CHAPTER-1
GENERAL INTRODUCTION

1.1. Introduction

The automotive industry is undergoing a technological change from fossil fuel driven vehicles to electric vehicles, especially in the passenger car segments. The prime motive for this revolution is to combat air pollution caused by fossil fuel engine' emissions due to burning of the same. To minimize the air pollution different nations raised different regulations [1].

The US Govt. through its numerous agencies on environmental traffic safety etc has promulgated a National Programme, known as California's Advanced Clean Car program—as the National Program [2]. Climate action tracker (CAT) projected US to produce greenhouse gas emission of 28-32% below 2005 level by 2030 because of the various initiatives adopted. The European Union's rule imposed in 2007, for passenger car, as fleet average of 158.7 grams of CO_2 per kilometer. Later they set 2015 and 2021 targets represent reductions of 18% and 40% respectively compared with that of the 2007 [3]. India has committed to cutting its greenhouse gas (GHG) emissions intensity by 33% to 35% percent below 2005 levels by 2030 [4]. Thus, reductions of CO_2 emission i.e., the reduction of green gases has become a major motto for automotive industry, and which enforce vehicle manufacturers to control the fuel consumption by the vehicles. Fuel consumed by vehicles is due to drivetrain losses, tyre rolling resistance, aerodynamic drag, braking energy, accessories etc.

Tyres provide a significant contribution to fuel consumption of vehicles due to the rolling resistance, which arises primarily from the viscoelastic rubber materials used in tyres, and the major contribution of tyre rolling resistance arises from tyre tread. A reduction of rolling resistance benefits in the fuel economy of vehicles and it is seen a reduction of 20-30% rolling resistance benefits up to 6% reduction of fuel consumption [5]. Thus, tyre with low rolling resistance is highly essential for the modern transport industry. New generation electric vehicles result high torque on tyre to start the vehicles and causing high heat generation and high wear of tyre. Hence, along with rolling resistance, the durability of tyre, low heat buildup, high wet traction and high stiffness of rubber compounds are also essential for the tyre tread application [6].

To focus on improvement of tyre durability, the abrasion resistance and the heat buildup properties of tyre play crucial role. As tyre gets more wear due to friction with road causing reduced tread depth, which leads to rapid scrape of the tyres. During operation, tyre is in continuous cyclic deformation and thus, continuous heat is generated in the tyre during operation, which boost the degradation of rubber molecules and leads to deterioration of tyre strength, cracking of tyre surface, increase of tyre wear and many other adverse characteristics of tyre , that finally lead to scrape of the tyres [7].

Tyre is a composite material consisting of rubber as base materials and different compounding ingredients, fillers, fabrics etc. Characteristics of rubbers, fillers and other compounding ingredients contribute on rolling resistance, heat buildup, mechanical strength as well abrasion resistance performance of tyre. However, rubber and fillers are the major contributors towards the performance of the same. Extensive studies have been carried out on development of rubbers, fillers such as carbon black, silica, nano particles etc are used to optimize different performance properties of tyre compounds [8].

Carbon black is the most common reinforcing filler used in tyre compounds which provides strength, increase abrasion resistance property, increase the stiffness of rubber compound, however, carbon black also results in filler-filler interaction, heat buildup, hysteresis energy loss in the rubber compound. The hysteresis energy loss is increased in filled rubber compounds because of filler-filler interaction, inadequate filler dispersion in rubber matrix etc. which causes high rolling resistance in tyre applications. Heat buildup in rubber compound during service accelerates the degradation of rubber molecules and attributed to less durability of tyres. Hence carbon black with optimum rolling resistance, heat buildup, filler-filler interaction, abrasion resistance, mechanical strength is recommended for tyre tread applications [9].

1.2. Research Objectives

The objective of this research work is to improve of tyre tread compound performance by modifying carbon black characteristics. One of basic sources of hysteresis loss in carbon black filled rubber compound is breakdown of carbon black filler-filler network in the rubber matrix. Carbon black with reduced filler interaction, has less propensity of filler-filler network formation and has lesser scope of hysteresis energy loss due to cyclic deformation of tyres during service. In this investigation attempts have been made to reduce the hysteresis energy loss of tyre tread compound by development of new carbon black with engineered morphology using the furnace process of manufacturing and modifying commercially available carbon black by suitable methods. To develop and modify carbon black with enhanced tyre tread property the mechanism of filler-filler interaction, hysteresis energy loss, abrasion resistance, heat buildup, mechanical strength, other dynamical and rheological characteristics of rubber compounds have been studied.

Carbon black with different particle size, surface area, structure, aggregate size, aggregate size distribution has different effects in tyre tread compounds. The filler-filler interaction, hysteresis energy loss of rubber compound on inter-aggregate distance of carbon black aggregates in rubber matrix is an important aspect of this study. The study focuses on the effect of aggregate size distribution, aggregate size and presence of different size of aggregates size on above said properties is another important objective of the study.

