UNIVERSITI TEKNIKAL MALAYSIA MELAKA

PREPARATION AND CHARACTERIZATION OF GREEN RUBBER FOAM FROM RECLAIMED RUBBER GLOVE

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering

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by

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This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Engineering Materials) (Hons.). The member of the supervisory committee is as follow:

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ABSTRAK

Kajian ini mengkaji kesan natrium bikarbonat terhadap saiz busa getah yang diperbuat daripada sarung tangan getah yang dikitar semula. Kelebihan menggunakan sarung tangan getah yang dikitar semula boleh mengurangkan kos bahan mentah disamping sifat plastik yang baik dan mudah untuk dicampurkan dengan getah mentah serta keperluan pemprosesan pada suhu yang lebih rendah. Dalam kajian ini, natrium bikarbonat digunakan sebagai agen peniup dan kesannya terhadap busa getah diuji untuk sifat fizikal seperti ketumpatan, ketumpatan relatif, nisbah pengembangan buih, ketumpatan sambung silang, kadar penyerapan air, sifat mekanikal seperti ujian mampatan dan morfologi melalui kemikroskopan electron imbasan (SEM). Getah boleh kembang disediakan menggunakan pencampur dalaman Haake dibusakan melalui proses pindahan haba menggunakan pengacuan mampatan dan oven aliran udara panas. Dalam kajian ini, sifat-sifat fizikal busa getah dikaitkan secara sistematik dengan sifat mekanikal busa. Kekuatan mampatan busa didapati menurun dengan penurunan ketumpatan sambung silang dan ketumpatan relatif busa, yang dikaitkan dengan pembentukan saiz sel yang besar dan peningkatan dalam bilangan sel per unit isipadu. Kajian ini adalah kajian awal untuk potensi penggunaan busa getah dikitar semula sebagai bahan tapak kasut.

ABSTRACT

This research studied the effect of sodium bicarbonate to foam size of rubber foam from reclaimed rubber glove. The advantages of using reclaimed rubber glove are reducing cost of raw materials, a part of good plasticity, easy to be mixed with raw rubber and requirement of low processing temperature. In this research, sodium bicarbonate was used as blowing agent to evaluate the effect of rubber foam on the physical properties such as density, relative density, expansion ratio, crosslink density, water absorption rate and mechanical properties such as compression strength and morphology through scanning electron microscopy (SEM). The expandable rubber samples were prepared using a Haake internal mixer and then expanded via heat transfer foaming process using a compression molding and an air circulating oven. In this study the physical properties of rubber foams were systematically correlated with its mechanical properties. The compression strength of the foam decreases with decreasing crosslink density and relative foam density which was associated with the formation of bigger foam cells and an increase in the number of cells per unit volume. This study is a preliminary study for the potential use of recycled rubber foam material as shoe insoles.

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LIST OF ABBREVIATIONS

ASTM	-	American Standard Test Method
TPNR	-	thermoplastic natural rubber
NR	-	natural rubber
SEM	-	scanning electron microscopy
TPE	-	thermoplastic elastomer
BR	-	polybutadiene rubber
SBR	-	styrene butadiene rubber
RR	-	reclaimed rubber
CIIR	-	chloro butyl rubber
BIIR	-	bromo butyl rubber
DOE	-	design of experimental
Rpm	-	rotation per minute
OM	-	Optical microscope
TMTD	-	Tetramethylthiuram-disulfenamide
CBS	-	Benzothiazyl-2-cyclohexyl-sulphenamide

LIST OF SYMBOLS

oC	-	Celsius
M/S	-	meter per second
%	-	percentage
kW	-	kilo watt
min	-	minute
kg	-	kilogram
mm	-	millimeter
μm	-	micrometer
s	-	Second
nm	-	nanometer
g	-	Gram
Hz	-	hertz

CHAPTER 1

INTRODUCTION

1.1 Background

In industrialized countries, rubber products are everywhere to be found, though few people recognize rubber in all of its applications. Since 1920, demand for rubber manufacturing has been largely dependent on the automobile industry, the biggest consumer of rubber products. Rubber forms a part of many mechanical devices in the kitchen, helps to exclude draughts and to insulate against noise. Sofas and chairs may be upholstered with foam rubber cushions, and beds may have natural rubber pillows and mattresses. Clothing and footwear may contain rubber for example elasticized threads in undergarments or shoe soles. Still other applications have been developed due to special properties of certain types of synthetic rubber, and there are now more than 100,000 types of articles in which rubber are used as a raw material (Pothen 2011).

