IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

# Puncture Resistant Coating for Automotive Applications

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***Abstract***— This Research focuses on developing a puncture proof coating on the inner liner of the tire by incorporation of nanoparticle in to the polysiloxane. Automobile has played a crucial role in the upliftment of society. This is also an important prerequisite for the progress of modern society Nanotechnology has paved new ways for innovative products. Carbon nanotubes (CNTs) are one of the ideal reinforcement phase because of their aspect ratio. This study focuses on the development of thin film composed of silicone sealant and multi-walled CNT over the rubber surface that acts as puncture resistant coating this process is carried out by mechanical agitation technique. Based on the results it can be observed that incorporation of MWCNTs has led to increase in the life of tire. Optimum results were obtained in terms of tensile and hardness for the developed coating. Fourier-Transform Infrared Spectroscopy (FTIR) was employed to identify inorganic materials in the matrix that might influence the mechanical properties under study.

***Keywords***— *Tensile test; Hardness tes; Puncture test; Carbon nanotubes; Fourier-Transform Infrared Spectroscopy (FTIR); silicone sealant; Nanocomposites*

## I. INTRODUCTION

Composite materials are the new generation materials that are developed to meet the requirements of new generation of rapid growing disruptive technologies in industries. These are made of two or more constituent materials that remain distinct in micro or nanoscopic levels while forming a single entity for macroscopic applications [1]. A composite material is a synthetic material created artificially out of two or more materials with dissimilar physical, chemical, and other properties. One of these components is called matrix phase while the other is called reinforcement phase. A composite is superimposed properties of two material Composite consists of two phase the major one is known as matrix. The distributed phase is called reinforcement. This is often harder, stronger having distinct properties. The idea of composite materials is not new. Nature is full of examples of composite materials. Matrix materials surround and provide necessary support for reinforcement phase by maintaining their relative positions. Most composites have been synthesised with a desire to enhance mechanical, structural or chemical properties [2]. These include enhancement of strength, stiffness, toughness, temperature associated properties, catalytic properties, wear resistance, radiation inhibiting properties, aesthetic properties, etc [3]. Reinforcement often at optimum proportion leads to increase in properties such as wear resistance, lubrication, corrosion resistance, impact strength improving the properties of the matrix material [4]. Silicone sealant is selected for vivid engineering applications [5]. Additionally, silicone compounds have great adhesion properties to rubber [6]. Silicone is composed of Si and O2. Silicone is preferred over epoxy because of its sustainability at cryogenic temperatures [7-8]. Carbon nanotubes (CNTs) have large aspect ratio in which diameter is in terms of nanometers and length in terms of angstroms. Their infusion in polymer matrix renders them for heavy load sustainability [9]. There are different types of CNTs single walled CNTs (SWCNTs) and Multiwalled CNTs (MWCNTs). MWCNTs are chosen to reinforce Silicone Sealant in this study. MWCNTs were selected because of their telescopic extension nature that matches the elasticity of the tyre, which could be added advantage for enhancing the tire life. The average MWCNT diameters used in this work were 25nm and average length of 10 micron. The Puncture test, Tensile and Hardness properties are studied on plain tire sample and compared on those with coated CNT samples with variable composition [10]. Silicone sealant coatings on inner line of tire containing weight fractions of 3%, 5%,7%, and 9wt.% MWCNTs were prepared.

## II. EXPERIMENTAL PROGRAM

### *2.1 Materials*

This section focuses on materials used such as Silicone Sealant, Rubber tire, and MWCNTs. MWCNTs were procured from Sigma Aldrich Industries, India as shown in Fig.1. The MWCNTs were manufactured by a chemical vapor deposition (CVD) process. The properties of the materials, as per the supplier data, are listed below in Tables I and II.

