typical hopper-dryer machine; and injection molding machine with capacity of 150 Ton. Composites characterization were conducted by hardness testing using shore durometer A based on standard of ASTM D2240-15[12]; tensile testing according to ASTM D 638-14 [13] with force of 50 kN; SEM observation refer to ASTM E 986-97[14] to determine surface morphology. Electrical resistivity of the composites was measured based on ASTM D257 [15] through frequency flow of 5000-100000 Hz.

3. Results and Discussion

The result of mechanical properties of the thermoplastic polyurethane composites reinforced with 5, 10, 15 vol.% carbon black is presented in Figure 1 (a) and (b) and Table 1. It shows that the highest tensile strength is discovered in a 10 vol.% composition of carbon black with a value of 20.44 MPa and the lowest value tensile strength is presented in the composite with carbon black 5 vol.% of reinforcement. The increasing tensile property is significant to the use of carbon black, which has relatively good adhesion that occurs between matrix and reinforcement materials. Composite reinforced with 15 vol.% of carbon black obtained 18.9 MPa, which is lower than 10 vol.% of carbon black. The decrease of tensile strength is could be caused by the weakening of bond between the interface of polyurethane and carbon black due to cavities caused by increasing reinforcement material. Figure 1 (b) describes strain value of the composites, which the highest strain is 501.7 % on composite reinforced with 10 vol.% of carbon black. From the figure, it can be concluded that the highest mechanical properties are produced on the composition 90 vol.% polyurethane composites reinforced with 10 vol.% carbon black.

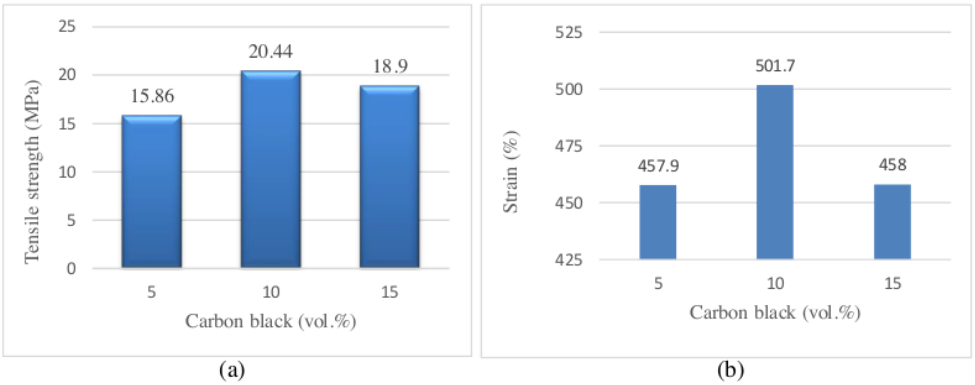

Figure 1. Mechanical properties of polyurethane composite with variation of carbon black of 5, 10, 15 vol.%: (a) tensile strength and (b) strain

Table 1 Mechanical properties and resistivity of polyurethane resistance with 5, 10, 15 vol.% CB

Sample	Characterization				Void
	Tension test	Strain strength	Hardness	Resistance	
Carbon black 5 vol.%	15.86	457.9	86.5	1.20×10^6	✓
Carbon black 10 vol.%	20.44	501.7	88.5	1.41×10^6	✓
Carbon black 15 vol.%	18.9	458	89.5	8.20×10^6	✓

With the significant addition of carbon black of 5 and 10 vol.%, the value of tensile strength and strain will increase until the optimal composition of 10 vol.%. These results are supported by previous studies by Broza et al. [3], that having a decrease of tensile strength is due to the embrittlement caused by the addition of carbon black. Also, reinforcing 15 vol.% of carbon black will decrease tensile strength because of the difficulty in distributing reinforcement particles and the tendency of the particles to agglomerate.

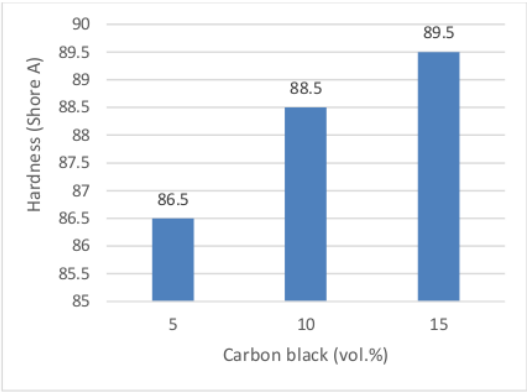

Figure 2. Hardness of polyurethane composite with variation of carbon black of 5, 10, 15 vol.%

Figure 2 shows the highest hardness is achieved by the reinforcement composition of 15 vol.% carbon black of 89.5 shore A, while the lowest hardness of 86.5 shore A is obtained by the composite reinforced with carbon black 5 vol.%. It can be said that increasing vol.% of carbon black could improve hardness of the composites.

