UNIVERSITI TEKNIKAL MALAYSIA MELAKA

POTENTIAL OF CARBON BLACK ELECTROSTASTIC FILLER FOR THE AUTOMOTIVE PAINT COATING APPLICATION

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

by

MOHD AZRIL BIN MOHD AZLI
B050810227

FACULTY OF MANUFACTURING ENGINEERING
2011

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **POTENTIAL OF CARBON BLACK ELECTROSTATIC FILLER FOR THE AUTOMOTIVE PAINT COATING APPLICATION**

SESI PENGAJIAN: 2010/11 Semester 2

Saya **MOHD AZRIL BIN MOHD AZLI**

Mengaku membenarkan Laporan PSM ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (√)

☐ SULIT (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia yang termaktub di dalam AKTA RAHSIA RASMI 1972)

☐ TERHAD (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

☐ TIDAK TERHAD

Disahkan oleh:

____

Alamat Tetap:

Bt.21, Jalan Seremban,

Kg Batu Serambai, 71600

Jelebu, Negeri Sembilan

____

PENYELIA PSM

(Tandatangan dan Cop Rasmi)

Tarikh: _________________________

Tarikh: _________________________

** Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

DECLARATION

I hereby, declared this report entitled "*Potential of Carbon Black Electrostatic Filler for the Automotive Paint Coating Application*" is the results of my own research except as cited in references.

Signature	:	…………………………………….
Author's Name	:	Mohd Azril Bin Mohd Azli
Date	:	19th May 2011

APPROVAL

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). The member of the supervisory committee is as follow:

………………..…………………………..…………………

Supervisor

(Signature & Official Stamp of Supervisor)

ABSTRAK

Penyelidikan ini bertujuan untuk mengetahui potensi karbon hitam digunakan dalam industri otomotif sebagai lapisan cat. Kesan daripada pemuatan karbon hitam dipelajari untuk menentukan formulasi terbaik lapisan cat konduktif. Karbon hitam (CB), polyester (PE), epoksi and aseton adalah 4 elemen utama dalam formulasi lapisan. Komponen ini dicampur menggunakan pengaduk mekanikal dan sebati sepenuhnya mengunakan pelarasan ultra-sonikasi. Peratusan karbon hitam berbeza dari 3, 5, 7, 9, 11 dan 13wt%. Cat disapu diatas lembaran aluminium untuk ujian dan analisis lebih lanjut. Ujian lekapan, impak dan kekerasan dijalankan untuk menentukan sifat mekanikal dari pembuatan cat komposit berasakan polimer. Hal ini diikuti oleh ujian pelapukan, ujian rendaman air dan ujian rintangan. Analisi mikroskop elektron dilakukan untuk mengetahui perilaku morfologi sampel. Penambahan karbon hitam mempengaruhi ciri fizikal, sifat mekanikal, morfologi permukaan dan kekonduktifan sampel. Kenaikan karbon hitam menyebakan penurunan pada sifat mekanikal sampel iaitu perilaku kekerasan, perilaku impak dan perilaku lekapan signifikasi dengan kenaikan bahan penambah. Kekonduktifan meningkat dengan peningkatan karbon hitam. Kekonduktifan direkodkan berada pada tahap EMI dan bukan pada tahap anti statik sepertimana didalam hipotesis.

ABSTRACT

This research is to investigate the potential of carbon black filled coating for automotive paint coating industry. The effects of the optimum carbon black loading were studied as to establish the best formulation of the conductive paint coating. Carbon black (CB), polyester (PE), epoxy and the acetone were 4 major elements in the coating formulation. The components were mixed using mechanical stirring and thoroughly homogenized through ultra-sonication setup. The percentages of CB in paint coating were varied from 3, 5, 7, 9, 11, and 13 wt%. The paint coatings were coated onto aluminium sheet for further testing and analysis. Adhesion test, impact test and durometer test were performed on the paint to determine the mechanical properties of the fabricated polymeric based paint composites. It was followed by weathering test, water immersion test and resistivity test. Scanning Electron Microscopy (SEM) analysis was conducted as to investigate the morphological behaviour of the samples. The addition of carbon black to the painting formulation affected the major physical characteristic, mechanical properties, surface morphology and the conductivity of the sample. The increases of the carbon black loading resulted the decreasing on the mechanical properties of the coating sample which the impact behaviour, hardness behaviour and adhesion behaviour of the coating sample, dropped significantly with the increasing content of this filler adhesion. The conductivity of the paint increased as the CB loading increase. The archived conductivity was in the EMI region instead of the anti-static region as hypothesized.

