ADHESION OF POLYMER COATED STEEL WIRE BY COMPRESSION MOLDING AND EXTRUSION PROCESS

TIJANI ABDULLAHI

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Faculty of Mechanical Engineering
Universiti Teknologi Malaysia

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To
My Beloved Family
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ABSTRACT

Steel wires coated with thermoplastics have found a wider range of application in the field of science and engineering. However, steel-polymer interfaces frequently suffer from poor adhesion strength that is undermining their long-term stability under external stress because of weak interaction between the steel and polymer surfaces. Therefore, the present study aims to investigate the influence of adhesive (Chemlok 213 and Cilbond 49SF) on the adhesion strength of galvanized and ungalvanized steel wire coating with thermoplastic polyurethane (TPU). Surface treatments including grinding with sandpaper, thermal oxidation and degreasing with alkaline solution were done on the steel wire substrate prior to coating by compression molding and extrusion process. The adhesion was characterized with a single wire pullout test and field emission scanning microscopy (FESEM). The experimental results confirmed that Cilbond 49SF adhesive with sandpaper grinding treated wire outperformed all other surface treatments tested. In comparison of the processes, compression molding process has an upper hand over the extrusion process because it provide an avenue for sufficient control of curing time required for optimum setting of the adhesive.
ABSTRAK

Wayar keluli yang disalut dengan thermoplastics telah menemui pelbagai jenis aplikasi dalam bidang sains dan Kejuruteraan. Walau bagaimanapun, antara muka keluli-polimer sering menderita daripada kekuatan rekatan miskin yang melemahkan kestabilan jangka panjang mereka di bawah tekanan luar kerana interaksi lemah antara permukaan keluli dan polimer. Oleh itu, kini kajian bertujuan untuk menyiasat pengaruh pelekat (Chemlok 213 dan Cilbond 49SF) kekuatan lekatan salutan dawai keluli tergalvani dan ungalvanized dengan termoplastik poliuretana (TPU). Rawatan permukaan termasuk pengisaran dengan kertas pasir, pengoksidaan terma dan sektor penyahgris dengan alkali penyelesaian yang dilakukan pada substrat dawai keluli sebelum salutan oleh proses membentuk dan penyemperitan mampatan. Lekatan itu yang disifatkan dengan ujian pullout tunggal wayar dan Field Emission Scanning Microscopy (FESEM). Keputusan eksperimen mengesahkan bahawa Cilbond 49SF pelekat dengan kertas pasir pengisaran dawai dirawat sejak lain rawatan permukaan yang diuji. Perbandingan proses, mencetak proses mampatan mempunyai satu atas tangan ke atas proses penyemperitan kerana ia memberi peluang untuk kawalan mencukupi pengawetan masa yang diperlukan untuk seting optimum pelekat.
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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Polymer coating is receiving increasing attention from both the researchers and industries as they offer an attractive low-cost substitute to the development of entirely new materials. Polymer coating of metal wire is done for the purpose of electrical insulation and corrosion protection, as well as the need to provide a superior surface for lubrication and to facilitate bonding to other structural media. Moreover, steel-cords reinforced thermoplastic composites are recyclable and use cost efficient raw materials (Golaz et al., 2011). Steel reinforced thermoplastic have found applications in the rehabilitation or upgrading of bridges and concrete buildings, in pressurized pipelines and in tires technology. Kamal (2013) added other areas of steel coated wire application which include the cable industry, offshore application and for transmission belts. While it is also possible to achieve the mechanical properties by using lightweight ultra-high strength wire as we know in the market now, there is a pending struggle of strength to weight ratio (Banfield and Casey, 1998). Polymer coatings give a better balance between cable weight reduction and greater cable flexibility (Lamb and Hashmi, 1991).

Enhancing the adhesion properties of solid interfaces between metals and polymeric materials is one of the most important issues in materials science because high adhesion strength of interfaces is essential to realizing their practical applications in film or paint coatings, joints, automobiles, aircraft, semiconductors, data-storage devices, thin-film transistors, and flexible
electronics (Yacobi et al., 2002; Amancio-Filho and Dos Santos, 2009; Pocius, 2012).

In particular, adhesion between steel and polymer composites is very important because steel is mechanically stronger than other metals and is widely used in the mechanical and microelectronics industries (Yacobi et al., 2002). Adhesives such as epoxy, acrylate, and cyanoacrylate are commonly used in industries (Yun et al., 2011). However, steel-polymer interfaces frequently suffer from poor adhesion strength, undermining their long-term stability under external stress because of weak interactions between the steel and polymer surfaces.

