Mechanical Properties of Polycarbonate Urethane (PCU) for Orthopedic Devices: Fabrication with Compression Molding

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Mechanical Properties of Polycarbonate Urethane (PCU) for Orthopedic Devices: Fabrication with Compression Molding

W. D. Lestari, R. Ismail, J. Jamari, and A. P. Bayuseno

1 Introduction

The lifespan of UHMWPE joints is often limited to 15–20 years [1]. The limitation of UHMWPE is that the material is stiff enough that it cannot imitate the viscoelastic properties of real articular cartilage such as those found in the hip joint. Based on these problems, there are two basic approaches that can be used to extend the life of the artificial hip joint. The first option is to reduce the wear rate of the UHMWPE ace tabular liner. The second option is to use an alternative substitute for UHMWPE which is similar in nature to real cartilage. The second option is a solution taken by many researchers recently, by looking for alternative materials that have mechanical properties similar to original cartilage.

Recent studies found the polycarbonate urethane (PCU) to be the most promising as an alternative bearing [2–6] solution to UHMWPE in orthopedic load bearing applications in the artificial hip prosthesis [7]. PCU is an attractive material which has combination of elasticity with durability, wear and corrosion resistance, toughness, mechanical stability, good tribological properties, good compatibility, biologically stable polymer with a low-elastic modulus (10–100 Mpa) [8, 9] that is similar to natural cartilage [10, 11]. Concerning to get the required properties of PCU, there are a few studies on the fabricated of this thermoplastic material. Miller et al. [12] assessed three processing methods of PCU (injection molding, compression molded, and 3D printed) to acquire the best material for long the performance of PCU implants in load bearing applications. The overall objective of this study is to evaluate the effect of

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compression molding PCU on the mechanical properties and material characterization for orthopedic devices such as bearing material of artificial hip joint application.

2 Materials and Method

2.1 Materials and Processing

Compliant polycarbonate urethane (PCU) Bionate 80A in pellet form. Processing methods utilized in this study by compression molding. The compression molding parameters in this study are shown in Table 1, as for the process shown in Fig. 1.

2.2 Mechanical Properties

The mechanical properties that use in this study were tensile test, compression test, and hardness test. Tensile testing is carried out based on the standard DIN EN ISO 527-2 type-1BA, while the compression test refers to ASTM D 6147-97 method A and research from Beckmann [13]. The hardness measurement in this study was taken using a Vickers hardness tester (Mitutoyo HM 200).

2.3 Materials Characterization

The morphological analysis of PCU specimens from the compression molding process was carried out using scanning electron microscopy (SEM). Furthermore, the materials characterization that is carried out were absorption test and density. Water absorption testing is carried out based on ASTM D750 standards andresearch conducted by Geary [14]. In addition, the density test is carried out according to the ASTM D792 standard.

Table 1 The compression molding parameter of PCU with a holding time of 30 s

Speciments	Melt temperature (°C)	Pressure (Kgf)
Speciment 1/PCU A	180	65
Speciment 2/PCU B	190	60
Speciment 3/PCU C	200	55

