CHAPTER I

INTRODUCTION

Short fibres, especially fibre glass have found a variety of applications in plastics because of the ease of mixing and subsequent processing advantages. Use of continuous cord reinforcement is well known in many industrial applications e.g., tires, V-belts, hoses, gaskets, oil seals, aerospace applications etc. The extent to which a discontinuous fibre can approach the performance of a continuous cord, depends critically upon its modulus relative to that of the matrix. Design of a short fibre-rubber composite depends on several factors : preservation of high aspect ratio (average length to diameter ratio of the fibre), control of fibre orientation, generation of a strong fibre-rubber interface, establishment of a high state of dispersion and optimal formulation of the rubber compound itself to accomodate processing and facilitate stress transfer. Moreover, short fibres provide high green strength, high dimensional stability during fabrication, improved creep resistance, good ageing resistance, damping, improved tear and impact strengths and anisotropy in mechanical properties. The manufacture of complex shaped engineering articles is impractical from elastomers reinforced with continuous fibres but is easily accomplished with short fibres. Short fibres can also be incorporated directly into the rubber compound along with other additives, and the compounds are amenable to the conventional standard rubber processing operations such as extrusion, calendering and compression, injection or transfer mouldings. Economic advantages are thus readily apparent since dipping, wrapping, laying and placing of the fibres generally associated with continuous cord reinforcement are avoided.

The term 'short fibre' means that the fibres in the composites have a critical length which is neither too high to allow individual fibres to entangle with each other, nor too low for the fibres to lose their fibrous characteristics. The term 'composite' signifies that the two main constituents i.e., the short fibres and the rubber matrix remain recognizable in the designed material.

In the following pages an attempt has been made to review most of the common aspects of short fibre reinforced rubber composites viz., component materials, preparation of the composites, rheological behaviour, fibre orientation, fibre dispersion and the mechanism of fibre-matrix adhesion, technical aspects, failure mechanism and uses of the composite materials.

I.1 COMPONENT MATERIALS

I.1.1 Types of fibre reinforcement : The degree of short fibre reinforcement of an elastomeric matrix is governed largely by the following characteristic properties of the short fibre : (a) its aspect ratio, (b) its adhesion to the matrix, (c) its dispersion in the matrix, and (d) its processibility and flexibility (which ensures minimum fibre breakage). Several authors [1-4] have suggested that an aspect ratio in the range of 100 - 200 is essential for high performance fibre-rubber composite. On the other hand, Chakraborty et al. [5] have observed that an aspect ratio of 12 gives optimum reinforcement in the case of jute fibre-carboxylated nitrile rubber (XNBR), while Murty and De [6,7] have reported that an aspect ratio of 15 in the case of short jute fibre-natural rubber (NR) system and 32 in the case of short jute fibre-styrene-butadiene rubber (SBR) system are sufficient for good reinforcement of the composites. The following types of fibres have been used for short fibre reinforcement.

I.1.1.1 Glass fibres : In view of their high potential as reinforcing agents for plastics, the suitability of glass fibres as reinforcing material for rubber has been extensively investigated [8]. Although a high initial aspect ratio can be obtained with glass fibres, their brittleness causes breakage of the fibres during processing. Czarnecki and White [9] have reported the mechanism of glass fibre breakage and severity of breakage with time of mixing. They have observed that not only the fibre length but also the distribution of fibre length changes with the time of mixing. Many investigators have considered short glass fibres for reinforcing rubbers because of their high modulus, high resilience and low creep [10-12]. Murty and De have studied the extent of fibre-matrix adhesion and physical properties of short glass fibre reinforced NR [13] and SBR [7] composites. The advantages of using small diameter fibre glass in SBR and nitrile (NBR) rubbers have been patented by Heitmann [14]. Manceau [15] has reported that glass fibres have a markedly lower reinforcing capability than cellulose fibres but can undergo higher elongation. In a patent [16] to PPG Industries Inc., it was reported that pre-impregnated glass fibres gave better reinforcement to rubber.

I.1.1.2 Cellulose fibres : The earliest references pertaining to the use of finely divided wood cellulose (Solkafloc) in rubber involve the work of Goodloe et al. [17,18]. They reported that compounding Solkafloc into rubber reduced the tendency of the rubber to shrink, killed the nerve, acted as a processing aid and also gave better economy without compromising the quality of the product. However, a high degree of strength reinforcement was unattainable because of the poor bonding between the fibre and the matrix in the composites [19]. Bonded composites of discontinuous cellulose fibres and vulcanizable elastomers having modulus and strength sufficiently high for use as replacement for composites from continuous fibre have been suggested by Boustany and Coran [4]. Two major advantages associated with short cellulose fibre reinforcement are its resistance to breakage during mixing and its rough surface which allows good fibre-rubber adhesion. Anthoine et al. [20] and Coran and Hamed [21] have reviewed the reinforcement of elastomers with discontinuous cellulose fibres while Goettler and Shen [22] have discussed the properties of different types of cellulose fibres and their mechanism of reinforcement. Various applications and the technical details of Santoweb[R] fibre reinforcement of rubber are given in technical reports of Monsanto Co. [23,24]. Rahman and Hepburn [25] have reported the technical advantages of using Santoweb H[R] fibres in oil-extended EPDM rubbers. They used a contour graph technique to assess the optimum amount of ingredients that need to be added for maximum physical properties. Young's modulus in extension was determined and correlated with a theoretical equation. For both fixed and variable strain test, fatigue life is improved upto the addition of 10 phr of the fibre, beyond which the fatigue life deteriorates. Solvent-swelling decreases with increasing fibre concen-