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<td>Abbreviation</td>
<td>Description</td>
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<tr>
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<td>-----------------------------------</td>
</tr>
<tr>
<td>µ</td>
<td>Micron</td>
</tr>
<tr>
<td>µm</td>
<td>Micro meter</td>
</tr>
<tr>
<td>ABA</td>
<td>Alternative blowing agents</td>
</tr>
<tr>
<td>ASTM</td>
<td>American Society for Testing and Materials</td>
</tr>
<tr>
<td>CFC</td>
<td>Chlorofluorohydrocarbons</td>
</tr>
<tr>
<td>CO₂</td>
<td>Carbon dioxide</td>
</tr>
<tr>
<td>DBTL</td>
<td>dibutyl tin dilaurate</td>
</tr>
<tr>
<td>DCM</td>
<td>Dichloromethane</td>
</tr>
<tr>
<td>DSC</td>
<td>Differential Scanning Calorimetry</td>
</tr>
<tr>
<td>EO</td>
<td>Ethylene oxide</td>
</tr>
<tr>
<td>FPF</td>
<td>Flexible polyurethane foam</td>
</tr>
<tr>
<td>FTIR</td>
<td>Fourier transform infrared spectroscopy</td>
</tr>
<tr>
<td>HDI</td>
<td>Hexamethylene diisocyanate</td>
</tr>
<tr>
<td>HFC</td>
<td>Hydrofluorocarbons</td>
</tr>
<tr>
<td>HR</td>
<td>High resiliency</td>
</tr>
<tr>
<td>IPDI</td>
<td>Isophorone diisocyanate</td>
</tr>
<tr>
<td>kg</td>
<td>Kilogram</td>
</tr>
<tr>
<td>LOI</td>
<td>Loss on ignition</td>
</tr>
<tr>
<td>m</td>
<td>mass</td>
</tr>
<tr>
<td>MC</td>
<td>Methylene Chloride</td>
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Md  Mass after hydrolysis
MDI  Diphenyl methane 4,4’-diisocyanate
MEKO  Methyl ethyl ketoxime
min  minute
mm  millimeter
Mo  Mass before hydrolysis
MPW  Mixed-paper waste
OWP  Office White Paper
ONP  Old Newspaper
Pd  Palladium
PEG  Polyethylene glycol
PMDI  Polymeric diphenyl methane 4,4’-diisocyanate
pphp  Parts per hundred polyol
PS  Paper Sludge
PU  Polyurethane
SEM  Scanning electron microscope
RNHCOOH  Carbamic acid
T  Temperature
Tc  Crystallization temperature
Tg  Glass transition temperature
Tm  Melting temperature
TDI  Toluylene 2,4-diisocyanate
TEDA  Triethylene diamine
<table>
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<tr>
<th>Symbol</th>
<th>Definition</th>
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<tbody>
<tr>
<td>TGA</td>
<td>Thermogravimetry Analysis</td>
</tr>
<tr>
<td>UV</td>
<td>Ultraviolet</td>
</tr>
<tr>
<td>$v$</td>
<td>volume</td>
</tr>
<tr>
<td>VPF</td>
<td>Variable pressure foaming</td>
</tr>
<tr>
<td>Wt</td>
<td>Weight</td>
</tr>
<tr>
<td>$\Delta H^\circ_{f(com)}$</td>
<td>Heat of fusion of composites</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>Interfacial surface tension</td>
</tr>
<tr>
<td>$\Phi$</td>
<td>Relative density</td>
</tr>
<tr>
<td>$\rho_f$</td>
<td>Density of foam</td>
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SIFAT-SIFAT DAN KEBOLEHBIOROSOTAN SISA KERTAS TERISI KOMPOSIT BUSA POLIURETANA

