CHAPTER I

INTRODUCTION

Rubber has been known to the civilized world for the last few centuries and its uses are so widespread that there is hardly any segment of civilization which does not make use of rubber based materials. During the nineteenth century several epoch-making discoveries were made in the processing and applications of natural rubber which resulted in a tremendous increase in the demand for rubber. The then available supplies of natural rubber were highly inadequate to meet the increased demand. This, coupled with the outbreak of the second world war, prompted intensive research on alternate sources for rubber, which culminated in the development of various synthetic rubbers, some of which were equivalent to

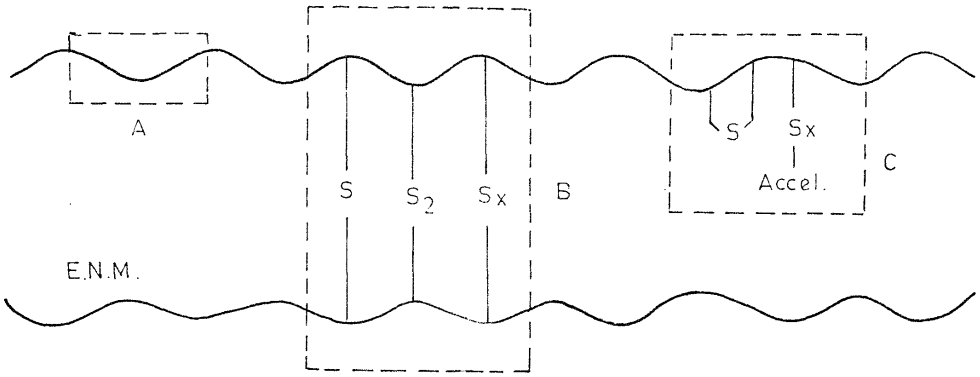

FIG. I.1. STRUCTURE OF AN ACCELERATED SULPHUR VULCANIZATE FROM NATURAL RUBBER

A – MAIN CHAINS OF MODIFIED AND UNMODIFIED POLYISOPRENE ;
B – CROSSLINKS ; C – CYCLIC AND PENDENT GROUPS ;
E.N.M. – EXTRA NET WORK MATERIALS.

to the chain. These changes have been described by Bateman and coworkers[1] and is illustrated in Figure I.1.

The development of various chemical probes[2] has enabled these different structures to be quantitatively characterized in vulcanizates. It is also known[3] that vulcanization can be done by quinone dioximes, resins, urethane reagents, maleimides, metal oxides and other reagents. All these developments led to the use of rubber in non-traditional areas, thus enhancing the demand for rubber.

With the petroleum crisis of 1973 and the consequent increase in the price of petroleum products, the cost of production of synthetic rubber has gone very high up. Also the increase in the price of chemical fertilizers and other agricultural chemicals, many of which are derived from petroleum products, has caused increase in the price of NR as well. This, together with the general increase in the price of other raw materials, has necessitated a manifold increase in the cost of production of rubber products in recent years. Hence there is an urgent need for ensuring a more judicious use of the available supply of rubber and rubber products. This can be achieved by improving the quality of rubber products and by suitably controlling the factors which contribute towards the failure of the products. In either case it is necessary to have a sound knowledge about the various ways in which rubber products fail during service. Thus studies on the failure properties of rubber has become important in the present context.

Failure of rubber is expected to be accompanied by changes in its structure. Also the failure surface, wherever available, offers a good area of research on the mechanism of failure. The following pages give a brief review of earlier theoretical studies on failure properties of rubber, studies on the structural changes associated with failure and microscopic examinations of failure surfaces.

I. FAILURE PROPERTIES OF RUBBER

Any product can be considered to have failed when it can no longer fulfil the functional requirements expected of it. This is true in the case of rubber products also. Thus failure of a tire can occur by the slow removal of the tread through abrasive wear or by chipping and groove cracking or by flex cracking and the consequent fatigue failure. Permanent set can cause failure in products like gaskets and seals. In rubber products the factors considered to be significant in contributing, either singly or in combination, towards the total failure, are tensile and tear fracture, heat buildup and thermo-oxidative aging, flex cracking, abrasion,ozone cracking and set. The factors like deterioration by light, radiation etc. are also contributing, but only to a lesser extent. Most of these factors are interrelated and determined by the fundamental characteristics of rubber.

I.1 Tear fracture : The toughness of rubber is conveniently described by its resistance to tearing. In principle, this might be characterized by the magnitude of the stress at which rupture occurs at the tip of a tear, but in practice the measurement of such localized stresses is extremely difficult. Rivlin and Thomas[4] have shown that the tear quality of rubbers can be expressed by a characteristic energy which is related to the elastic energy stored in the highly strained zone at the tip of the growing tear. The tearing energy T is approximately given by

$$T = d.E_B \qquad \text{... (I.1)}$$

where E_B is the strain energy per unit volume required to break the rubber in simple extension and d is the effective diameter of the small zone of rubber at the tip of the tear. The value of the tearing energy, which is a property of the rubber under the conditions of the test and does not depend upon the type of test used, but varies greatly with the nature of the rubber and of any filler and with the rate and temperature[5]. While giving