Effect of Thermoplastic Polyurethane on Properties of Polyvinyl Chloride in Designing Bedpan

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LIST OF ABBREVIATIONS

ANSYS	Analysis System
AUTOCAD	Autodesk's Computer-aided Design
ASTM	American Society for Testing and Materials
C	Carbon
CAD	Computer Aided Drafting
Cl	Chloride
DSC	Differential Scanning Calorimetry
HCl	Hydrochloric acid
kg	Kilogram
min	Minute
mm	Millimeter
MPa	Mega Pascal
ms	Milliseconds
NaOH	Sodium Hydroxide
SEM	Scanning Electron Microscopy
TGA	Thermal Gravimetric Analysis
TPU	Thermoplastic Polyurethane
Pa	Pascal
PVC	Polyvinyl Chloride

LIST OF SYMBOLS

%	Percent
°C	Celsius

Kesan Termoplastik Poliuretana Terhadap Ciri-ciri Polyvinyl Klorida Dalam Mereka Bentuk Bedpan

ABSTRAK

Komersial bedpan yang dibuat daripada plastik keras memberikan ketidak selesaan kepada pesakit. Untuk mengatasinya satu kajian dijalankan. Kajian ini dijalankan untuk menentukan sifat mekanikal, fizikal dan termal campuran TPU/PVC untuk digunakan sebagai bahan untuk membuat bedpan. TPU dan PVC dicampurkan dengan menggunakan kaedah campuran leburan dan menjalani kaedah acuan mampatan panas untuk menghasilkan sampel. Sampel PVC/TPU dengan ratio 90/10, 70/30 dan 50/50 melalui ujian tegangan, penyerapan air, rintangan kimia, SEM, TGA dan DSC. Analisa simulasi menggunakan perisian ANSYS workbench dilakukan pada akhir ujian. 50TPU dipilih sebagai nisbah yang sesuai kerana mempunyai kekuatan tegangan yang baik, modulus yang lebih rendah dan keanjalan yang tinggi. Campuran TPU dan PVC telah mengurangkan penyerapan air berbanding TPU disebabkan TPU mempunyai daya menyerap air yang tinggi kerana bersifat hidropilic dan PVC bersifat hidropobic. Asid hidroklorik (HCl) mempunyai kesan yang kuat pada campuran TPU/PVC berbanding sodium hidroksida (NaOH) untuk semua komposisi campuran. Gambarajah SEM menunjukkan bahawa 50TPU mempunyai permukaan yang lebih rata dan gumpalan campuran PVC/TPU di permukaannya sedikit menghilang apabila kandungan TPU bertambah. Keputusan ujian TGA menunjukkan penguraian berlaku dalam dua peringkat untuk campuran TPU/PVC. Penguraian PVC adalah lebih rendah daripada TPU dan lebih tinggi daripada campuran TPU/PVC. Berdasarkan keputusan DSC, campuran TPU/PVC mendedahkan satu peralihan suhu lebur (Tm) terhasil bagi sampel 10TPU, 30TPU dan 50TPU. Ia menunjukkan keboleh campuran antara TPU dan PVC kerana hanya terdapat satu suhu lebur. Untuk kajian analisa simulasi, kesan tekanan ke atas tegasan pada ketebalan dinding yang berbeza pada lengkung TPU, PVC dan 50TPU telah menunjukkan bahawa 0.5mm mempunyai tekanan maksimum tertinggi pada tekanan 8psi berbanding ketebalan 0.8mm dan 1.0mm. Tekanan von mises yang paling rendah didapati pada ketebalan 1.0mm dan tekanan 3psi. Ketebalan 1.0mm dipilih untuk digunakan sebagai ketebalan bedpan disebabkan nilai kebolehubah bentuk yang rendah dan 50TPU dipilih sebagai bahan bedpan kerana mempunyai ciri-ciri yang baik dan kos yang rendah dari TPU.

Effect of Thermoplastic Polyurethane on Properties of Polyvinyl Chloride in Designing a bedpan