DEDICATION

This report was dedicated to my mother, Zaiton bte Ismail, and all my siblings. Besides that, this project also dedicated to my grandfather and my grandmother, Ismail bin Itam and Shamsiah bte Bidin. And not forgotten, thanks to my supervisor Mr. Jeefferie bin Abd Razak and all my friends who encourage me in knowledge and other.

This report I'm fully dedicate to all of you…

ACKNOWLEDGEMENT

In the name of Allah S.W.T the most gracious and the most merciful, and Muhammad S.A.W, the Messenger of Allah, first and foremost I am heartily thankful to my supervisor, Mr. Jeefferie Bin Abd Razak, whose guidance and support me in developing my understanding of the project. Besides, I want to thank to my parents and my sisters that always give encourage and supports me in the project. Lastly thank to all of those who supported me in any aspect during the completion of the project.

TABLE OF CONTENT

LIST OF TABLE

LIST OF FIGURES

LIST OF ABBREVIATIONS AND SYMBOLS

ASTM	-	American Standard Testing of Material
CB	-	Carbon Black
UV	-	Ultra Violet
ESD	-	Electrostatic Discharge
SEM	-	Scanning Electron Microscopy
EDS	-	Energy Dispersive X-Ray Spectrometry
MACT	-	Maximum Achievable Control Technology
wt%	-	Percent of Weight Fraction
^0C	-	Degree Celsius
σ	-	Conductivity
ρ	-	Resistivity
R	-	Resistant
I	-	Ampere
V	-	Voltage
w	-	Width
h	-	Height
Ω	-	Ohm
J	-	Joule
N	-	Newton

CHAPTER 1
INTRODUCTION

1.1 Introduction

Effective conductive coatings are increasing essential in a broad range of application. A major segment is for the anti-static protection. This includes primers for electrostatic protection, coating and ink that have been used in printed circuits applications. Most of this application end use are satisfied by coating utilizing a conductive filler at various loading level. One of the conductive material is carbon black that is preferred conductive filler in many cases for several important reason such as, readily available, cost effective and readily dispersed and stabilized in liquid (Sichel *et al*., 1982). Carbon black is a material produced by incomplete combustion of heavy petroleum products such as tar, coal tar, ethylene cracking tar, and a small amount from vegetable oil. Carbon black is a form of amorphous carbon that has a high surface-area-to-volume ratio, although its surface-area-to-volume ratio is low compared to that of activated carbon.

Over the years, carbon blacks have proven to be one of the most versatile functional fillers as a pigment in the painting production industries. Other that providing the electrical conductivity, they also provide lasting protection against ultraviolet light. Carbon blacks function as a low cost pigment that producing various shades of black color in the final product. Consider as the potential of carbon black as non-expensive material and very good in their anti-static behavior, this research will further investigate the best optimum formulation of carbon black polymer coating for an anti-static application of automotive industry.

1.2 Problem Statement

Coating in automotive application operates in an environment containing electromagnetic emissions such as magnetic generated from the automotive engine, broadcast transmitter and other electrical system. Electromagnetic also can be generated from natural sources such as atmospheric electrical disturbance and static precipitation. This electromagnetic emission can cause a lot of problem such as disruption of the engine performance and others. To provide better performance of the engine, this electromagnetic emission must be controlled in the acceptable limit. Due to the problem, this research was carried out to develop the conductive coating. Great attentions were focused on the carbon black loading to be incorporated in the paint coating for the automotive painting industry. These were due to the advantages of the carbon black in its structure, surface chemistry and size of the carbon black particles. This research will covered the properties of the coatings such as fracture energy, hardness, glass transition, and barrier properties on weathering.

The correct formulation of carbon black based polymeric coating for the automotive application was not based only on the desire final properties of the particular compound, but also on the specific properties of the carbon black itself. The properties were particle size, structure, and their purity. These critical elements of the carbon black were combined with various polymer carrier resins in the compounding process to produce the finished compound. Thus, the potential of the carbon black filler in the paint was the major focus in this research.

1.3 Objectives

The purposes of this project are:

1.3.1 To study the effect of carbon black addition in anti-static paint formulation.

1.3.2 To correlate physical, mechanical, electrical properties of the paint with the morphological characteristic.

1.4 Hypotheses

1.4.1 The carbon black loading will affect the properties of the coating.

1.4.2 The addition of carbon black will enhance the black colour and conductive behavior of the paint.

1.5 Importance of Study

The aim of this research is to develop a new alternative paint formulation for the automotive application. Thus, by conducting this research, it was expected to give an alternative to the automotive industry of better painting formulation with lower cost due to the utilization of waste carbon black provided by CABOT (M) Sdn Bhd.

