Chapter VIII

Summary and Conclusions

The main objective of this work has been to develop blends of EPDM and CIIR rubbers to utilize the high ageing resistance of EPDM and the air impermeability of CIIR. Compatibility, morphology and physical properties of the blends were investigated as a function of blend composition and curing systems. The major conclusions of the study are summarized below.

The degree of compatibility of different grades of EPDM with a particular grade of CIIR was investigated. From the analysis of mechanical properties and ageing resistance it was found that, out of the four grades used, two grades of EPDM (301-T and NDR-4640) are compatible with CIIR. The morphological studies justified this observation. This behaviour is explained on the basis of the comparable viscosities and extent of unsaturation of the components of these blends. Both these blends give rise to an additive behaviour of mechanical properties with blend composition suggesting covulcanisation. The effect of compatibiliser, chlorosulfonated polyethylene (CSPE), on the comparatively less compatible EPDM/CIIR blends was investigated. The resulting blends were characterized for their morphological and mechanical properties. The results obtained from the various analysis suggest that 10 phr of CSPE can be effectively used as a compatibiliser for certain incompatible EPDM/CIIR blends.

A detailed study on the physical properties of sulphur cured blends of EPDM and CIIR with respect to blend ratio, ageing resistance etc. have been conducted. The sulphur cured EPDM/CIIR vulcanizates are found to display linear or better variation in mechanical, physical and other properties with blend composition. Although good mechanical properties are exhibited by NDR-4640/CIIR blends,
their thermal and steam ageing resistance is low. On the other hand, resilience, flex crack resistance and ageing resistances are better for 301-T/CIIR blends which is probably due to the comparatively low viscosity and more saturated nature of 301-T. Based on the physical property studies, 301-T/CIIR blends are found to be most promising for high temperature applications such as curing envelopes, conveyor belts etc.

Two methods have been tried to further improve the mechanical properties of compatible blends of EPDM with CIIR. Both the methods directed at developing a satisfactory network structure in each of the phases and at the interface.

First method investigated was precuring of the CIIR or EPDM phase to a low level prior to blending so that optimum crosslink densities can develop in both elastomer phases and at the interface after final curing. The distribution of curing agents and fillers in both the components of an elastomer blend plays a vital role in determining the curing behaviour and vulcanizate properties of the blend. The distribution of curatives and fillers largely depends on the nature of elastomers. It was found that precuring chlorobutyl to a low level followed by blending with EPDM and then curing the blend is an efficient way of obtaining optimum crosslink density in both the elastomer phases and in the interphase. Precuring possibly slowed down the migration of curatives from CIIR to EPDM. This novel route is found to improve the mechanical properties of EPDM/CIIR blends significantly over their conventional counterparts. The processing safety of the blend compounds was not affected by precuring.

Second method adopted was resin curing of NDR-4640/CIIR blends. It is known that resinous linkages provide vulcanized networks of outstanding heat resistance. It was found that in addition to the improved ageing resistance, the mechanical properties, which are influenced by uniform crosslinking of both the phases and in the interphase are remarkably improved by resin curing. This may be due to the reduced curative migration owing to the larger size of phenolic resin molecules.
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when compared with the curatives used in sulphur curing. The properties are found to be a weighted average of the properties of the component elastomers. Considering the remarkable improvement in the ageing resistance during resin curing over sulphur cured counterparts, the resin cured blends form a very useful class of rubbers for high temperature applications.

In the concluding chapter, investigations on the processability and the specific requirements of the blends inorder to use them for fabrication of products such as curing envelope are discussed.

The rheological evaluation showed that among the precured, sulphur cured and resin cured blends, highest shear viscosity and minimum die swell are observed for precured blends and maximum for sulphur cured blends. The shear viscosities of both pure systems and blends decrease with increase in shear rate at all temperatures. At high shear rates the temperature has little effect on viscosity and all the points converges to a small area. This shows that effect of shear surpasses the effect of temperature for controlling the flow properties of blends of EPDM and CIIR. The viscosity of pure CIIR is lower than that of pure EPDM at higher shear rates and the viscosities of the blends were in between that of pure components. At low shear rate at 100 °C, the die swell decreased slowly with increase in CIIR content in the blends but at higher shear rate, the die swell increased with increase in both temperature and CIIR content in the blends.

The thermal degradation resistance is the maximum for resin cured EPDM/CIIR vulcanizates and highest thermal degradation resistance was for blends containing higher percentage of EPDM than that of pure EPDM. Thus blending improved the thermal degradation resistance of elastomers. Air permeability was found to be minimum for precured blends and among them, least air permeability was for blends containing higher percentage of chlorobutyl.

The thermal diffusivity was highest for EPDM and blends containing higher percentage of EPDM, possibly due to the increased extent of interaction between
EPDM and carbon black. The thermal diffusivity values increased slightly with ageing. The thermal diffusivity of elastomers and their blends can be improved significantly by the addition of small amounts of boron nitride. This is highly attractive, especially for products like curing diaphrams, envelopes etc. where the increased thermal diffusivity not only enhances the green tyre curing rate but also may reduce the extent of bladder degradation. In general, the blends exhibit an additive behaviour and an optimum compromise of properties can be attained by using a blend containing 60 % EPDM and 40 % CIIR.

It can be concluded that 60/40 EPDM/CIIR blend can be used for the high temperature applications especially for the manufacture of hot air curing envelopes as this particular blend composition satisfies the required envelope features in terms of tensile strength, tear strength, ageing resistance, flex crack resistance, thermal diffusivity and air permeability. Therefore it is possible to fabricate curing envelopes having attractive properties with this blend.