CHAPTER I

INTRODUCTION

At present, carbon black is widely used as a reinforcing and coloring agent in rubbers, inks, paints, plastics, paper, protective coatings, and electrically conductive applications. However, due to rapid industrial growth, demands of material improvement concerning carbon black additives that satisfy increasingly stringent requirements, such as higher strength, modulus, thermal properties and low electrical conductivity, heat distortion temperature, and cost reduction has extended accordingly. In order to achieve these requirements the application of carbon black has to be dictated to qualify for certain properties.

It is important to know the carbon black properties, especially its dispersion behavior to achieve the maximum mechanical, optical and electrical properties induced by the carbon black filler. Therefore considerable research work has been focused on the carbon black dispersion behavior. It is very important to understand the role expected of carbon black on the overall practical applications.

Many special grades of carbon black are available as powders or beads as well as pellets. The selection of a carbon black depends on the application as well as the compounding process, and the techniques that will be used for incorporation of the carbon black. Each grade of carbon black must therefore be matched to its particular field of requirements regarding the quality and the uniformity of the product. The benefits of using carbon black can be negated if the wrong selection of carbon black type, grade, and quality are made.

While no attempt has been made to model the incorporation process, some attention has been given to dispersive mixing. McKelvey (1962) considered a system of two particle agglomerates suspended in a viscous liquid under shear. His equation predicts that some minimum force must be exceeded before agglomerates break. Additionally, only agglomerates oriented properly to the direction of force will be broken: the flow pattern must be such that orientation of agglomerate is continuously changing. The ease of dispersion is proportional to the size of individual particle.

Tadmor et al. (1976) presented that agglomerates form dissimilar particles in shear and elongation flow fields. In a subsequent paper [Manas-Zloczower et al. (1982)], Manas-Zloczower, Nir, and Tadmor attempted to fit their model to the actual mixing of rubber compounds in an internal mixer, assuming that dispersive mixing is dominated by the agglomerate rupture in a narrow gap, high shear field. Tadmor's analysis predicts that the rate of agglomerate rupture is independent of agglomerate size, but rather depends on the size of aggregate.

The effect of mixing time on the development of the physical properties of rubber containing carbon black has been studied by Boonstra and Medalia (1963). Microscopic examination of compounds mixed for very short times led them to conclude that during the incorporation stage, rubber penetrates into the voids between carbon black aggregates. The increase in viscosity during the incorporation stage is due to increasing filler volume: however, Boonstra and Medalia suggest that the total filled volume should include not only the filler but also rubber that is occluded within the agglomerates. During the dispersive stage of mixing, these agglomerates are broken down, the amount of occluded rubber decreases, and thus the filled volume decreases, leading to lower viscosity. Dizon et.al.[Cotten (1975) and Dizon (1976)] suggested that bound rubber increases the rate of dispersive mixing by increasing the effective radii of individual aggregate. They argued that the larger effective radii led to higher stresses during mixing and thus higher power consumption. Thus, Dizon recommends the use of the power curve (i.e., plot of torque versus mixing time) as a measure of rubber-filler interaction.

Cotten (1975), studied mixing of carbon black with rubber and determined the dispersion rate by changes in mixing torque. The incorporation process is the wetting of carbon black with rubber and displacement of entrapped air. Microscopic examination of carbon black filled rubber compounds at the early stages of mixing shows that, as carbon black becomes incorporated, it forms relatively large agglomerates (10-100 μm). During the subsequent dispersive mixing stage, these agglomerates are broken down to a size less than 1 μm. The final dispersion of carbon black depends not only on the specific characteristics of carbon black, but also on the mixing conditions (time, temperature, severity) and characteristics of the rubber.

Manas-Zloczower et.al. (1994) studied carbon black agglomerate dispersion in simple shear flows and found two different breakup mechanisms denoted as rupture and erosion. The dispersion process depends directly on the structure and morphology of the carbon black aggregate, the geometry and intensity of the applied flow field, and the packing and cohesive strength of the carbon black clusters used.

Matrix incorporated within the agglomerate can alter agglomerate structure and consequently influence the dispersion process. Previous studies of PDMS (Polydimethyl siloxane) infiltration into silica agglomerates and its influence on dispersion mechanism [Bohil et al. (1994)] have revealed that matrix filled agglomerates are more resistant to dispersion than the dry clusters. This result comes about because of the strong interactions between the PDMS chains and the silica surface.

Polypropylene (PP) is one of the lowest density polymers (0.90 g/cm^3) and is extremely versatile because of it excellent processability, mechanical and physical properties and high heat distortion resistance. Therefore, PP is one of several commodity plastics which are used for adding filler/reinforcement. One of the most important polymers for the study of carbon black dispersion is PP.

This work was concerned with the incorporation of carbon black into PP and its dispersion behavior. This study focused on the agglomerate dispersion behavior of high structure carbon black, low structure carbon black, their blends (high and low structure carbon black) and the processing history of the carbon black agglomerate as they affect the dispersion process.