The use of rubber in so many applications results in a growing volume of rubber waste. With the increase in demands, the manufacturing and use of rubber and the rubber products has increased tremendously both in the developed and less developed countries. By the middle of 1980s less than 1% of the worldwide polymer consumption was in the form of reclaim. At the beginning of 20th century half of the rubber consumed was in the form of reclaim. It is expected that in 21st century most of the scrap rubber will be recycled in the form of reclaim because of day to day increase in environmental

awareness. One of the various problems which mankind faces as it enters into the 21st century is the problem of waste disposal management.

Since polymeric materials do not decompose easily, disposal of waste polymers is a serious environmental problem. Large amounts of rubbers are used as glove and tires for airplanes, trucks and car. Reclaimed rubber is the product resulting when waste vulcanized scrap rubber is treated to produce a plastic material which can be easily processed, compounded and vulcanized with or without the addition of either natural or synthetic rubbers. Reclaiming of the waste rubber can cost half that of natural or synthetic rubber, some properties that are better than those of virgin rubber, requires less energy in the total production process than does virgin material and it is an excellent way to dispose of unwanted rubber products, which is often difficult.

Although reclaim rubber is a product of discarded rubber articles it has gained much importance as additive in various rubber article formulations. It is true that mechanical properties like tensile strength, modulus, resilience and tear resistances are all reduced with the increasing amounts of reclaim rubber in fresh rubber formulation. But at the same time the reclaim rubber provides many advantages if incorporated in fresh rubber. The increase in the awareness of waste management and environment related issues has led to substantial progress in the utilization of rubber waste. Recycling materials back into its initial use often are more sustainable rather than finding new applications.

1.2 Problem statement

Various shoe sole in the market nowadays made from simple, single materials in a single layer or they can be complex with multiple structures or layers and materials. Each of its show their unique properties on their application of shoe sole which have their

advantages and disadvantages for the customer. According to the domestic waste, recycling of rubber waste poses a challenging environmental, economic and social problem. The latex industry has expanded over the years to meet the world demands for gloves, tire, latex thread and others. This industry has always been at the mercy of rapid and drastic changes, both in the cost of raw rubber and the prices of finished goods. The waste rubber formed in latex-based industries is around 10–15% of the rubber consumed. Domestic and contaminated industrial gloves that do not require specific handling are disposed along with other household wastes as non-hazardous municipal solid wastes into domestic landfills. In a landfill, residual chemicals example accelerators will leach out as the rubber biodegrades. Under standard landfill conditions, vinyl is not biodegradable but the plasticizers will leach out from the material when in contact with non-aqueous solvents. Nitrile itself is not biodegradable and the chemical by-products leaching out will be similar to those produced by NR gloves. NR latex gloves and other rubber products containing sulphur liberates sulphur dioxide and water when incinerated and the remaining carbon backbone oxidised to carbon dioxide in an aerobic environment.

The formation of a higher percentage of waste latex rubber (WLR) in latex factories is due to the unstable nature of the latex compound and the strict specifications in the quality of latex products. As waste latex rubber (WLR) represents a source of high-quality rubber hydrocarbon, it is a potential candidate for generating reclaimed rubber of superior quality (Abraham, Thomas 2011). Rubber sole shows good properties in terms of lightweight, durable, flexible and can reduce shock force to the feet. Hypothesis that reclaimed rubber it will able to show similar performance in term of shoe sole as replacement for pure synthetic or natural rubber. The usage of reclaimed rubber is aimed to reduce the effect on environmental problem and at the same time produce shoe sole with significant properties at cheaper cost.