ABSTRACT

Commercialized bedpan made from hard plastic gives discomfort to the patients. The study was perform to improved. The present study determines the mechanical, physical and thermal properties of TPU/PVC blend in order to be used as material to fabricate a bedpan. TPU and PVC were mixed by melt-mixing method and were undergoing hot press compression molding to make a sample. The samples of PVC/TPU with ratio 90/10, 70/30 and 50/50 were subjected to tensile, water absorption, chemical resistance, Scaning Electron Microscopic (SEM), Thermal Gravimetric Analysis (TGA) and Differential Scanning Calorimetric (DSC) test. The simulation analysis using ANSYS workbench software was performed at the end of test. 50TPU was chosen as the best ratio of TPU/PVC blend because they have good tensile strength, lower modulus and high elasticity. The blending of TPU and PVC has decreased the percentage of water absorption of TPU since TPU has highest water gain due to hydrophilic nature and PVC has hydrophobic nature. Hydrochloric acid (HCl) had a stronger effect on TPU/PVC blend compared to sodium hydroxide (NaOH) for all blend compositions for chemical resistance test. The result of SEM micrograph shows that the sample became smoother when more TPU was added. The 50TPU sample exhibits smoother surface and cluster of blend on its surface diminish when increasing TPU content. TGA result shows that the decomposition occur in two stage for TPU/PVC blend. The decomposition of PVC was lower than TPU and higher than TPU/PVC blend. Based on DSC result, TPU/PVC blend revealed one transitions melting temperature (Tm) formed for sample of 10TPU, 30TPU and 50TPU. It shows the miscibility between TPU and PVC since it exhibited only one melting temperature. For the simulation analysis study, the effect of pressure on von mises stress of different bedpan thickness of TPU, PVC and 50TPU curve has indicated that 0.5 mm has the highest maximum stress at pressure 8psi compared to thickness of 0.8mm and 1.0mm. The lowest von mises stress was observed at thickness of 1 mm and pressure of 3 psi. Thickness of 1.0mm was chosen to be used as an inflatable bedpan thickness since the deformation value is lower and 50TPU chosen as materials of bedpan because it gives good properties and lower the cost than TPU materials.

CHAPTER 1

INTRODUCTION

1.1 Research Background

In recent years, polymers are being increasingly popular in production of medical appliances. The advantage of polymer materials includes low cost manufacturing processes which can lead to variety products of polymer materials in medical application. One of the medical products that used polymer as the raw material is bedpan. Bedpan has been used in the care of bed-ridden persons for the purpose of collecting human waste either feces or urine for subsequent disposal (Young, 1990).

According to Bunker Rosdahl et al. (2008) in their textbook of basic nursing, bedpan can be defined as a shallow vessel used for urination and defecation by clients who are confined to bed. In hospitals, nursing homes and similar facilities where person are bed ridden, it is customary for such persons to use bedpans when elimination or discharge of body waste (Rosdahl et al., 2008; Williams, 1995). Most of the hospitals use bedpans as portable toilet solutions for bedridden patients suffering from incontinence or other diseases that prevent them from using a normal bathroom.

Recently, the conventional bedpan made from plastic or a coated metal is rigid and shaped which to some extent will conform the body and in some ways make patient feels uncomfortable. After bedpan was used by one patient, it is thoroughly sterilized and sanitized before it will be reused by another patient. This practice has resulted in not only high initial cost of stainless steel bedpans, but the repeated sanitization or autoclaving is also time consuming and relatively expensive (Rickmeier et al., 1971). The use of the rigid bedpan is demanding of the attendant to help the patient. Usually, more than one attendant is often required because they must lean over the bed, back muscles are used and consequently must be exceptionally strong to avoid injury to the attendant and patient (Vernon, 1995).

In this study, bedpan was improved using the inflatable structure in order to provide comfortable, safe, hygienic, and easy to use in order to help in preventing complications to patient, nurses and caretakers. This reduces physical exertion or injury to patient and caretaker. No cleaning is required as this unit reduces contamination among the patient. The concept of bedpan is easy and offers comfort for patient by rolling the patient and place inflatable bedpan holder with disposable hygienic bag under the patient and roll it back to recumbent position, follows by inflating air by a pump system.

In designing and manufacturing of healthcare facilities and medical devices application, it is important to consider the functionality requirements and also the safety requirements as well. For many years, polyvinyl chloride (PVC) was considered a very desirable material for use in the production of medical devices, because of its safety, performance and cost criteria. These attributes made PVC an especially appealing base material for fluid storage bags and medical tubing (Lubrizol, 2012). According study by Saeki et al. (2002), PVC is one of the most widely used polymeric materials, due to its good chemical stability, low cost and easy processing (Saeki et al., 2002).

More than 25 per cent of all plastic based disposable medical devices used in hospitals are made from PVC. PVC devices are easier to sterilize, transparent, chemically stable, cost effective, and easy to process by different technologies and have long shelf-life stability. In addition, PVC often has important functional attributes such as convenience in use, softness and flexibility. However, the presence of plasticizers in flexible PVC products since PVC are plasticized with phthalates continues to be a source of concern with respect to potential public health and environmental exposures (Thornton, 2000). Due to this problem, thermoplastic polyurethane (TPU) was introduced to replace the addition of plasticizer to PVC.

