

## ABSTRACT

The band formation behaviour during mill processing of an elastomer depends on its rheological and failure behaviour. Experiments for the study of band formation behaviour for natural rubbers (NR), styrene-butadiene rubber (SBR), polychloroprene rubber (CR), acrylic rubbers (AR101 and AR201), epoxidised natural rubber (ENR) and polybutadiene rubber (BR) and their filled compounds (filled with different fillers like carbon black, silica, whiting, etc.) have been carried out over a range of temperatures ( $45^{\circ}$  -  $100^{\circ}\text{C}$ ), friction ratios (1.05-2.0) and filler loadings (0- 65 phr for NR and 0-50 phr for other rubbers). The experiments have been carried out in drop mill and continuous mill operations. The critical nip gap (the nip gap at which the material does not band on either roll but simply drops down) has been determined for the above mentioned rubbers and their filled systems. It has been found to increase with friction ratio for CR, AR101 and AR201 but decrease with friction ratio for filled NR and SBR. The BR does not band at all under any condition of temperature, filler loading and friction ratio. A theoretical model based on dimensional analysis has been developed to describe these behaviours. From this model three 'Mill Band Formation Indices' have been defined for three types of behaviours and are found to be constant for a particular system at a constant temperature. Also a quantity known as 'Mill Band Formation Exponent', which depends on characteristics of materials has been defined and found to have positive values for CR, AR101 and AR201 while negative for NR and SBR and their filled systems. In the case of continuous mill operation critical transition time for front to back roll (F-B) transition has been defined which decreases with increase in friction ratio, temperature and filler loading.

The detailed rheological analysis of different rubbers shows that these rubbers obey the power law model and exhibit pseudoplastic flow behaviour i.e., viscosity decreases with increase in the rate of shear. The variation of viscosity with temperature rate of shear and filler loading has been used to explain the band formation characteristics of the compounds. The increase in the viscosity with level of filler loading has been expressed in the form of a polynomial relation. The activation energy of melt flow has been found to increase first with rate of shear and then decrease. Highly filled systems give negative activation energy. The running extrudate swell increases with increase in shear rate up to a limit beyond which it decreases. It also decreases with increase in filler loading and temperature of extrusion. The variations of extrudate swell with shear rate and filler loading have been presented in the form of an exponential relation for ENR and AR201.

The tensile failure properties of gum and filled rubbers have been evaluated at different temperatures and strain rates. The results are presented in the form of failure envelopes which have been correlated with the band formation behaviour. It has been established that the systems which have elongation ratio at break,  $\lambda_b$  higher than 4.0 show good band formation behaviour whereas those with  $\lambda_b < 4.0$  show anomalous band formation behaviour.

The structural changes in the elastomers during milling at different temperatures and friction ratios have been studied using IR spectroscopy and electron spectroscopy for chemical analysis. The concentration of carbonyl groups ( $>CO$ ) for all the rubbers and -OH group for NR and ENR have been found to initially decrease and then increase with time of milling for all the rubbers. The ESCA studies of milled and unmilled rubbers also confirm these observations.

**Key Words:**

Natural rubber, Styrene-butadiene rubber, Epoxidised natural rubber, Polychloroprene rubber, Acrylic rubbers, Mill processing behaviour, Band formation behaviour, F-B transition, Critical nip gap, Critical transition time, Mill band formation index, Mill band formation exponent, Band tearing, Band splitting, Rheological behaviour, Viscosity, Ultimate properties, Failure envelope, Mechanochemical degradation.