

Contents

I.	Abstract	I
II.	List of Abbreviation	IV
III.	List of Symbols	VI
IV.	List of Figures	VIII
V.	List of Tables	XVI
1.	GENERAL INTRODUCTION	1
1.1.	Introduction	1
1.2.	Research Objectives	2
1.3.	Outline of Thesis	4
•	References	5
2.	LITERATURE SURVEY	6
2.1.	Introduction	6
2.2.	Tyre Tread Compounding and Properties	9
2.2.1.	Reinforcement of Rubber Compound	9
2.2.2.	Payne Effect of Rubber Compound	12
2.2.3.	Hysteresis and Rolling Resistance of Rubber Compounds	13
2.2.4.	Wet Traction Property of Tyre Tread	15
2.2.5.	Wear Resistance of Tyre tread Compounds	17
2.2.6.	Magic Triangle Properties of Tyre Tread	19
2.3.	Carbon Black and its Characteristics	21
2.3.1.	History of Carbon Black	21
2.3.2.	Basic Features of Carbon black	22
2.3.2.1.	Carbon Black Particle Size and Surface Area	22
2.3.2.2.	Carbon Black Structure	24

2.3.2.3.	Aggregate Size Distribution	26
2.3.2.4.	Surface Chemical Property of Carbon Black	29
2.4.	Carbon Black Development/ Modification for Tyre Tread Compound	30
2.5.	Research scopes.	34
•	References	35
3.	MATERIALS AND METHODS	41
3.1.	Raw Materials Used in the Studies.	41
3.1.1.	Carbon Black	42
3.1.2.	Rubbers	43
3.1.2.1.	Natural Rubbers (NR)	43
3.1.2.2.	Polybutadiene Rubber (PBR)	44
3.1.2.3.	Styrene Butadiene Rubber (SBR)	45
3.1.3.	Process Oil for Rubber Compounding	48
3.1.4.	Anti-Degradation Agents	49
3.1.5.	Micro-Crystalline Wax	50
3.1.6.	Stearic Acid	50
3.1.7.	Zinc Oxide	51
3.1.8.	N-cyclohexyl-2-benzothiazolesulfenamide (CBS)	51
3.1.9.	Sulphur	51
3.1.10.	Pre-vulcanization agent (PVI)	52
3.2.	Testing and Characterization of Carbon Black	52
3.2.1.	Nitrogen Surface Area	53
3.2.2.	Iodine Adsorption Number	53
3.2.3.	Measurement of Carbon Black Structure	54
3.2.4.	pH Testing	55
3.2.5.	Aggregate Size Distribution	55
3.3.	Carbon Black Modification	57
3.3.1.	Modification of Carbon Black During Manufacturing	58
3.3.2.	Ozone Treatment of Carbon Black	59
3.3.3.	Treatment of Carbon Black with BTEAC	59
3.4.	Rubber Compounding and Testing	60
3.4.1.	Mixing of Rubber Compound	60

3.4.2. Rubber Process Analyzer	61
3.4.3. Rheological Characteristics	61
3.4.4. Mooney Viscosity	63
3.4.5. Measurement of Bound Rubber Content	64
3.4.6. Compression Molding	64
3.4.7. Ultimate Tensile Strength Testing	65
3.4.8. Hardness	65
3.4.9. Abrasion Resistance Measurement	65
3.4.10. Dynamic Mechanical Analysis	66
3.4.11. Heat Buildup Measurement	66
3.5. Microscopic and Material Characterization of Carbon Black and Rubber Compounds	67
3.5.1. High Resolution Transmission Electron Microscopy (HRTEM) Analysis	67
3.5.1.1. Preparation of Carbon Black Sample	67
3.5.1.2. Preparation of rubber Compound Sample	67
3.5.2. Atomic Force Microscopy (AFM) study	68
3.5.3. X-Ray Diffraction (XRD) Analysis	68
3.5.4. Thermogravimetric Analysis (TGA)	69
3.5.5. CHNS-O Analysis	69
• References	70
4. MODIFICATION OF TYRE TREAD COMPOUND BY OPTIMIZED AGGREGATE SIZE AND AGGREGATE SIZE DISTRIBUTION OF CARBON BLACK	74
4.1. Study the Effect of Carbon Black Aggregate Size Distribution with Different FWHM Value on Tyre Tread Compounds	74
4.1.1. Carbon Black with Different Morphological Features	75
4.1.1.1. Carbon Black Parameters and Aggregate Size Distribution	75
4.1.1.2. High Resolution Transmission Electron Microscopy (HRTEM)	77
4.1.2. Performance of Rubber Compound with Tailored Carbon Black Fillers	79
4.1.2.1. Rubber Mixing and Compounding	79
4.1.2.2. Curing and Processing characteristics	80