1.3 Objective

The main objectives on this research are:

i. To prepare rubber foam from reclaimed rubber glove through melt compounding using internal mixer.

ii. To study the effect of sodium bicarbonate loading as blowing agent in physical properties and mechanical properties.

iii. To characterize the physical properties and mechanical properties of rubber foam made from reclaimed rubber glove.

1.4 Scope

This research is to study the effect of sodium bicarbonate loading as blowing agent to prepare the rubber foam from reclaimed rubber glove through melt compounding using internal mixer followed by various physical and mechanical testing. Then characterize the properties of rubber foam made from reclaimed rubber glove. Some analysis such as morphology was performed to support the data.

1.5 Chapter Overview

There are five chapters in this report where for the Chapter 1 that is the introduction of the research. This consists of research background, a problem statement, and objectives of the project, scope and chapter overview. Next its continue for the Chapter 2 that is the literature review and covers the fundamental of shoe sole, elastomer foam, reclaimed rubber glove and also a general overview of the current development of shoe sole in the market. Then for the Chapter 3 there is the methodology of this research, response surface methodology and it discuss the raw material specification, equipment and experimental procedures used in this study. After that, for the Chapter 4 there is results and discussion of the data. Finally, Chapter 5 is formulate procurement review and list of potential research and also proposed future work.

CHAPTER 2

LITERATURE REVIEW

2.1 Shoe Sole

A shoe is an item of footwear intended to protect and comfort the human foot while doing various activities. Shoes are also used as an item of decoration. The design of shoes has varied enormously through time and from culture to culture, with appearance originally being tied to function. Shoes have traditionally been made from leather, wood or canvas, but are increasingly made from rubber, plastics, and other petrochemical-derived materials. The parts of a shoe are pretty common, regardless of the specific style of footwear. All shoes have a sole, which is the bottom of a shoe, which is in contact with the ground. Soles can be made from a variety of materials, although most modern shoes have soles made from natural rubber, polyurethane, or polyvinyl chloride (PVC) compounds. Soles can be simple, a single material in a single layer or they can be complex, with multiple structures or layers and materials. When various layers are used, soles may consist of an insole, midsole, and an outsole.

The insole is the interior bottom of a shoe, which sits directly beneath the foot under the foot bed. The purpose of insole is to attach to the lasting margin of the

upper, which is wrapped around the last during the closing of the shoe during the lasting operation. The outsole is the layer in direct contact with the ground. Dress shoes often have leather or resin rubber outsoles; casual or work-oriented shoes have outsoles made of natural rubber or a synthetic material like polyurethane. The layer between the outsole and the insole in shoe is typically the function for shock absorption. Some types of shoes, like running shoes, have another material for shock absorption, usually beneath the heel of the foot, where one puts the most pressure down. Different companies use different materials for the midsoles of their shoes. Some shoes may not have a midsole at all. Most types of shoes are designed for specific activities. For example, boots are typically designed for work or heavy outdoor use. Athletic shoes are designed for particular sports such as running, walking, or other sports. Some shoes are designed to be worn at more formal occasions, and others are designed for casual wear (James 2011). Figure 2.1 shows the example of shoe sole in shoes.

