TIME-DEPENDENT MECHANICAL PROPERTIES OF ELASTOMERIC
BLOCK POLYMERS IN LARGE TENSILE DEFORMATIONS

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ABSTRACT

Consideration is given to the stress-strain and ultimate tensile properties of an unplasticized and a plasticized styrene-butadiene-styrene triblock polymer at temperatures from -40 to 60°C. It is concluded that the time dependence of their mechanical properties and also their high tensile strengths result from energy dissipation associated with the plastic deformation, and eventual disruption, of the colloidal polystyrene domains. A similar mechanism is undoubtedly responsible for the high strength of segmented diisocyanate-linked (polyurethane) elastomers and also styrene-butadiene rubber vulcanizates filled with colloidal polystyrene spheres. It is further concluded that a non-crystallizable elastomer will exhibit high strength provided it contains about 25% of colloidal plastic particles, uniformly dispersed. For optimum reinforcement, the particles should deform plastically to dissipate stored elastic energy, thus relieving unfavorable stress concentrations in the vicinity of slowly growing, or incipient, cracks.

INTRODUCTION

All polymeric materials that exhibit high strength and toughness contain a dispersed phase. For example, the toughest plastics and fibers are semicrystalline; rubber is dispersed in polystyrene to impart toughness; and reinforcing fillers are ordinarily incorporated in non-crystallizable elastomers because, without filler, they are weak except under special test conditions (1).
Recently, considerable interest has developed in thermoplastic elastomers, exemplified by styrene-butadiene-styrene (SBS) triblock polymers. When the styrene content is about 25% and the molecular weight of the polymer is not unduly low, the material is an exceptionally strong and tough elastomer, consisting of a rubbery polybutadiene matrix in which aggregates (domains) of polystyrene chains are dispersed. By anchoring the ends of the triblock molecules, the colloidal domains impart a permanent three-dimensional structure, hence preventing viscous flow below the softening temperature of the domains. In addition, the domains function as nonrigid filler particles, and chain entanglements in the polybutadiene phase assume the role of network junction points.

Like the triblock polymers, segmented diisocyanate-linked (polyurethane) elastomers, which are alternating block polymers, exhibit high strength. Such polymers are ordinarily not crosslinked by primary valence bonds but contain plastic domains formed from the so-called hard segments. Other elastomeric materials whose toughness results from dispersed domains are the silicone-polycarbonate block copolymers and the ionomers, the latter being copolymers of α-olefins and carboxylic acids in combination with mono- or divalent cations.

In this paper, the manner in which plastic domains affect the mechanical properties and, in particular, impart high toughness and strength are considered. Toward this end, a discussion is first given of key results from a recent study of two triblock elastomeric materials, namely, Kraton 101 and Thermolastic 226 supplied by the Shell Chemical Company. Then, the ultimate properties of these materials are considered along with results from a recent study of styrene-butadiene rubber (SBR) vulcanizates reinforced with colloidal polystyrene spheres. Finally, tensile strength data on diisocyanate-linked elastomers are discussed.

MECHANICAL CHARACTERISTICS OF TRIBLOCK POLYMERS

Materials and Experimental

As discussed previously, Kraton 101 is a styrene-butadiene-styrene (SBS) triblock polymer whose $M_w$ is about 76,000 and which contains about 27% by volume of polystyrene. Thermolastic 226 is an SBS triblock polymer that contains about 11% of an inorganic pigment and about 35% plasticizer. On a total volume basis, the volume fractions of polystyrene and plasticizer are about 0.20 and 0.38, respectively. Provided the plasticizer remains entirely in the rubbery matrix (an assumption which undoubtedly is not strictly valid), the matrix contains nearly equal amounts of polybutadiene and plasticizer.