1.6 Scope of Study

Most conductive coating in the prior technology was applied either by vacuum depositions or spraying. The purpose of this invention is to develop a conductive coating which could increase the surface conductivity of the automotive body or parts for anti-static application. In producing the conductive coating for this invention, the adhesive was mixed with conductive filler. The adhesive material used was polyester and which is carbon black was utilized as pigment for anti-static and conductive purposes. The conductive coating was developed in the matrix solution of epoxy resin and hardener. The resin was dilute using acetone solution and mixed with the carbon black at various percentages. The produced paint was tested for physical, mechanical and electrical properties using standard laboratory equipment. The paint was also examined under SEM for morphological analysis.

1.7 Thesis Overview

At the beginning of this thesis, it will start with the Chapter One as the introduction of the study. Chapter One explained the background of this invention, problem statement, objectives of the research, hypotheses, the importance of study, scope of the study and the thesis overview. Chapter Two presents the literature review that relates the theories on the polymer based coating and the investigation for the potential of the carbon black as the innovative pigment for anti-static paint coating that can be applied in the automotive industry. In this chapter, it also mentioned about the other material that been used such as epoxy as the adhesive material, polyurethane as the binder and toluene which is an organic solvent. Study on the properties of the carbon black also been included in this chapter. Besides that, this chapter also explore the coating formulation that been used in other previous research. Chapter Three, explained in details the methodology for the overall research works, mainly; raw materials and sample preparation, and coating method. Another important component that included in this chapter is about the various types of properties and related testing. The result and discussion for the project testing have been state at the Chapter Four. At the end of the report the conclusion and recommendation were written at the Chapter Five of the report.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter presents the literature review that relates to the theories for development of carbon black conductive paint coating. This chapter covers the related material that been used, sample preparation and the manufacturing process that involved in this research. Comprehensive review related to the carbon black conductive coating for automotive application and the theories will be covered extensively.

2.2 Coating Technology

Car painting industry has undergone incredible changes by way of materials and processes development following the general progress of manufacturing technology from the start of the twentieth century until today. Early coating processes, involved the use of air drying paints, sanding of each layer and polishing, all of which needed weeks for completion. All the coating steps were executed manually. The development of better and more efficient processes have brought in dramatic changes over the last 100 years.

Introduction of mass production requiring faster curing paints, better film performance in terms of corrosion and durability of colors, improved environmental compatibility, and fully automated processes for better reliability, characterize the most important milestones in this field. The number of applied coatings had been reduced to four or five layers, all hand sprayed this time. The function of these layers were corrosion protection for the primers, smoothness and chip resistance for the primer surface, and color and weather resistance for the final top-coat layer (Joachim *et al.*, 2008).

In the 1950s the process of applying the primer changed to dip coating, a more automated process, but a hazardous one owing to the solvent emission of the solvent-borne paints. Explosions and fire hazards forced automotive manufacturers to introduce either waterborne paints or electro-deposition paints. In the 1970s the anodic deposition coatings, mostly based on maleinized polybutadiene resins, quickly gave way to cathodic ones owing to better corrosion protection by their modified epoxy resin backbones and reactive polyurethane-based crosslinkers, increased throwing power, and higher process reliability. At the same time, the single layer top coats were gradually replaced by two-layer top coats consisting of a thin base coat and a thicker clear coat applied wet-on-wet. The base coats are responsible for color and special effects (for example, metallic finish), whereas the clear coats provide improved durability using specially designed resins and formula ingredients like UV-absorber and radical scavengers (Joachim *et al.*, 2008).

Today, most clear coats in Europe are based on two-component formulation consisting of an acrylic resin with OH-functions and a reactive polyurethane crosslinker. The rest of the world still prefers the one-component technology based on acrylic resins and melamine crosslinkers. An interesting one-component technology based on carbamate functionality has been recently introduced in the United States (Green, 2001). All these developments contributed to an improved film performance resulting in better corrosion protection and longer top-coat durability.

Furthermore, raw material development in the pigment section, with improved flake pigments based on aluminum and new interference pigments that change color depending on the angle in which they are viewed, has resulted in enhanced brilliance and color effects of automotive coatings (Rochard , 2001). Coating can be defined as mixture of various materials. The question arose are as to how much of which material and how do these things related. The material are fall into four categories which are resin (binder), pigment, solvent and additive. Along with the continuous improvements of the application technology, new polymer based coating were developed to contribute toward the legally enforced environmental compliance of the processes.