TABLE I. PROPERTIES OF THE MWCNTS AS PER THE SUPPLIER'S SPECIFICATIONS

| Material | Multi-walled Carbon Nanotubes (MWCNTs) |
|---|---|
| Manufacturing Process | Chemical Vapor Deposition (CVD) |
| Diameter | 10-30 nm |
| Length | 2.5-20 microns |
| Purity | >95% (MWCNT) |
| Amorphous carbon | < 3% |
| Residue (Calcination in air) | <2% |
| Average interlayer distance | 0.34 nm |
| Surface area | > 350 $m^2/g$ |
| Charging | 2180 (capacity: mA h/g) |

| | |
|---|---|
| Discharging | 534 (capacity: mA h/g) |
| Volume Resistivity | 0.1-0.15 ohm.cm (measured at pressure in powder) |

Fig. 1. Multi-walled Carbon Nanotubes

TABLE II. PROPERTIES OF THE OTHER MATERIALS AS PER SUPPLIERS SPECIFICATIONS

| Material | Values |
|---|---|
| Silicone sealant | Specific Gravity: 0.92<br>Temperature Resistance: -60°C to 180°C<br>Hardness( Shore A): 16 to 25 |

*2.2 Preparation of the Specimens*

The MWCNTs used in this work were of industrial grade with a purity of > 95 wt%. The MWCNTs were added in varying concentrations, 3%, 5%, 7 % and 9% of the total weight of the Silicone sealant composite. The Silicone sealant added with the MWCNTs and coated on 80mm*20mm specimens as shown in **Fig.2**. The specimens were then cured at room temperature for 12 hours before being tested.

Fig. 2. Specimens with respective compositions a.5wt%, b. 3wt%, c.7wt%, d.WC

*2.3 Methodology*

The methodology adopted for characterizing the developed nanocomposites are structural which are Tensile Test , Hardness Test and Puncture Test which determines mechanical properties of developed composites and microstructural studies which is FTIR which analyses the chemical bonds.

## III. RESULTS AND DISCUSSION

*3.1 Mechanical characterization*

This section highlights tensile tests and puncture tests conducted on 5 replicas of each composition of the modified samples as per ASTM standards.

*3.1.1 Slow Rate Penetration Test*

Penetration resistance is an end-use performance of flexible materials where a sharp-edged product can destroy the integrity of the coating layer. The standard calculation requires the maximum load to break the coating. The experiment setup was performed according to ASTM F1306 standard. Material response to penetration will vary with numerous factors, such as coating thickness, rate of penetration, temperature, shape and type of probe. The rate of penetration was set to 1mm/min. The experiment was carried out on Micro UTM Tinius Olsen as shown in **Fig.3** which has an accuracy of +/- 0.005%. The results of slow rate penetration test are shown in Table III. The force v/s penetration on the specimen is shown in **Fig.4**.

Fig. 3. Slow rate penetration test setup

TABLE III. RESULTS OF SLOW RATE PENETRATION TEST (PUNCTURE TEST)

| Sl. No. | Specimen | Maximum Load (N) | Probe Penetration (mm) |
|---|---|---|---|
| 1 | SS (Plain Silicone) - SS | 53 | 2.0 |
| 2 | SS+ 3wt% of MWCNTs - A1 | 60 | 4.0 |
| 3 | SS+ 5wt% of MWCNTs - A2 | 64 | 3.5 |
| 4 | SS+7wt% of MWCNTs - A3 | 56 | 3.0 |
| 5 | SS+9wt% of MWCNTs - A3 | 35 | 4.0 |

