Role of fly ash particles from power station as a filler in rubbers

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Abstract: Ash residues are wastes of coal-fired power plants, which are generally classified into two main categories, namely, fly ash (FA) and bottom ash (BA). This has made FA relatively inexpensive, and its usages have the benefit of decreasing environmental problems. Since FA particles consist of silicon dioxide similar to precipitated silica (PSi) but with lower silicon dioxide (SiO_2) content, FA could function as either semi-reinforcing filler or extender (diluent), depending on FA loadings and polymeric systems. This research aims to investigate the role of FA on properties of rubbers with different polarity, namely, natural rubber (NR), nitrile rubber (NBR) and their blends. Cure behaviour, viscoelastic properties and mechanical properties were monitored. Results revealed that FA provided cure promotion phenomenon in NR compounds which was attributed to the presence of metal oxide probably acting as cure activator. Regarding viscoelastic properties, it has been found that addition of FA to NR increased elastic modulus and shear viscosity under both oscillatory and steady shear flows. Moreover, the oscillatory test results exhibited the unexpected increase in magnitude of viscous response with increasing FA loading in FA filled NR compounds. The explanation was proposed in terms of a ball-bearing effect provided by FA particles with spherical shape associated with the occurrence of molecular degradation induced by inorganic constituents particularly manganese, iron and copper in non-rubber component of NR as well as the small amount of heavy metals including iron, copper in FA. In addition, the storage softening phenomenon of uncured NR compounds highly filled with FA was observed which could be suppressed by the incorporation of amine-based antioxidant (6-PPD). The magnitudes of viscous response promotion and storage softening phenomenon were smaller in the case of NBR compounds. Tensile properties of silane-treated FA filled vulcanisates were found to be improved in a similar fashion to the PSi filled ones as filler loading increased up to 30 phr. Dynamic mechanical behaviour including resilience as well as compression set of vulcanisates filled with FA appeared to be superior to those filled with carbon black and PSi at a given filler loading. Evidently, results obtained suggested that it was possible to add value of wastes of coal-fired power plants, FA, by partly substituting PSi in rubber products. By this means, rubber products filled with silane-treated FA possessing good dynamic mechanical properties with comparable tensile properties could be prepared with lowered product costs.

Keywords: Fly ash, Natural rubber, Nitrile rubber, Blends, Cure behaviour, Viscoelastic properties, Mechanical properties

1. INTRODUCTION

Fillers are added to rubber for a variety of purposes, of which the most important are enhancements in reinforcement, processability and material costs [1]. Typically, fillers used in rubber industry are classified into reinforcing and non-reinforcing fillers. In some cases, fillers are divided into black and non-black types. There are basically two categories of reinforcing fillers - carbon black and mineral or 'white' fillers such as fumed and precipitated silica [2]. In rubber industry, due to its fine particle size (high specific surface area), such silica is widely used as non-black reinforcing filler to improve mechanical properties of vulcanisates, particularly hardness and resistances to tension, tear and abrasion. Although silica is still well accepted among rubber technologists, the use of some other fillers from the natural resources as alternative reinforcing fillers in NR has been carried out to replace silica in rubber compounds [3]. Such fillers include clay, lignin, black rice husk ash (BRHA) and white rice husk ash (WRHA), and cellulose fiber.

Ash residues are wastes of coal-fired power plants; these include fly ash (FA) and bottom ash [4,5]. FA is a relatively inexpensive by-product, and its usages have the benefit of decreasing environmental problems. Furthermore, FA has been used in industry as a consequence of such advantages as low cost, smooth spherical surface and good processability of the filled materials [6]. In previous study [3, 7-12], it has been reported that FA particles consist of silicon dioxide similar to silica but with the lower content of silicon dioxide than silica. Consequently, the addition of FA to rubber compounds is able to enhance rubber properties similar to that of commercial silica, but with the smaller magnitude.

The present work aims to investigate the role of FA on properties of rubbers with different polarity, namely, natural rubber (NR), nitrile rubber (NBR) and their blends. Cure behaviour, viscoelastic properties and mechanical properties were monitored.

2. METHODOLOGY

2.1 Materials

Natural rubber (NR, STR20), supplied by Union Rubber Products Co., Ltd. (Bangkok, Thailand), and Nitrile rubber (NBR) with bound acrylonitrile content of 33.5 and 35% were supplied by Zeon Advanced Polymix Co., Ltd. (Bangkok, Thailand). HAF carbon black (N330) was purchased from Thai Carbon Black Public Co. Ltd, (Bangkok, Thailand). Silica either from fly-ash particles (designated as FASi) or commercial precipitated silica (designated as PSi) were also used as fillers. The fly ash (FA) particles were supplied by Mae Moh Power Station of KNR Group Co., Ltd. (Lampang, Thailand). The characteristics (dimensions, average particle size, shape and surface area, density and pH) of the fly ash particles can be found in previous work. Our previous results [14 pod] suggested that the major component of FA was SiO_2