Carbon black with improved dispersion and distribution in rubber matrix would limit the flocculation of carbon black aggregates and consequently lower the possibility carbon black network formation. Carbon black with improved affinity towards rubber molecules through chemical interaction as well as physical interaction would lead to increase filler polymer interaction, reduce filler-filler interaction as a result improve filler dispersion and improved rubber performance could be possible in rubber matrix. Carbon black with different crystallinity and surface functionality has different levels of reinforcement with different types of rubber molecules with different chemical nature. Hence the modification of surface morphology and surface chemistry of carbon black are the extended scope of this study. In this work carbon black surface crystallinity as well as surface chemistry were modified and the effect of the same on tyre tread compound properties was studied

1.3. Outline of the Thesis

In the present research major focus is given to carbon black morphological characteristics including carbon black surface crystallinity, surface functional groups, structure, particle size, aggregate size and aggregate size distribution patterns and their corresponding influences in the rubber compounds, suitable for tyre tread application. The thesis is presented in 8 Chapters. **Chapter-1:** General Introduction, that deliberates on the scope of the srudy. **Chapter-2** is Literature survey which covers the carbon black history, properties, applications, carbon black development carried out for tyre applications particularly for tyre tread application. In **Chapter-3** different types of materials, different testing methods and characterization techniques have been discussed, in this chapter the modification and development of carbon black have been discussed. The major research on carbon black development and carbon black modifications are discussed from **Chapter-4** to **Chapter-7**, which are briefly outline below.

Chapter-4: Modification of tyre tread compound by optimized aggregate size and aggregate size distribution of carbon black: In this part of the research, the concept of carbon black structural units such as aggregates are discussed. It demonstrates the carbon black aggregate size, the pattern of aggregate size distribution and the effect of the same on rubber compound performance are detailed for tyre tread application.

Chapter-5: Correlation of carbon black parameters with rubber compound properties for development of improved tyre tread compounds: Carbon black is characterized with aggregate, structure, surface area, particle size etc and each parameter has significant effect on rubber compound properties. In this chapter rubber compound properties are correlated with different carbon black parameters. The correlations were analysed statistically and interpreted by R-square value, and based on the same, the scope of carbon black development for tyre tread compound are drawn.

Chapter-6: Simultaneous changes on carbon black surface and structural morphology to improve tyre tread compounds: Carbon black surface and structural morphology has been modified by Ozone treatment. In this chapter the morphology changed due to ozone treatment characterized by TEM, XRD and the effect of ozone treated carbon black were studied in rubber compound for tyre tread application.

Chapter-7: Improvement of tyre tread compounds by treatment of carbon black with benzyl tri-ethyl ammonium chloride (BTEAC):: In this chapter the attempt has been made to modify surface characteristics of carbon black by chemical treatment. The effect of chemically modified carbon black has been studied for the lowering of rolling resistance property as well as to optimize magic triangle properties of tyre tread compounds.

In **Chapter-8**: **Conclusions and Summary:** overall conclusions and summary of the research have been discussed and the scope of further carbon black development have been outlined for future research on tyre tread compound improvement.

- ***References***:

1. *Xiaosong Z et al, A review of greenhouse gas emission profiles, dynamics, and climate change mitigation efforts across the key climate change players, Journal of Cleaner Production (2019), 234, 1113.*
2. *Jeff Houk, Joey Huang, and Eric Sussman (Sonoma Technology), benefits of adopting California's Advanced Clean Cars II Standard in Sixteen US States, The International Council on Clean Transportation, May 24, 2023.*
3. *European Union Regulation No. 1222/2009 of the European Parliament and of the Council of 25 November 2009 on the Labelling of Tyres with Respect to Fuel Efficiency and Other Essential Parameters. Official Journal of the European Union (2009).*
4. *Climate Transparency Report 2020 INDIA.*
5. *Michelin, The Tyre Rolling Resistance and Fuel Savings, Societe de Technologie Michelin (2003).*
6. *Zhang P, Morris M, Doshi D, Materials Development for Lowering Rolling Resistance of tires, Rubber Chemistry and Technology (2016), 89, 79.*
7. *Suastawa W, Sukadana IBP, Analysis of the Effect of Temperature on Tire's Durability on Engkel Truck Vehicle. Logic : Jurnal Rancang Bangun dan Teknologi (2009), 19, 20.*
8. *Donnet JB, (Ed.). Carbon Black: Science and Technology, Second Edition (2nd ed.). Routledge, (1993).*
9. *NIIR Board of Consultants and Engineers, The Complete Book on Rubber Processing and Compounding Technology, Asia Pacific Business Press Inc (2006)*