4.1.2.3.	Effect of Aggregate Size Distribution on Payne Effect	80
4.1.2.4.	Hysteresis Energy Loss and Rolling Resistance	84
4.1.2.5.	Abrasion Resistance Property	86
4.1.2.6.	Tensile Properties	87
4.2.	Incorporation of Bigger Size Aggregates into Carbon Black Morphology and Investigate the Rubber Performance for Tyre Tread Compounds	88
4.2.1.	Design of Carbon black Morphology	90
4.2.2.	High Resolution Transmission Electron Microscopy	93
4.2.3.	Rubber Compound Properties	96
4.2.3.1.	Mixing and Testing	96
4.2.3.2.	Curing and Processing Characteristics	97
4.2.3.3.	Filler-Filler Network Formation	97
4.2.3.4.	Dynamical Properties of Rubber Compound	99
4.2.3.5.	Mechanical Properties of Rubber Compounds	101
4.3.	Conclusions	102
•	References	103
5.	CORRELATION OF CARBON BLACK PARAMETERS WITH RUBBER COMPOUND PROPERTIES FOR DEVELOPMENT OF IMPROVED TYRE TREAD COMPOUNDS	106
5.1.	Introduction	106
5.2.	Carbon Black Development	106
5.2.1.	Characteristics of Carbon Black	107
5.2.1.1.	Surface Area and Structure of Carbon Black	107
5.2.1.2.	Aggregate Size Distribution	108
5.2.1.3.	High Resolution Transmission Electron Microscopy and Structural Morphology	109
5.3.	Rubber Compound Properties and Their Relationship with Carbon Black Parameters	112
5.3.1.	Rubber Compounding and Mixing	112
5.3.2.	Processing and Curing Characteristics	112
5.3.3.	Payne Effect of Rubber Compound and its Relationship with Aggregate Size	113
5.3.4.	Heat Buildup in Rubber Compounds and Effect of Payne Effect	118
5.3.5.	Hysteresis Loss of Rubber Compound as Dependent on Aggregate Size Distribution	120

5.3.6. Abrasion Resistance Property and Structure Co-efficient Parameter	122
5.4. Conclusions	125
• References	127
6. SIMULTANEOUS CHANGES ON CARBON BLACK SURFACE AND STRUCTURAL MORPHOLOGY TO IMPROVE TYRE TREAD COMPOUNDS	129
6.1. Background	129
6.2. Ozone Treatment of Carbon Black and Characterize of Change in Surface Phenomena	131
6.2.1. Ozone Treatment Method of Carbon Black	131
6.2.2. Characterization of Carbon Black on Ozone Treatment	131
6.2.2.1. High Resolution Transmission Electron Microscopy (HRTEM) Analysis	131
6.2.2.2. X-Ray Diffraction (XRD) Analysis and Characterization	134
6.2.2.3. Thermogravimetric Analysis (TGA) and Study of Crystallinity	136
6.2.2.4. Changes in Carbon Black Properties on Ozone Treatment	137
6.2.2.5. Measurement of Volatile Matters Present in Carbon Black and pH of Carbon Black	138
6.3. Study the Effect of Ozone Treated Carbon Black in Rubber Compound Properties	140
6.3.1. Carbon black Properties	141
6.3.2. Rubber Compound Properties of Ozone Treated carbon Black	143
6.3.2.1. Rheological Properties of Rubber Compounds	144
6.3.2.2. Transmission Electron Microscopy (TEM) Analysis of Rubber Compounds	146
6.3.2.3. Rubber Process Analysis	148
6.3.2.4. Physical Properties	150
6.3.2.5. Dynamic Mechanical Analysis	153
6.3.2.6. Magic Triangle Properties for Tyre Tread Compounds	157
6.4. Conclusion	158
• References	160

7. IMPROVEMENT OF TYRE TREAD COMPOUNDS BY TREATMENT OF CARBON BLACK WITH BENZYL TRI-ETHYL AMMONIUM CHLORIDE (BTEAC)	163
7.1. Introduction	163
7.2. Carbon Black Functionalization with Benzyl Tri Ethyl Ammonium Chloride (BTEAC) and its Properties.	164
7.2.1. Treatment of Carbon Black by BTEAC Treatment	164
7.2.2. Carbon Black Properties on BTEAC Treatment	165
7.2.3. Thermogravimetric Analysis (TGA) of Carbon Black to Estimate Functionalization	167
7.2.4. High Resolution Transmission Electron Microscopy (HRTEM) Analysis	168
7.3. Study the Effect BTEAC Treated Carbon Black in Rubber Compound Properties for Tyre Tread Application	170
7.3.1. Rubber Compounding	170
7.3.2. Curing Characteristics	171
7.3.3. Dispersion Analysis by Atomic Force Microscopy	173
7.3.4. Bound Rubber Content	175
7.3.5. Rubber Process Analysis and Payne Effect	176
7.3.6. Dynamic Mechanical Analysis	178
7.3.7. Physical Property	182
7.4. Effect of Loading and Optimization Rubber Compound Properties for Tyre Tread Compounds.	183
7.4.1. Rubber Compounding	184
7.4.2. Rubber Process Analyzer	184
7.4.3. Mechanical Properties	187
7.4.4. Effect of Filler Loading on Rolling Resistance and Wet Tract Property of Tyre Tread Compound	188
7.4.5. Magic Triangle Properties	190
7.4.6. Conclusion	193
• References	195

8. CONCLUSION	198
8.1. Introduction	198
8.2. Modification of Tyre Tread Compound by Optimized Aggregate Size and Aggregate Size Distribution of Carbon Black	199
8.3. Correlation of Carbon Black Parameters with Rubber Compound Properties for Development of Improved Tyre Tread Compounds	200
8.4. Simultaneous Changes on Carbon Black Surface and Structural Morphology to Improve Tyre Tread Compounds	201
8.5. Improvement of Tyre Tread Compounds by Treatment of Carbon Black with Benzyl Tri-Ethyl Ammonium Chloride (BTEAC)	202
8.6. Future Scope	204
LIST OF PUBLICATIONS	206