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APPROVAL AND DECLARATION SHEET

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LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURES

µ	Micron
µm	Micro meter
ABA	Alternative blowing agents
ASTM	American Society for Testing and Materials
CFC	Chlorofluorohydrocarbons
CO_2	Carbon dioxide
DBTL	dibutyl tin dilaurate
DCM	Dichloromethane
DSC	Differential Scanning Calorimetry
EO	Ethylene oxide
FPF	Flexible polyurethane foam
FTIR	Fourier transform infrared spectroscopy
HDI	Hexamethylene diisocyanate
HFC	Hydrofluorocarbons
HR	High resiliency
IPDI	Isophorone diisocyanate
kg	Kilogram
LOI	Loss on ignition
m	mass
MC	Methylene Chloride

Md	Mass after hydrolysis
MDI	Diphenyl methane 4,4'-diisocyanate
MEKO	Methyl ethyl ketoxime
min	minute
mm	milimeter
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
T_c	Crystallization temperature
Tg	Glass transition temperature
Tm	Melting temperature
TDI	Toluylene 2,4-diisocyanate
TEDA	Triethylene diamine

TGA	Thermogravimetry Analysis
UV	Ultraviolet
v	volume
VPF	Variable pressure foaming
Wt	Weight
$\Delta H^{\circ}_{f(com)}$	Heat of fusion of composites
γ	Interfacial surface tension
Φ	Relative density
P_f	Density of foam

SIFAT-SIFAT DAN KEBOLEHBIOROSOTAN SISA KERTAS TERISI KOMPOSIT BUSA POLIURETANA

ABSTRAK

Penyelidikan difokuskan pada kajian sifat-sifat busa poliuretana diperkuat dengan sisa kertas yang berbeza jenis dan kandungan. Perbandingan ke atas kesan tiga jenis sisa kertas seperti lumpur kertas (PS), kertas putih pejabat (OWP) dan surat khabar lama (ONP) ke atas sifat-sifat fizikal, mekanikal, terma, biorosotan dan morfologi busa poliuretana telah dikaji. Hasilnya menunjukkan busa ONP nyata mempunyai nilai kekuatan mampat, modulus mampat dan kekerasan paling tinggi berbanding komposit busa PS dan OWP. Semakin meningkatnya pembebanan pengisi telah meningkatkan sifat-sifat mekanikal tetapi mengurangkan ketumpatan busa. Kajian mikroskop elektron imbasan (SEM) menunjukkan bahawa penambahan sisa kertas di dalam poliuretana mengurangkan struktur terbuka sel busa. Kajian biorosotan komposit busa sisa kertas meningkat dengan semakin meningkatnya pembebanan pengisi sisa kertas. Bagaimanapun komposit busa ONP menunjukkan perosotan yang lebih tinggi di dalam tanah berbanding busa OWP dan diikuti komposit busa PS. Keputusan analisis terma-gravimetri (TGA) menunjukkan komposit busa PS mempunyai kestabilan haba yang paling tinggi berbanding komposit busa OWP dan ONP. Kalorimetri imbasan perbezaan (DSC) menunjukkan dengan semakin meningkatnya pembebanan pengisi telah mengurangkan nilai pelakuran haba komposit dan kehabluran komposit. Komposit busa PS menunjukkan penghabluran yang paling tinggi. Kehadiran trietilena diamina (TEDA) sebagai pemangkin telah meningkatkan kekuatan mampat, modulus mampat, kekerasan, ketumpatan dan kehabluran komposit busa sisa kertas. Ketahanan terhadap terma komposit busa sisa kertas dengan TEDA adalah paling tinggi daripada komposit busa sisa kertas tanpa pemangkin. Mikrograf komposit busa sisa kertas dengan TEDA menunjukkan penambahan pengisi dan pemangkin boleh memberi kesan kepada sambung silang komposit busa untuk menghasilkan struktur sel yang kecil. Komposit busa sisa kertas dengan metilena klorida (MC) mempunyai kekuatan mampat, modulus mampat, kekerasan dan penghabluran yang lebih tinggi tetapi ketumpatan dan kestabilan haba yang rendah berbanding komposit busa sisa kertas tanpa pemangkin. Gantian separa toluena di-isocianat (TDI) di dalam difenil metana 4,4’-di-isocianat (MDI) untuk busa ONP menunjukkan kekuatan mampat, modulus mampat, kekerasan dan ketumpatan yang lebih tinggi berbanding dengan komposit busa MDI/ONP. Mikrograf komposit busa TDI/MDI/ONP menunjukkan bahawa struktur sel busa yang lebih rapat. Komposit busa TDI/MDI/ONP mempunyai kestabilan haba yang baik daripada komposit busa MDI/ONP.

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