THE EFFECT OF SAMPLE PROCESSING PARAMETERS ON BREAKDOWN PROPERTIES OF POLYETHYLENE AND POLYPROPYLENE BLENDS

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DEDICATION

This project report is dedicated to my family, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my late father and my late mother, who taught me that even the largest task can be accomplished if it is done one step at a time.

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ABSTRACT

This project determined the effect of sample processing parameters on breakdown properties of polyethylene (PE) and polypropylene (PP) blends. Thermoplastic polymer blends composed of high density polyethylene (HDPE) and PP homopolymer were formulated through melt blending method with different temperatures and durations. The breakdown properties of the polymer blend samples processed at different temperatures and durations were investigated and analysed. Six different processing parameters, i.e., 170°C temperature and 5 minutes duration, 170°C temperature and 15 minutes duration, 180°C temperature and 5 minutes duration, 180°C temperature and 15 minutes duration, 200°C temperature and 5 minutes duration, and 200°C temperature and 15 minutes duration were chosen for investigation purposes. The result of breakdown strength obtained were analysed using Weibull software. The results showed that blending PE and PP at 180°C temperature and 15 minute duration resulted in the highest breakdown strength of the material. These AC and DC performance provide a useful insight into the optimal processing parameters to prepare laboratory scale PE and PP blends.

ABSTRAK

Projek ini menentukan kesan parameter pemprosesan sampel pada ciri-ciri pecah tebat campuran polietilena (PE) dan polipropilena (PP). Campuran polimer termoplastik yang terdiri daripada polietelina berketumpatan tinggi (HDPE) dan homopolimer PP dirumuskan melalui kaedah pencairan campuran pada suhu dan tempoh masa yang berbeza. Sifat pecat tebat campuran polimer pada suhu dan tempoh masa berbeza dikaji dan dianalisa. Enam parameter pemprosesan sampel, iaitu pada suhu 170°C dan tempoh 5 minit, suhu 170°C dan tempoh 15 minit, suhu 180°C dan tempoh 5 minit, suhu 180°C dan tempoh 15 minit, suhu 200°C dan tempoh 5 minit, dan suhu 200°C dan tempoh 15 minit dipilih untuk tujuan penyiasatan. Hasil kajian pecah tebat yang diperoleh dianalisa menggunakan perisian Weibull. Hasil tersebut menunjukkan parameter pemprosesan campuran PE dan PP pada suhu 180°C dan tempoh 15 minit menghasilkan nilai pecah tebat yang terbaik. Maklumat ini adalah amat berguna untuk mendapatkan parameter pemprosesan sampel campuran PE dan PP yang optima untuk kegunaan makmal penyelidikan.

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LIST OF ABBREVIATIONS

AC	-	Alternative current
ASTM	-	American Society for Testing and Materials
CDF	-	Cumulative distribution function
DC	-	Direct current
DSC	-	Differential scanning calorimetry
EPR	-	Ethylene propylene rubber
HDPE	-	High density polyethylene
HVAC	-	High voltage alternative current
HVDC	-	High voltage direct current
iPP	-	Isotactic polypropylene
IVAT	-	High voltage high current
LDPE	-	Low density polyethylene
MTFF	-	Mean time to failure
PE	-	Polyethylene
PI	-	Polyimide
PP	-	Polypropylene
PVC	-	Polyvinyl chloride
sPP	-	Syndiotactic polypropylene
SR	-	Silicone rubber
UTM	-	Universiti Teknologi Malaysia
UV	-	Ultraviolet
XLPE	-	Cross-linked polyethylene

LIST OF SYMBOLS

d	-	thickness
E	-	Breakdown strength
g	-	gram
Hz	-	Hertz
kV	-	Kilovolt
mm	-	milimeter
V	-	Volt
°C	-	Degree Celcius
%	-	Percentage
α	-	Scale parameter (alpha)/Characteristic life
β	-	Shape parameter (beta)

CHAPTER 1

INTRODUCTION

1.1 Problem Background

A composite mainly comprises a polymer that yields great mechanical and electrical properties. In high voltage applications, conventional composites are ideal to be used for constructing dielectric materials and high voltage insulation. However, in long term applications, conventional composites are often prone to corrosion, tracking, degradation due to heat radiation, and low resistance against surface pollution and acidic open air environment. The degradation and failure of solid insulating materials is the common cause of problems in electrical equipment, which may occur short circuit, arcing and up to the extent of flashover. Therefore, polymers have emerged as the best of materials to meet demand request as the power level increased [1].

Cross-linked polyethylene (XLPE) has been used at higher voltages of AC and DC power systems. XLPE is thermoset insulating material, so it is more bonded together and this cross connection is done chemically and physically by using cross-polymer method, a process that changes the molecular chain molecular structure. Physically for high voltage cables, electrical insulation is the largest element. XLPE can work at a temperature of 90℃ because it has a high thermal resistance and good mechanical properties. Therefore it can be used in a complex power transmission environment [2]. However, at the end of its life cycle XLPE cannot be reprocessed due to cross-linked structure. Therefore XLPE becomes a non-recyclable material [2]. Meanwhile, the electrical properties of the insulation can be affected by the emission generated during the cross-linked process [3].

Compared to other insulation materials such as polyvinyl chloride (PVC), ethylene propylene rubber (EPR) and silicone rubber (SR), XLPE is suitable for

voltage range from low to high voltage. In addition, the tensile strength, elongation and resistance of the larger impact are the XLPE mechanical properties higher than many other insulations. To further enhance the heat deformation and reduce resistance, the addition of carbon black can be used. Even at the temperatures of soldering irons, the XLPE insulation will not melt or drip, and it has increased flow resistance and improved ageing characteristics [4, 5].