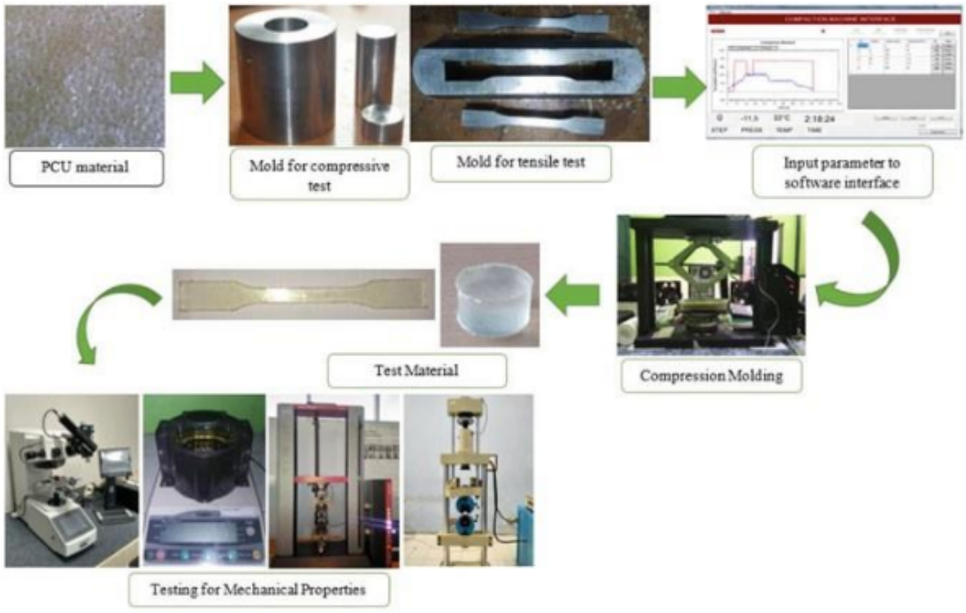

Fig. 1 The compression molding process of PCU material

3 Results and Discussion

3.1 Mechanical Properties

Tensile Test. The tensile test results show that the average modulus of elasticity for PCU A specimens is 11.36 MPa with a strain of 402.93%, PCU B specimens 10.86 MPa with a strain of 402.94%, and PCU specimen C 10.82 MPa with a strain of 402.93%.

Compressive Test. The results of the compressive test on each specimen in this study are shown in Table 2.

Hardness. Hardness testing is based on ASTM D2240 standards. The standard required for PCU is to have a hardness value of 83–85.5 shore A. The results of PCU material hardness testing with a compression molding process are shown in Table 3.

Table 2 Compressive test results

Name	Diameter	High	Mod. Elastic	Stress	Max. strain
Parameter			Strain 0.5–0.25%	30 min	Entire areas
Unit	mm	mm	MPa	MPa	%
PCU A	29.72	5.92	0.1760	1.7143	25.054
PCU B	29.84	5.92	0.1145	1.4077	25.055
PCU C	29.66	6.05	0.1168	1.0928	25.054

Table 3 Results of hardness testing of PCU specimens

PCU specimen	Average hardness (HV)	Hardness (Shore A)	Hardness Standards (Shore A)	Differentiation (%)
Model A	807.0	89.3	83–85.5	4.44
Model B	760.4	85.6	83–85.5	0.01
Model C	686.6	80.3	83–85.5	

3.2 Material Characterization

SEM. The SEM results shown in Fig. 2, it can be seen that the resulting specimens still have rough surface. In addition, there are also waves which are probably the result of the pressing process and the melting temperature is not suitable, so that it has not yet produced a homogeneous surface.