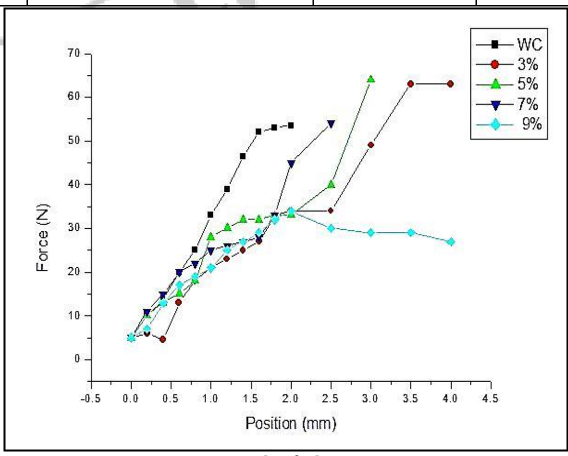

Fig. 4. Force vs Position Graph of Slow Rate Penetration Testing

*3.1.2 Tensile testing*

The coated and uncoated specimens were also examined under tensile load to assess their mechanical properties such as Youngs Modulus, Ultimate Strength and Deflection. The results obtained were compared to those the uncoated specimen. The results are presented in Table IV. The load curves are shown in **Fig 5**. From Fig.5, it follows that the stress and strain of different compositions has increased linearly upto certain point. For 7wt.% MWCNT filler it has shown maximum stress. The line of WC (Without Coated) has overlapped with 3% filler composition. The reasons could be non uniform distribution of MWCNT in the sealant base. For 7wt.% of MWCNTs in the matrix young's modulus obtained was 1580 N/mm2 as compared to for without coated specimen of 988 N/mm2, an increase of 60%. However, for increased dosage of MWCNTs beyond 7wt.% up to 9wt.% the stress vs strain graph decreased after certain point. From the stress-strain curve, as shown in Fig.2, the area under the curve for specimen A4 was higher when compared to other compositions. From this, it can be concluded that 7 wt% was the best composition for tensile strength when compared to the other reinforcement compositions. The stress v/s strain graph of the modified samples is shown in **Fig.6**.

Fig. 5. Tensile test setup

TABLE IV. RESULTS OF THE TENSILE TESTS

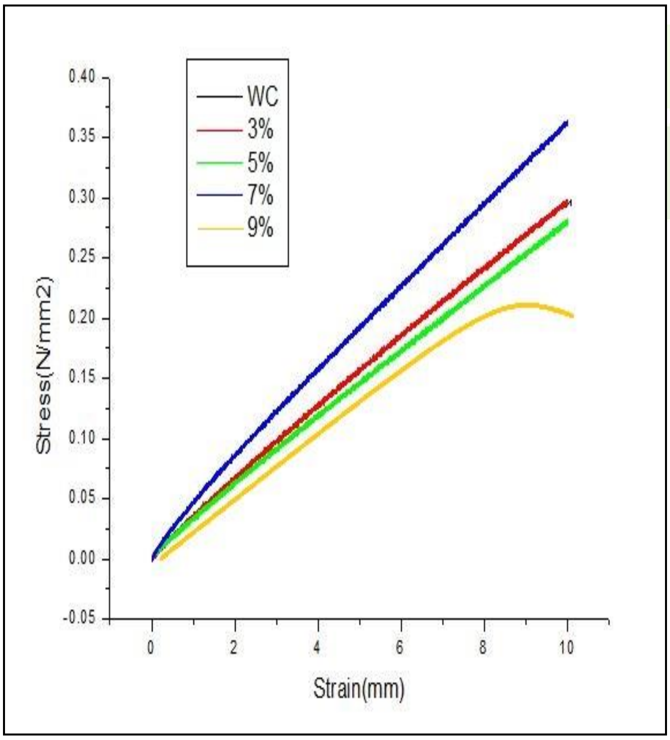


Fig. 6. Stress vs. Strain Graph of tensile testing

*3.1.3 Hardness Testing*

The resistance of the thin film against indentation is charaterized shore hardness. Shore scale is quantifying factor for hardness of the polymers. Among the scales avaolable to determine the scales available to polymers, Shore A is intensonally selected to characterize soft elastomer and rubbers. Scale D is used to quantify hardness of materials such as plastics. Durometer is an instrument used to calculate Shore D. The ASTM Standard for Durometer Hardness Test is ASTM D2240. Table V shows the values of Shore A and Shore D hardness of weight compositions of MWCNT WC, 3%, %5, 7%, 9%. Figure 3 shows the graph where it is seen that the shore hardness increases upto 7% wt composition and decreases then after.