2.3 Polymer Based Coating

New polymer coating and barrier technologies are designed to be more resistant to cracking when laminates are stressed and movement occurs. These new technologies have superior toughness and impact resistance in comparison to industry standard gel coats and barrier coats. These new coatings are Maximum Achievable Control Technology (MACT) compliant for both marine market applications, as well as the stricter reinforced market applications. The new coating technologies will require some process modifications, but are applied similarly to conventional gel and barrier coats (Fred, 2007).

In addition to crack resistance these new coating and barrier technologies offer a number of other benefits including gloss retention of the coating after weathering, water resistance, and wear resistance of the coating surface. The surface can be tailored to specific physical, optical, electronic, chemical, and biomedical properties by coating a thin film of material on the surface of interested.

Conventional nanoparticle coating methods include dry and wet approaches. Dry methods include physical vapor deposition (Zhang *et al*., 2000), plasma treatment (Vollath *et al*., 1999), chemical vapor deposition (Takeo *et al*, 1998) and pyrolysis of polymeric or non-polymeric organic materials for the in situ precipitation of nanoparticles within a matrix (Yulu *et al*, 2003). For wet methods of coating nanoparticles, it includes sol–gel processes, emulsification and solvent evaporation techniques (Green, 2001).

2.4 Emulsion Paint

Since the first oil crisis in 1973, the trend of solvent and the requests for no pollution or low pollution paints from users have raised requests for emulsion paints. With the following progress in polymerization technology in synthetic resin emulsion, coating performance and decorative functions have been deployed, raising its position in the painting field. Furthermore, since the synthetic resin emulsion paints have less content of organic solvent compared with not only solvent-based paints but also water-based ones, they are in the advantageous position from the viewpoint of pollution and resource saving. The composition of emulsion paints is complex compared with solution paints because they use dispersion resins (Toshinaga Kaneda *et al*., 1988). The formulated components include not only synthetic emulsion and pigments but also plasticizing agents, film-formation auxiliary agents, viscosity bodying agents, viscosity adjusters, dispersing agents, wetting agents, antiseptic agents, antifungal agents, anti-foam agents, anti-freezing agents, stabilizes and etc. The form of water dispersion resins are divided into colloidal dispersion, emulsion, and suspension according to the particle size. They are used as vehicles for painting. The characteristics of these dispersion resins and general water-soluble resins are classified in the Table 2.1. (Toshinaga *et al*.,1988).

Table 2.1: Characteristic of water-based paints (Toshinaga *et al*.,1988)

Characteristics	**Water Solubility**	**Colloidal dispersion**	**Emulsion**	**Suspension**
Particle size (μ)	>0.005	0.01 to 0.05	0.05 to 0.5	0.5 to 10
Molecular weight	Low	Medium	High	Low to medium
Viscosity	High	Medium	Low	Low
Resin solid content	Low	Medium	High	High
Amount of organic solvent	Much	Medium	Non	Medium
Coating workability	Bad	A bit bad	Good	Good
Gloss	Good	A bit bad	Bad	A bit bad
Film formation	Bad	A bit bad	Bad	A bit bad

Physical performance	Bad	A bit bad	Good	A bit bad
Water resistance	Bad	A bit bad	A bit bad	A bit bad

2.5 Solvent-based coating

Solvent-borne paint, which consist of polymer as binder, which form films only by evaporation of solvent, are call physical drying paint to achive sufficient properties in films. These polymers have mainly rather high molecular mass. Addition of this polymer may contain molecular structures which support the evaporation of the solvent during the film formation. The film which are form by a chemical crosslinking process, are much better resistance against solvent and other agent than films who are only formed by physical drying (Mueller, 2006).

The reason why solvent evaporates very fast is the tendency of the binder resin molecules to form the molecular associates. Particularly the molecules may form crystalline domains. This tendency may result in negative film properties, such as brittleness. Therefore most of the physical drying polymer needs the additional of plasticizers to form optimal film properties. Additionally, there are other resin component which is combined with the physically drying main resins to improve gloss, leveling and appearance of the coating (Mueller, 2006).

2.6 Conductive Polymer

Conductive polymers and plastics are increasingly desired for a growing number of sophisticated end-uses. Most plastics are naturally non-conductive or insulator in nature. Because of their ease of fabrication, polymers are highly desirable materials for construction, where some transfer of electrical charges are desired to increase the conductivity. This had resulted in plastics that can be used in four distinct application categories of increasing conductivity which are insulating (e.g. wire coating), dissipative ("anti-static" polymers), conductive (materials capable of conducting