Figure 3 illustrates a noticeable change in the structure shown by the red arrow. This change is caused by the increasing of carbon black, which allows the formation of high structures thus increasing contact between the particles. Carbon black with high structure has good disperse-ability properties and is able to fill voids in composites. The high particle interaction will simultaneously increase the value of electrical conductivity. Figure 3 (a) and (b) shows cavities, which are marked by yellow arrows, and visible blobs, marked by red rectangles. These swellings are caused by in-homogeneous distribution of reinforcements. The cause of the cavities in the composite could be affected by high moisture of composite in certain area

so that it would absorb air and produce an uneven density. This is in accordance with the results of SEM examination, which is seen as voids.

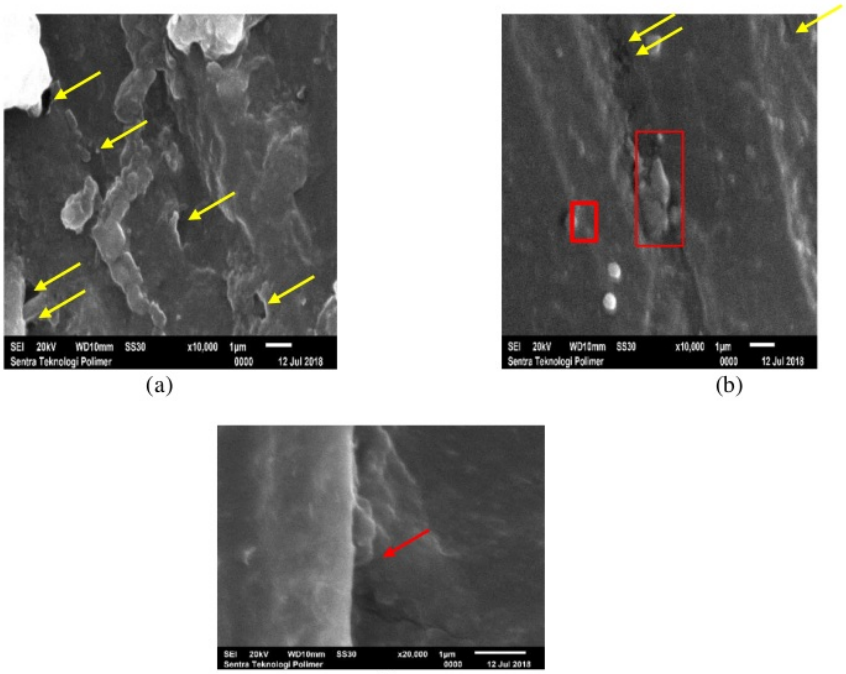

Figure 3 SEM examination of polyurethane composite-carbon black with variation: (a) 5 vol.%, (b) 10 vol.%, (c) 15 vol.%

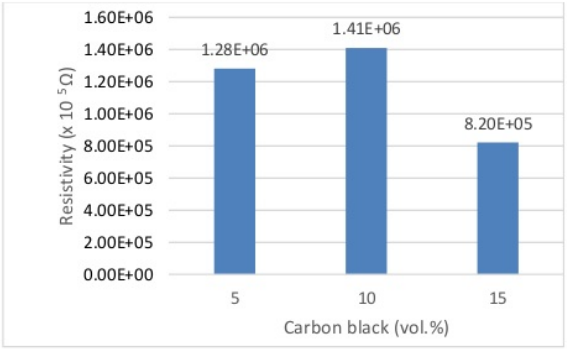

Figure 4. Resistance of polyurethane composite with variation of carbon black of 5, 10, 15 vol.%

Figure 4 explains the variation of surface electrical resistance. It can be seen that the composite with carbon black of 10 vol.% obtained the highest resistance value of 1.41 x 10^6 Ω. The smallest resistance value is shown on carbon black of 15 vol.%, with resistance value of 8.20 x 10^5 Ω. Based on previous research, the addition of carbon black can reduce the value of electrical resistance efficiently by minimum addition, because the particles have a rounded and branched round structure, high surface area and small particle size.

4. Conclusions

Addition of carbon black to the thermoplastic polyurethane improved the following properties of the composite. The maximum tensile strength and strain was achieved at carbon black 10 vol.%. Increasing carbon black from 5 to 15 vol.% will improve hardness of the polyurethane composites, with the highest value of 89.5 shore A. As for resistivity, carbon black of 15 vol.% has the least resistance value of 8.20 x 10^5 Ω. SEM examination revealed that voids appeared on all composite and increasing carbon black reinforcement generated the particles tend to agglomerate.

5. Acknowledgements

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