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Rheological Properties of Rubber-Carbon Black Compounds and Boundary Conditions on Solid Surfaces*

The flow properties of rubber compounds are quite complex in comparison to the behavior of thermoplastics or gum rubber.

In recent years, the author and his co-workers have sought to make serious studies of both the rheological properties of rubber compounds and of the character of the boundary conditions on metal walls.

Rheological Properties

Measurements of shear viscosities have been carried out with rubber compounds with varying levels of carbon black and with differing black particle size. At volume loadings of 20 % carbon black and more, the compounds exhibit yield values, Y. i.e. stresses below which there is no flow. The magnitude of Y increases roughly inversely with ultimate particle size.

Similar yield values are exhibited by polymer compounds containing other small particulates such as talc, titanium dioxide, and calcium carbonate. Such polar particulates increase viscosities more and give higher yield values than carbon blacks of equivalent particle size.

Rubber compounds exhibit highly thixotropic behavior. The stress fields at the start of flow strongly depend upon time and previous history. The longer the rest history, the greater the stress overshoot in the transients.

Stress relaxation following a sudden strain or shear flow leads to a finite rather than a zero asymptotic stress.

Extrudate swell of rubber compounds is quite low and decreases with decreasing particle size and increasing particle loading. The compounds generally exhibit improved extrudate surface quality. The magnitude of swell from slit dies is greater than that from capillary dies.

Boundary Conditions

It is found in experiments using pressurized rotational rheometer similar to that of Turner and Moore (8), that when the applied pressure on an elastomer or rubber compound is reduced to 0.2 MPa, a lower slip is initiated. The slip is observed both in the reduced magnitudes of torque and in the markings on rubber caps removed from rotors. Slip is initiated at outer radii and propagates radially inward.

The levels of stresses extended by rubber compounds on rotors made from different materials vary depending upon the nature of the surface and its roughness. This is most clearly seen at low levels of imposed pressures. For smooth rotors, it was found that stresses order as :

Copper / Brass > aluminum > Steels > PTFE

At higher pressures, smooth and grooved rotors from different materials (except for PTFE, which is usually lower) give similar values. However, a system, filled with 7 percent stearic acid gave lower stresses on smooth as opposed to grooved rotors. This indicates the existence of a thin layer of lubricant on the surface of the rotor.

Slippage was also induced in the extrusion of rubber compounds by using porous metal dies and injection pressurized air. Experiments were carried out using various die systems attached to a cold feed rubber extruder.

The air pressure required to create a lubricate air layer and cause substantial drops in extrusion pressure was of the order 0.25 MPa.

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Effect of Surface Roughness and Mechanical Interlocking on Adhesion*

The apparent strength of adhesion has been measured for a soft elastic layer of rubber, adhering to model porous substrates, consisting of rigid plates containing regular arrays of cylindrical holes. Two contributions to the apparent strength have been identified and compared with the predictions of a simple theoretical treatment. In one case the strands of adhesive are assumed to pull

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