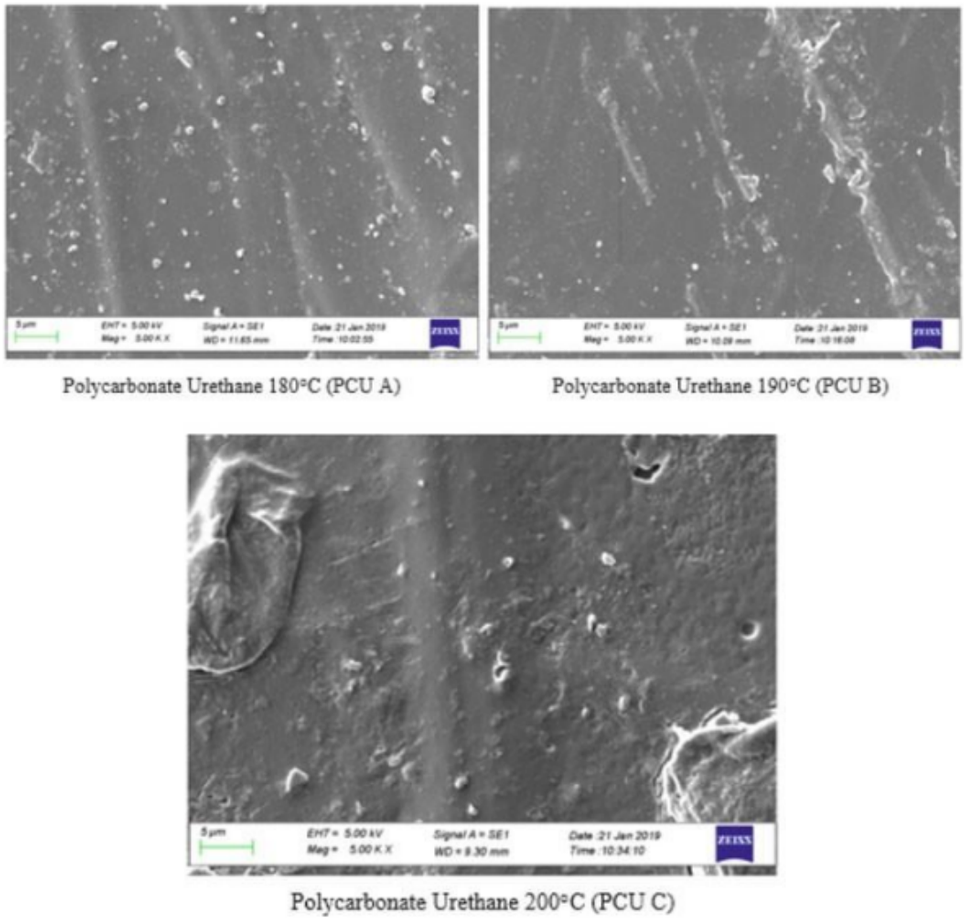

Fig. 2 Morphology of PCU specimen seen by SEM

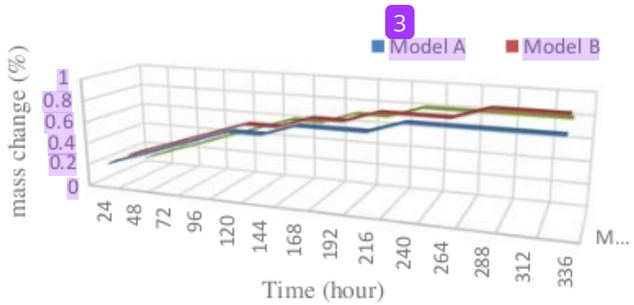

Fig. 3 The absorption test PCU material from compression molding

Tabel 4 Density test results of solid PCU specimens

PCU specimen	Density standard (g/cc)	Density obtained (g/cc)	Differentiation (%)
Model A	1.19	1.18	0.84
Model B	1.19	1.19	0.00
Model C	1.19	1.18	

Water Absorption. The standard required for PCU is having the ability to absorb water by 0.85–1.2%. Absorption test results are then made a graph of mass and time increment (see Fig. 3). Based on graph, it can be seen that the PCU A and PCU C specimens have the same total mass gain. As for PCU B specimens, the mass gain was smaller than PCU A and PCU B specimens.

Density. The standard required for a PCU is to have a density or density value of 1.19 g/cc. Based on Table 4, it can be seen that the standard density and density of the PCU specimens made by the compression molding process are relatively the same, with a difference of only 0.01 g/cc in model A and model C, whereas in model B the density is exactly the same, 1.19 g/cc.

4 Conclusion

Based on the experiment, it was concluded that the appropriate temperature for the PCU compression molding process was between 180 and 200 °C with a pressure of 65–55 kgf and a holding time of 0–0.5 min. The results of characterization in the form of density and water absorption tests were also in accordance with existing standards. As for the mechanical testing, it is still not maximal, but also in accordance with the existing standard range. Based on this, it can be said that the PCU material manufacturing method by means of compression molding can be adapted to process PCU material for medical equipment purposes.

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