Thermoplastic polyurethane (TPU) is a polymer that widely used in medical device applications. They are versatile engineering thermoplastic with elastomeric properties and play an important role in the rapidly growing family of thermoplastic elastomer. Thermoplastic polyurethane has easy processing feature and like thermoplastic that becomes soft when heated and solidified when cooled but has excellent properties like elastomer which high elasticity. This criterion is ideal for the melt processing manufacturing methods such as injection, extrusion, blow molding, vacuum foaming and solution casting.

1.2 Problem Statement

Bedpans have been used by the bedridden patient who cannot leave their bed to use standard toilet. Most of the commercialized bedpans made from hard plastic such as polypropylene and polyethylene give difficult to the patients as they need to move their body to sit on the bedpan. Furthermore, this bedpan can deposit bacteria since they only leave the bedpan on the floor or on the bed. Another problem towards patient is inconvenience during the use of conventional bedpan which made of metal or plastic that has cold and hard surface and pose discomfort in use. The caretakers also facing difficulties in lifting the overweight patient onto the bedpan.

Current bedpan also does not conform to the natural anatomical contour of human buttock and this may exert force and depress the muscle and tissue of the periphery buttock area of the patient. The use of diaper by patient causes discomfort and uneasiness due to tendency of developing pressure sores and infection. The patient may become too dependent on the diaper or bedpan and this may lead to anxiety and depression.

Polyvinyl chloride (PVC) is one of the major thermoplastics used today and produced in a huge amount worldwide due to its softness, inexpensive and flexibility. However, the presence of plasticizers in flexible PVC products continue to be a source of concern with respect to potential public health and environmental exposures. Thermoplastic polyurethane (TPU) exhibits excellent properties such as high tensile strength, flexibility, good low temperature and abrasion resistance but extremely expensive. TPU was introduced to replace the addition of plasticizer to PVC. Blend of TPU with PVC can enhance the processability of TPU since PVC offers easier processing and low cost.

The concept of bedpan in this research was designed from polyvinyl chloride/thermoplastic polyurethane to provide convenience and comfort to the patients. The bedpan with disposable diapers is placed under hips of patients and bedpan inflated after air pumped into the bedpan. This bedpan offers comfort to the patients as the bedpan is flexible and ergonomic. Thermoplastic polyurethane is naturally biocompatible thus it is hygienic to use.

1.3 Objective

The main objective of this research is to study the mechanical, physical and thermal properties of the polyvinyl chloride and its blend with thermoplastic polyurethane in designing bedpan. The specific objectives of this study are:

- To study the effect of blend ratios (90/10, 70/30 and 50/50) on the mechanical properties, morphology, water absorption, chemical resistance and thermal properties of PVC/TPU blends.
- To optimize wall thickness of bedpan using PVC/TPU blend by using finite element analysis (ANSYS).

1.4 Scope of Study

The characterization and investigation of mechanical, morphology, water absorption, chemical resistance, thermal properties and optimized wall thickness using finite element analysis (ANSYS 15-Workbench) of bedpan from polyvinyl chloride (PVC) and thermoplastic polyurethane (TPU) blend were carried out. PVC and combination of of TPU were mixed by melt-mixing method using Brabender Internal Mixer Plastograph EC machine at different ratios (90/10, 70/30 and 50/50) of PVC/TPU. The melt mixing was running at temperature 180ºC and speed 60 rpm. The blends of PVC/TPU sample from melt mixing were then undergoing hot press compression molding to produce sample with 1 mm thickness. The samples were then cut according to the standard dimensions for mechanical, morphology, water absorption, chemical resistance and thermal properties testing.

The samples produced were tested using mechanical test which are tensile testing (ASTM D638-02 standard). The tensile test gives the information on tensile strength, elongation at breaks and modulus of elasticity of the blend of PVC/TPU. The morphology of the TPU/PVC blend was studied by using Scanning Electron Microscopy (SEM). The water absorption testing (ASTM D570-98) and chemical resistance testing (ASTM D543-14) were determined by immersing the sample in water and chemical and their weights were taken periodically. Water absorption testing was used to get the information on the effect of water exposed on dimension or weight change of PVC/TPU. Chemical resistance testing was tested by using sodium hydroxide (NaOH) and hydrochloric acid (HCl) as chemical reagent to get the information on the effect of these chemicals to dimensions or weight of the PVC/TPU blend.