TABLE V. SHORE HARDNESS TEST RESULTS

| Sl. No. | Composition | Shore D Hardness | Shore A Hardness |
|---|---|---|---|
| 1 | WC,A1 | 4 | 30 |
| 2 | SS+3wt%,A2 | 9 | 45 |
| 3 | SS+5wt%,A3 | 15 | 60 |
| 4 | SS+7wt%,A4 | 24 | 75 |
| 5 | SS+9wt%,A5 | 17 | 60 |

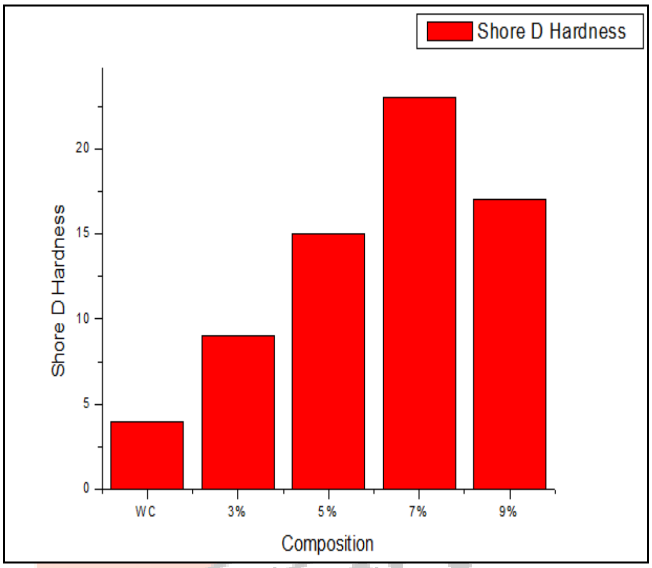


Fig. 7. Shore D Hardness test

*3.1.2 Morphological Characteristics*

Fourier Transform Infrared Spectroscopy was conducted on the selected samples (A2, A3, and A4) to study identifies organic materials in the matrix that might influence the mechanical properties under study.

## Fourier Transform Infrared Spectrography

Peaks in FTIR spectrum are used to realize the presence of elements. Perkin-Elmer model spectrum one instrument was empolyed to conduct FTIR. Membrane samples were converted to powder form before the testing. FTIR spectra of silicone sealant added MWCNTs were tested using a FT-IR spectrometer (Perkin-Elmer, model spectrum one. The FTIR spectra of silicone sealant was compared to 3 samples of MWCNT compositions 3%, 5%, 7%. FTIR spectra were obtained in a range of frequency from 4000 cm-1 to 400 cm-1. The peaks in the range of 2890cm-1 to 3200 cm-1 corresponds to O-H (intramolecular bonded) which presents in MWCNTs samples A2, A3, A4. Peaks in the range 1450 to 1500cm-1 corresponds to C-H bending (methyl group) present in the sample A2 and A4 and 1550 to 1600cm corresponds to N-H bending amine in sample A3. The range of frequency from 1250 to 1350 corresponds to C-N stretching in samples A2, A3, A4. The range from850cm to 950 cm corresponds to C=C ending alkene in samples A2, A3, A4.