Recent years in the world have seen the development of a variety of new epoxy resins, where BPA is no longer a constituent (Yun et al., 2011). One of the more interesting scientific solutions to the problem is the development of epoxy resins from Schiff bases (Langer et al., 2014). The presence of the –CH=N-Ar azomethine group in a resin macromolecule improves adhesion of the coating to a metal substrate and increases its thermal stability. In addition, Schiff bases constitute good corrosion inhibitors and are good passivation agents for steel, copper and aluminium (Atta et al., 2006b; Mija et al., 1996; Atta et al., 2006a). Epoxy resins which contain in their structure a complex metal ion have better thermal stability and very good mechanical properties while maintaining low processing temperatures (Atta et al., 2006a; Langer et al., 2014).

There are different approaches to modify epoxy resins to improve these shortcomings and maintain those properties that have been proven desirable. There are various ways to achieve this: Choi et al. (2004) recommended introduction of substituents into the mesogenic units, this recommendation conform with the earlier submission of Ribera et al. (2003). Introduction of a flexibility spacer, decouples the reactive end-functional group from the rigidrod mesogenic group (Castell et al., 2004). However, Giamberini et al. (1997) insist on altering the curing reaction of rigid-rod mesogenic epoxy monomers with aliphatic dicarboxylic acids. Polymer products manufacturers and parts producers took advantage of the research on various adhesive modifications to produce adhesive products with improved thermal
stability and a very good mechanical property while maintaining low processing temperatures.

Not all polymeric materials are compatible for bonding with steel wire, using High Density Poly-Ethylene (HDPE) coated on metal (Xie et al., 2008). He further declared that it gives a strong composite material that provides an excellent tensile strength, highly abrasion-resistant and is unaffected by acidity or alkalinity. Lamb and Hashmi (1991) worked on polymer coating of superfine wire, describing it as a lightweight wire rod that resists aggressive chemicals, withstands freeze-thaw cycles and continuous subzero temperatures without cracking. Golaz et al. (2011) recommended thermoplastic polyurethane for coating on galvanized steel. Low-cost processing of polymer composite materials can be done by compression molding, extrusion or hot press machine. Martyn et al. (2009) thought that co-extrusion may be used successfully to apply a polymer coating onto the wire with better bonding between the coating and the rope by studying the mechanism of interface formation and adhesion behavior.

Nevertheless, bonding and joining between polymer and steel is an important issue because thermoplastic are highly un-reactive materials with a low polarity and therefore, cannot adhere on steel wire. It is thus necessary to change the interface properties to promote adhesion. This can be achieved by chemical modification of bulk polymer material, by physio-chemical modification of one or both constituents of the interface, and/or by the use of coupling agents (adhesives) that are chemically reactive with both polymeric material and metal (Lu et al., 2005a; Golaz et al., 2011). In view of this background this study is to examine the effect of some commercial adhesives on the adhesion of polymer coated steel wire rope by extrusion process and compression molding.
1.2 Problem Statement

The use of polymer coatings depends strongly on their service conditions and the chemical or physical bonding properties of the composite. Polymer coated steel wires are currently in applications in tire technology, the cable industry, offshore application and for transmission belts. Hence (Golaz et al., 2013) and (Kamal, 2013) deduced that bonding and joining between polymer and steel is an important issue because most plastics are highly un-reactive materials with a low polarity and therefore, cannot adhere on steel wire. Poor adhesion can be caused by many factors such as mismatch of adhesive material used between the polymer and the metal substrate, impurities and in appropriate surface which failed to initiate the required bonding mechanism etc.

Beside adhesion, the appropriate processing method to use is an important factor which influences the adhesive bond of polymer coating on steel wire. Therefore, this study will focus on promoting the adhesion of thermoplastic Polyurethane (TPU) on steel wire by identifying the effective adhesive material for TPU polymer coating of steel wire by compression molding and extrusion process.

1.3 Objectives

1. To study the effect of adhesive material for TPU polymer coating of steel wire by compression molding and extrusion process.

2. To conduct a single wire pull-out test for adhesion properties of TPU polymer-steel wire cord.
1.4 **Scope of Research**

1. Prepare the polymer coated steel wire by compression molding and extrusion process with and without adhesive materials.

2. Conduct surface treatment and modifications to better adhesion of TPU polymer to steel wire.

3. Conduct a pull-out adhesion test and microstructure analysis for the samples prepared.

1.5 **Research Output**

The expectation of the study is to produce a polymer coated steel wire rope with a good adhesion for excellent strength and toughness that can yield a high resistance to oil and water.

1.6 **Contribution**

Polymer coated steel wire rope have found applications in the rehabilitation or upgrading of bridges and concrete buildings. With evidence from the rehabilitation of the Maryland Bridge in Lagos and the construction of the second Niger bridge all in Nigeria, as well as the construction of second bridge of Penang Malaysia. Steel wires reinforced polymeric composites are currently in applications in tires technology, in the cable industry, offshore application and for transmission belts. This study is to improve more on the application of polymer (Thermoplastic Polyurethane) coated steel wire rope in offshore application, which will all together help the offshore industries such as oil and gas, which are the larger contributors to the economy of Nigeria and Malaysia.
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