The sample was subjected to thermal testing by using thermal gravimetric analysis (TGA) and differential scanning calorimetric (DSC) testing. TGA was used to characterize and determine the effect of thermal on decomposition and thermal stability of PVC/TPU blend. DSC was used to determine the glass transition temperature (Tg), and melting transition temperature (Tm) of the PVC/TPU blend. The designing and modeling of bedpan using the AutoCAD 14 and finite element analysis (FEA) were carried out in this research by using ANSYS 15-Workbench as to study the pressure and inflation rate needed for the bedpan to fully inflate to sustain up to 100 kilogram load. Optimized shape and wall thickness of PVC/TPU bedpan were determined via simulation by ANSYS 15-Workbench and mechanical tests were conducted to support the analysis. The cross-section model was designed to choose the suitable thickness for fabrication of the bedpan.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter spreads motivation in full detail of the study performed. As a start, the review of processing, structure and properties of PVC and TPU from others researcher are studied. The research and development of PVC and TPU in medical application review are discussed to highlight its importance in designing bedpan. This chapter also discusses the polymer blend definition and review of processing and properties of PVC/TPU blend which have been studied by other researchers. Finally, this chapter discusses the design and material used in significance of designing this new inflatable bedpan.

2.2 Polyvinyl Chloride

Polymers cover various areas of the polymerization product of synthetic or semi-synthetic, which refers to the fact that in a semi-liquid state they are malleable, and have properties of plasticity. Polyvinyl chloride (PVC) is an inexpensive commodity plastic material that is used in a wide variety of industrial and domestic applications (Williams et al., 2002). PVC is a thermoplastic material which consists of PVC resin compounded with varying proportions of stabilizers, lubricants, fillers, pigments, plasticizers and processing aids. These materials can be heated to a certain temperature and solidify when they cool (Lenntech, 2014). Different compounds of these ingredients have been developed to obtain specific groups of properties for different applications.

PVC is a material which commercial success has been to a large extent due to the discovery of suitable stabilizers and other additives which has enabled useful thermoplastic compounds to be produced (Brydson, 1999). PVC is a vinyl polymer which was constructed by repeating vinyl groups which is ethenyl with one of their hydrogen replaced with a chloride group. In chemistry, vinyl or ethenyl is the functional group $-CH=CH_2$, namely the ethylene molecule ($H_2C=CH_2$) minus one hydrogen atom. Since its commercialization in the early 1920, PVC is the third most widely produced plastic, after polyethylene and polypropylene. Over 50 % of PVC manufactured is widely used in construction industries because it is cheap, durable, and easy to assemble. PVC is highly customizable and can be made softer and more flexible with the addition of plasticizers (Cowen, 2010).

PVC can be constructed in various forms; clear or colored, rigid or flexible, depending on the added compounds and final application that needs to be achieved (Lenntech, 2014). There are two basic forms of PVC which are rigid and plasticized. The rigid PVC as its name suggests is an unmodified polymer and exhibits high rigidity. Unmodified PVC is stronger and stiffer than PE and PP. The plasticized PVC is modified by the addition of a low molecular weight species which plasticizer used to flex the polymer. Plasticized PVC can also be formulated to give products with rubbery behavior. PVC is often compounded with additives to improve the properties (Harper, 2000).

2.2.1 Structure of Polyvinyl Chloride

Understanding the structure of PVC becomes very useful because it enables us to make early predictions about the nature of PVC. PVC are linear polymers and substantially thermoplastic. The presence of the chlorine atom causes an increase in the inter chain attraction and hence an increase in the hardness and stiffness of the polymer. PVC is also more polar than polyethylene because of the C-Cl dipole. The structure of PVC is shown in Figure 2.1.

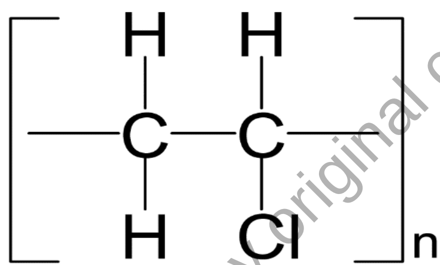

Figure 2.1: Structure of PVC.

The polymer has a resistance to non-polar solvent in which has a lower solubility parameter. The solubility parameter of PVC is about 19.4 MPa. In fact, it has very limited solubility, making it the only effective solvent and capable of interacting with the polymer in some forms. It is suggested that PVC is capable of acting as a weak proton donor and thus effective solvents are weak proton acceptors.

There are many plasticizer materials that are suitable for PVC. They have similar solubility parameters to PVC and are also weak proton acceptors. There is material that has too high a molecular weight and large a molecular size to dissolve the polymer at room temperature but they may be incorporated by mixing at elevated temperatures to give stable mixtures at room temperature. The presence of chlorine in large quantities in the polymer