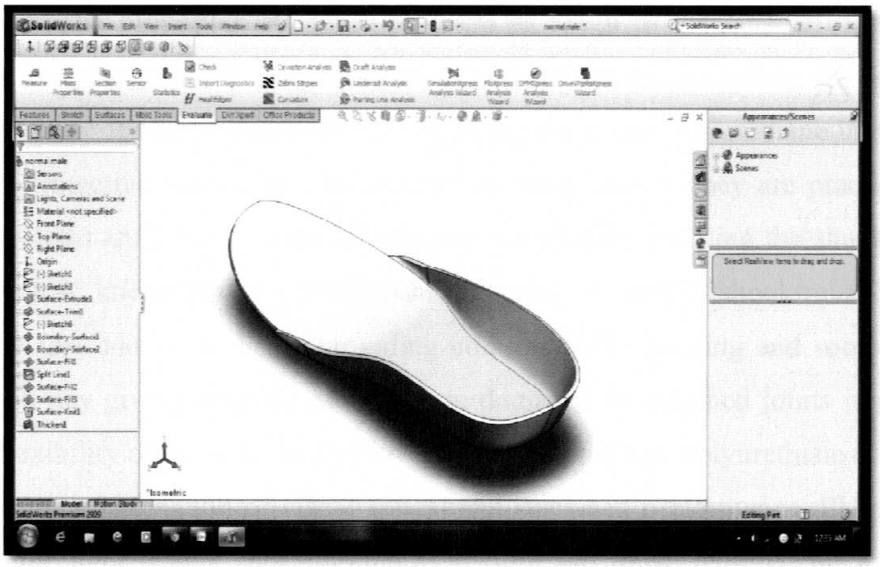

Figure 2.1: Example of shoe sole in shoes view from solid work

2.1.1 Type of shoe sole in the market

There are several types of soft shoe sole available in the market. They all facilitate foot development and walking, but differ in terms of sole construction and materials and specific benefits. These soles also are available in different sizes and thickness. The sole of the shoe should be thick enough for protection while allowing the foot to move as naturally as possible. For a shoe manufacturer it can be a challenge to meet the varied demands that consumers place on their shoes, but there is one special polymer that meets these many demands and is so extraordinarily versatile that it is now the heart and soul of good, modern shoe technology (James 2011). There are different types of soles in the market that are PU (polyurethane) Sole, TPR sole and Leather sole.

Polyurethane (PU) is lightweight and extremely durable. With slight changes in its chemical properties, it makes products as tough as the outsole on a safety shoe, as springy as the cushioning in a cross-trainer, or as striking and versatile as synthetic leather. PU double density safety shoes use polyurethane in both the hard, protective outsole and the soft, cushioning insole. They are practical and lightweight and offer a range of advantages including reducing the shock forces to the feet, knees, hips and lower back, reducing the risk of shock-related injury to the feet and lower back, providing comfort by cushioning and soothing the feet all day giving ongoing protection to damaged or inflamed joints improving the flexibility of the sole. In fashion and casual footwear, polyurethane offers the dynamite combination of visual appeal and sustained performance. PU outsoles have the light weight and high-quality texture and finish required for a fashion shoe, but they also outperform other materials in durability and resistance to oil and abrasion. Polyurethane is highly valued in the sports shoe industry because of the ease with which it can be molded, and it provides great cushioning, durability and flexibility.

Thermo Plastic Rubber, TPR is another type of shoe sole in the market. TPR is the combination of PU and rubber. Thermo Plastic Rubber soles are produced by compounding and molding rubber granules of solid raw material. Rivers use only the highest quality materials in their TPR Soles. They do not use shredded old car tires which is common in this type of sole. TPR is renowned for its slip resistance and shock absorption. In footwear industry, TPR is used in the production of shoes soles, safety shoes sole and industrial shoes sole, sports shoes sole, ski-boot soles, kiddy shoes sole and related decorative accessories, modification modifier for SMC (sheet molding compound) and other thermoset and thermoplastic composites.

Leather shoe sole is actually a car to carpet concept sole, we cannot use it daily and is not for rough use and it's using for Brogue models shoes. The properties of leather shoe sole are made from best quality leather, offers premium safety against several hazards, unique design and durable. Shoe sole leather has a good capacity for withstanding the deformations of abrasion, compression, and bending, and it must also maintain its linear dimensions upon wetting and subsequent drying. Leather shoe sole must be sufficiently dense to retain the thread tacks after part of the stitches have been abraded away on the walking surface of the sole. Leather with greater plasticity is selected for sewn methods of fastening, since excessive stiffness makes the manufacturing process difficult and the threads wear out quickly during use.

2.1.2 Design of shoe sole in the market

A shoe consists of two primary components that are the sole and the upper. The upper covers the dorsal, medial, and lateral aspects of the foot, and the sole provides stability and cushioning at the interface between the ground and the