ABSTRAK

PROPERTIES AND BIODEGRADABILITY OF WASTE PAPER FILLED POLYURETHANE FOAMS COMPOSITES

ABSTRACT

The research is focused to study the properties of polyurethane foam reinforced with different types and content of waste paper. The comparison of the effects of three types of waste paper, such as paper sludge (PS), old newspaper (ONP) and office white paper (OWP) on physical, mechanical, thermal, biodegradable properties and morphology of PU foam was studied. The result show ONP foam significantly highest value of compressive strength, compressive modulus and hardness compared than PS and OWP foam composites. The increasing filler loading improved the mechanical properties but reduced the density of foam. Scanning electron microscopy (SEM) study indicated that the addition of waste paper in polyurethane foam reduced the open cell structure of foam. The biodegradation study of waste paper foam composites increased with increasing of waste paper loading. However, the ONP foam composites showed higher degradation in soil compared to the OWP foam and followed by PS foam composites. The results of thermogravimetric analysis (TGA) showed PS foam composites has highest thermal stability compared with OWP and ONP foam composites. The PS foam composites exhibit the highest of crystallization. The presence of the triethylene diamine (TEDA) as catalyst has improved the compressive strength, compressive modulus, hardness and density of waste paper foam composites. The thermal stability of waste paper foam composites with TEDA is higher than waste paper foam composites without TEDA. The micrographs of waste paper foam composites with TEDA show the addition of filler and catalyst can affect the crosslinking of the foam composites to produce the smaller cell structure. The waste paper foam composites with methylene chloride (MC) have higher of compressive strength, compressive modulus and hardness but lower the density and thermal stability compare to waste paper foam composites without MC. The morphology of waste paper foam composites with different filler loading with MC show smaller open cell compared to without catalyst. Partial replacement of toluene diisocyanate (TDI) in diphenyl methane 4,4’-diisocyanate (MDI) of ONP foam indicates higher compressive strength, compressive modulus, hardness and density compared to MDI/ONP foam composites. The micrograph of TDI/MDI/ONP foam composites show that the foam close cell structure compared to MDI/ONP foam composites. The TDI/MDI/ONP foam composites have better thermal stability than MDI/ONP foam composites.
CHAPTER 1

INTRODUCTION

1.1 Research Background

1.1.1 The Necessity for Biodegradable Plastic

Disposal of plastic waste into landfills has became increasingly prohibitive due to high costs and legislative pressure. Growing environmental awareness and reductions in available landfill capacity have prompted plastics recycling programs in most developed countries (Joseph, 1995). In the past, plastic polymeric materials have been designed to degradation. However, with mounting environmental and legislative pressure to reduce plastic and packaging wastes, there has been an increased demand for biodegradable polymers that are compatible with the environment (Mohee et al., 2007). Plastic foams are synthetic polymers that are used widely throughout the world for various applications. Synthetic polymeric foams have pervaded every aspect of modern life. Although foams provide numerous benefits, they also cause a significant environmental problem because of their recalcitrant and xenobiotic nature. Biodegradation may provide solution to the problem, but not enough is known about the biodegradation process of synthetic plastic and plastic based foams (Gautam et al., 2007). Petroleum based foams
are, like most of the plastics and resins from which they are issued, non-biodegradable, even over several decades time (Perkowitz, 2000).

An obvious benefit of recycling and use of biodegradable plastic is that both reduce the requirement for landfill or incineration of waste materials. Biodegradable plastics can be managed by composting, generally perceived as more environmentally beneficial than landfill or incineration. In fact, advocates of composting often refer to it as natural or biological recycling (Fenton, 1992). Composting, in contrast, is designed to accelerate biodegradation and serve as an alternative to landfilling. Use of biodegradable plastics permits disposal through composting and therefore can reduce the burden on landfill if system to direct the product or package to composting are in place and utilized. In addition, for products that pose a litter problem, the use of biodegradable plastics can greatly reduce their prevalence and longevity in the environment (Freedonia, 2004).

The ASTM standard D5988-03, biodegradability of plastic materials has been defined as the capability of undergoing decomposition into carbon dioxide, methane, water, inorganic compounds or biomass predominantly by the enzymatic action of microorganisms. The standard requires 60–90% decomposition of the plastic within 60–180 days in a composting environment (Mohee et al., 2007).

The increasing research interest in biodegradable polymers over the past two decades has led to the availability of a large variety of novel polymers with claims of biodegradability. Among these polymers, polyurethanes (PUs) are an interesting family of materials. The PUs are segmented multiphase elastomers. They are a unique class of polymers because a large variety of PUs with widely varying physical and chemical properties can be synthesized. Recently, biodegradable materials have gained importance