Recently, increased development of cable insulation using polypropylene (PP) material is due to the nature of this material that is environmentally friendly and recyclable. In meeting the demand of cables operating at higher temperatures today, the use of PP with a relatively high melting point compared to PE is a better choice. PP also has higher breakdown strength, which is very important to increase the voltage level of cable operation and ampacity line. However, PP is a material that has a strong tenderness and rigidity, weak resistance to low temperature effects, and low thermal conductivity [6].

There are many advantage and disadvantages of each material as insulators. In order to determine the lifespan and integrity of insulation for the operation of the economic system and reliable, selecting the best insulation material is very important. In relation to this, research on the dielectric behaviour of this material system has been carried out. Despite numerous positive experimental results reported on the use of nanocomposites as electrical insulating materials, there exists many fundamental challenges to be addressed. In this study, the effect of sample preparation at difference temperature and duration on breakdown properties of polyethylene and polypropylene blends were investigated.

1.2 Problem Background

For many years, XLPE has been widely used as insulation for power cables. In processing, XLPE cables require degassing resistance and gel impurity management. In 2016, improvements to breakdown strength, with a test on the breakdown of the mini-cable specimen can be seen in polyethylene and polypropylene blends when compared to XLPE's own performance [1].

Nowadays, with increasing world population and increasing industrial technologies, the demand on power supply also increases. Higher users demand makes the high operating temperature and heat accumulation of cables, which is the main factor of degradation for insulation of cable systems. Because of that, insulation materials for electrical equipment must be able to sustain at higher temperatures. In 2016, the use thermoplastic blends materials such as high density polyethylene (HDPE) and low density polyethylene (LDPE), polypropylene blends showed better thermal and electrical performance with respect to XLPE that has significant impact with continuous operating temperature of 90°C [7, 8].

Although studies on the dielectric strength of pure polymeric materials with micro or nanoparticles have been widely carried out, it can be seen that high voltage polymer mixing applications are limited to electrical properties. Most studies were conducted on a mixture of mechanical and physical properties of the mixed polymer. However, evaluating the breakdown strength of the mixed material is also important to investigate their ability to be used in high voltage insulation systems [9]. Therefore, the breakdown strength of HDPE and PP blends at different processing temperature and duration was investigated in this work.

1.3 Research Goal

1.3.1 Research Objectives

The objectives of the research are:

(a) To investigate the effect of sample preparation temperature on breakdown properties of polyethylene and polypropylene blends.

(b) To investigate the effect of sample preparation duration on breakdown properties of polyethylene and polypropylene blends.

(c) To analyse the correlation between temperature, duration and breakdown properties of polyethylene and polypropylene blends.

1.4 Research Scope

This study focused on the breakdown properties of polyethylene (PE) and polypropylene (PP) blends. The polypropylene used was polypropylene homopolymer grade Titanpro 6531M while the polyethylene used was high density polyethylene (HDPE) grade Titanzex HI2000, obtained from Lotte Chemical Titan. Six types of polymer blends composed of 80% PP and 20% HDPE mixed at 170°C temperature and 5 minutes duration, 170°C temperature and 15 minutes duration, 180°C temperature and 5 minutes duration, 180°C temperature and 15 minutes duration, 200°C temperature and 5 minutes duration, and 200°C temperature and 15 minutes duration were chosen for study purposes.

The breakdown test was conducted in AC field and the increment of the voltage was 1 kV every 20 seconds until the sample failed. In DC field, the increment of the voltage was 2 kV every 20 seconds until the sample failed. The distribution of dielectric strength was plotted and analysed using Weibull distribution analysis.

1.5 Contributions

The work gave the following contributions:

(a) Determine correlation between temperature, duration and breakdown properties of polyethylene and polypropylene blends.

(b) Improve understanding of the breakdown properties of polymer blends of compositions HDPE and PP mixed and blends at different temperatures and durations.

(c) Evaluation of dielectric strength distribution using Weibull software.

1.6 Project Timeline

The project 1 and project 2 timeline can be referred to the Figure 1.1 below.

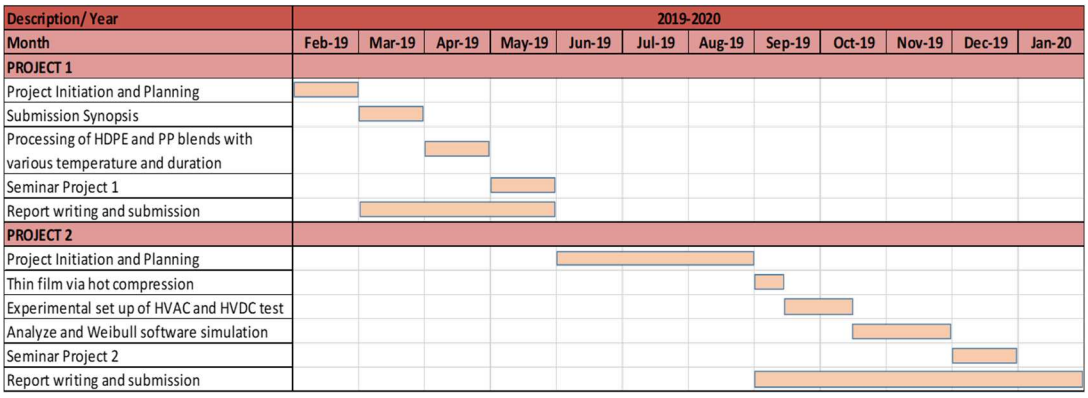

Figure 1.1 Project schedule for project 1 and 2

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