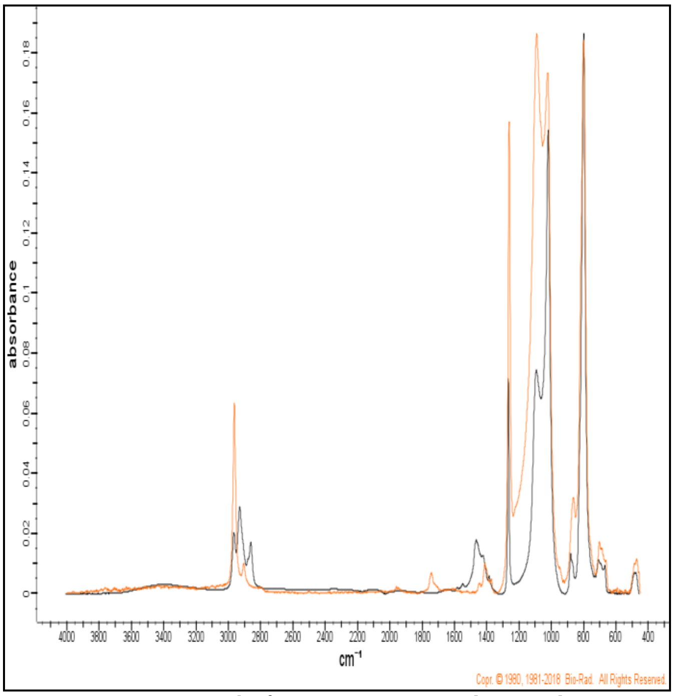


Fig. 8. FTIR graph of 3 wt.% MWCNT vs. silicone sealant

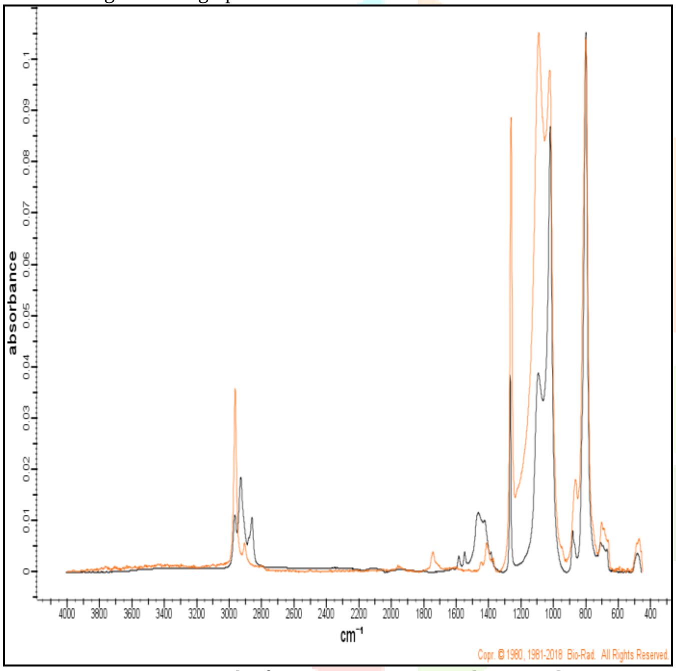


Fig. 9. FTIR graph of 5 wt.% MWCNT vs. silicone sealant

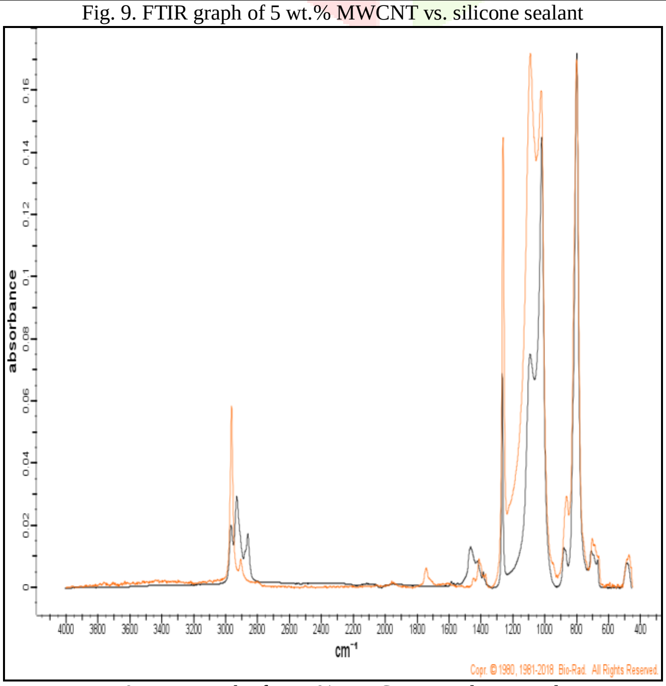


Fig.10. FTIR graph of 7 wt.% MWCNT vs. silicone sealant

## IV. Conclusion and Future Scope

In conclusion, it can be noted that CNT based thin film composed of silicone sealant is one of the best alternative for puncture resistant coating on rubber tire surface. Silicone inherently being a abrasive material its property is amplified by CNT's infusion. In terms of mechanical properties, tensile, hardness, slow rate penetration test of the modified thin film are explored. In order to realize the CNTs application to the maximum possible extent, some technical issues are yet to be addressed adherence of the CNTs to the rubber matrix by certain functionalization groups is yet to be realized. Sacrifice of flexibility of rubber by the addition of silicone and CNT is one of the critical issue which needs to addressed. The effect of CNTs on the rubber life of tire is also one of the important issue which needs to be addressed. The increase in the existing tire life because of slight modification by film coating is need of the hour for reducing carbon foot print on earth.

## *Acknowledgements*

This work is fully supported by KLE Technological University (Formerly known as B. V.Bhoomaraddi College of Engineering & Technology) under the "Research Experience for Undergraduates" grant Ref 2014-15 Sl. No 15 (PI Dr. N R Banapurmath & CO-PI Dr. Shankar A Hallad) all authors would like to thank KLE Society and KLE Technological University (BVBCET), Hubballi for providing funding and support.

