# ABSTRACT

The aim of the thesis is to improve tyre tread compound by modifying carbon black characteristics which is most widely used in tyre industry. Carbon black characteristics are referred to its particle size, surface area, structure, aggregate size and aggregate shape, aggregate size distribution, surface crystallinity and amorphous, surface porosity, surface chemical nature etc. Carbon black particles are fused together to form aggregates during the manufacturing process, which are the primary and discrete structural units of carbon black. The aggregate size and the aggregate size distribution of carbon black affects rubber compound properties in myriad ways. In this study different carbon black grades with engineered morphology have been developed in furnace process of manufacturing which are characterized with different morphological parameters and the same has been achieved by controlling manufacturing conditions of the corresponding carbon black.

Full width half medium (FWHM) is a potential measure of aggregate size distribution of carbon black which indicates the pattern of aggregate size distribution and carbon black characterized with high FWHM value indicates its broad aggregate size distribution. A carbon black with broad aggregate size distribution results in a low rolling resistance property for tyre tread compound and carbon black with narrow aggregate size distribution provides enhanced mechanical strength in the tyre tread compound. When carbon blacks are characterized with similar FWHM value, the effect of aggregate size distribution was characterized by differential volume distribution (dV/dD) value in the aggregate size distribution. Differential volume distribution (dV/dD) of the aggregate size distribution is indicative of the extent of corresponding size aggregate present in the system. Hence, larger dV/dD value for a particular aggregate size indicates the highest extent of same size aggregates present in the system. In this study differential volume distribution value at 150 nm aggregate size was considered for N330 grade carbon black and was denoted by $(dV/dD)_{150}$. It has been seen, the experimental carbon black characterized with large value of $(dV/dD)_{150}$ with respect to control carbon black N330 provides reduced filler-filler interaction, reduced rolling resistance and reduced heat buildup property.

The carbon black is further characterized by presence of smaller size aggregates in the system and in this study which was characterized by $d_{10}$ value. The $d_{10}$ value of a carbon black is defined as the limit of the aggregate size, which occupy '10%' of total aggregate volume in the

carbon black, hence carbon black with lower $d_{10}$ indicates presence of larger extent of smaller size aggregate compared to the carbon black characterized with comparatively larger $d_{10}$ value. The $d_{10}$ value of carbon black was corelated with Payne effect of the rubber compounds. A linear relationship is observed between Payne effect of rubber compounds with $d_{10}$ value of corresponding carbon black with a negative slope of the plot, which indicates carbon black with lower $d_{10}$ value results in high Payne effect in rubber compound due to generation of larger filler-filler interaction. The lower $d_{10}$ value further increases the heat buildup in tyre tread compound due to generation of high filler-filler interaction in the rubber compound.

The hysteresis loss of the carbon black filled rubber compound was explained by a novel aggregate size distribution co-efficient (A) parameter which is defined in terms of broadness of aggregate size distribution (FWHM) and mean size of the aggregates. It has been seen that hysteresis loss of rubber compound is decreased with increasing value of 'A', that demonstrates carbon black with combined properties of broader aggregate size distribution and higher mean value leads to lower hysteresis loss of rubber compounds. A 'structure co-efficient parameter ($\hat{S}$)' of carbon black has been introduced and it is seen that carbon black with high 'structure co-efficient parameter value leads to superior abrasion resistance property for tyre tread compound.

Carbon black modification was further carried out by ozone treatment and treatment with benzyl tri ethyl ammonium chloride (BTEAC). Ozone treatment of carbon black affects on carbon black surface morphological characteristics in such a way that it distorts the crystalline arrangement and increases the amorphous characteristics, it further generates surface porosity which causes increase of NSA/ STSA ratio, where NSA represents total nitrogen surface area of carbon black and STSA represents statistical thickness surface area of carbon black. Ozone treatment further generates substantial oxygen containing functional groups on carbon black surface which reduces the pH of carbon black. The effect of ozone treated carbon black was studied in SBR1712-BR based rubber compound as well as SSBR-BR based rubber compounds. It is seen that ozone treated carbon black provides low rolling resistance property in tyre tread compound based on SBR1712-BR as well as SSBR-BR rubber system. It is observed that due to presence of living polar groups in SSBR molecules, SSBR-BR system provides superior performance in rolling resistance reduction compared to SBR1712-BR rubber system. Ozone treatment caused increased surface porosity, high amorphous behavior, and high surface functional groups which benefits in rubber reinforcement with enhanced filler dispersion, and results in enhanced mechanical strength, high storage modulus and superior wear resistance properties in new generation tyre tread compound system based on SSBR-BR.

On treatment of carbon black with BTEAC the morphological nature and aggregate size distribution of carbon black remain intact. The effect of BTEAC treated carbon black was studied on SBR1712-BR as well as SSBR-BR compound. It is seen treatment of carbon black with BTEAC the dispersion and distribution of carbon black in rubber matrix was improved as characterized by atomic force microscopic study. The treatment of carbon black with BTEAC further increases the affinity of carbon black with rubber molecules as result it provides lower filler-filler interaction in rubber matrix and consequently provides reduced Payne effect in rubber compounds. BTEAC treated carbon black reduces hysteresis energy significantly in both the rubber system, which was measured at 60ºC. Hence treatment of carbon black with BTEAC leads to low rolling resistance for tyre tread compound and the same affects more prominently with SSBR-BR based rubber system. Treatment of BTEAC on carbon black can take advantage of incorporation high filler loading in rubber compound. The increased filler loading in rubber compound leads to increased modulus, increased compound stiffness, increased abrasion resistance and increased wet traction property. It has been seen that, incorporation of 5 phr higher BTEAC treated carbon black loading can be considered as preferred selection for electric vehicle tyre tread compound where reduced rolling resistance, enhanced abrasion resistance and high compound stiffness are recommended.