## *References*

[1] Rosen BA, Laufer CN, Kalman DP, Wetzel ED, Wagner NJ. Multi-threat performance of kaolin-based shear thickening fluid (STF)-treated fabrics. Proceedings of SAMPE. 2007 Jun 3;3(7).

[2] Wagner NO, Wetzel E. Advanced body armor utilizing shear thickening fluids. In23rd Army science conference, Orlando, FL 2002 Dec 2 (Vol. 3).

[3] Varelidis PC, Papakostopoulos DG, Pandazis CI, Papaspyrides CD. Polyamide coated Kevlar™ fabric in epoxy resin: mechanical properties and moisture absorption studies. Composites Part A: Applied Science and Manufacturing. 2000 Jun 1;31(6):549-58.

[4] Bakar NA, Salleh J, Ahmad MR, Ahmad NA, Suhaimi SA. Puncture resistance of nanofilled coated high strength woven fabric. In2012 IEEE Symposium on Business, Engineering and Industrial Applications 2012 Sep 23 (pp. 477-480). IEEE.

[5] Liu Q, Spears DA, Liu Q. MAS NMR study of surface-modified calcined kaolin. Applied Clay Science. 2001 Jul 1;19(1-6):89-94.

[6] Amerio E, Fabbri P, Malucelli G, Messori M, Sangermano M, Taurino R. Scratch resistance of nano-silica reinforced acrylic coatings. Progress in Organic Coatings. 2008 Apr 1;62(2):129-33.

[7] Chattoraj S, Shi L, Sun CC. Profoundly improving flow properties of a cohesive cellulose powder by surface coating with nano-silica through comilling. Journal of pharmaceutical sciences. 2011 Nov 1;100(11):4943-52.

[8] Kolodziej M, Bokobza L, Bruneel JL. Investigations on natural rubber filled with multiwall carbon nanotubes. Composite interfaces. 2007 Jan 1;14(3):215-28.

[9] Atieh MA, Girun N, Ahmadun FL, Guan CT, Mahdi E, Baik DR. Multi-wall carbon nanotubes/natural rubber nanocomposite. AzoNano–Online Journal of Nanotechnology. 2005;1:1-1.

[10] Morka A, Jackowska B. Ballistic resistance of the carbon nanotube fibres reinforced composites–Numerical study. Computational Materials Science. 2011 Feb 1;50(4):1244-9.