9. Proposed flame retardancy model

The results presented above show that the organic oxygen containing hydrocarbons can render the fabric flame retarded in terms of vertical flame test. Any physical model that is proposed to explain their action will require mass and energy balances that must consider the following effects:

- The effect of elongational viscosity and surface tension effects on the propensity for melt dripping; and
- The effect of the built in stresses on fibre pullback.

For the flame retardant to be effective it will have to fulfil in one or more of the following criteria:

- Providing a thermal heat sink effect to reduce the effective surface temperature of the polymer;
- Reduce the viscosity of the molten polymer in order to accelerate the drip rate M_{drip};
- Lower the surface tension in the polymer melt so as to lower the adhesion forces and accelerate drip rate;
- Decrease the rate of volatilisation of polymer degradation products;
- Change the colour of the molten polymer in order to increase the radiation heat loss; and
- Decrease the flammability of the volatile decomposition products.

As far as the elongational viscosity is concerned, Figure 25 shows a possible model that could be used.

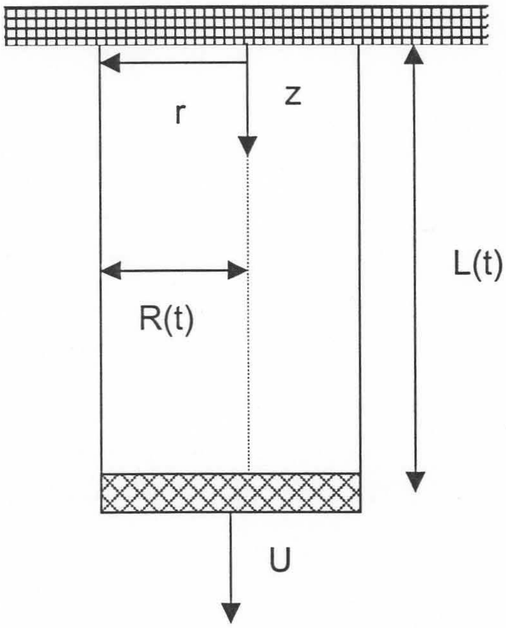

Figure 25: Schematic diagram for the model of elongational viscosity.

In this model a mass of molten polymer is drawn down by gravity forces (F=m.g) at a speed U. Therefore, the dimensions change with time, and length (L) as well as sample radius (R) has to expressed as L(t) and R(t).

Surface tension is caused by an imbalance of forces that act at the interface between the polymer melt and the air. These forces are attractive in nature and the imbalance occurs because there are only two dimensions present in any surface. The imbalance of forces tends inwards for liquids and solids, so the attractive forces in the polymer melt tend to draw the molecules on the surface to the inside of the liquid. This process causes a skin to develop that resists change, the skin being the surface tension. This is the basis for the thermodynamic principle that new surfaces will not form spontaneously, but require an input of work or a positive Gibbs Free Energy change.

Consider a bead of molten polymer at the bottom edge of a solid piece of fabric. Tate's law states that there must be a balance of forces. The force that pulls the drop downwards is the gravity force, and the upward force is the surface tension at the circumference of the drop. At the point of incipient detachment, the forces are in equilibrium. At this point the equation $mg = 2r\gamma$ holds where m is the mass of the drop in kilograms, r is the radius of the drop in meter, g is the gravitational constant in $kg.m/s^2$ and γ the surface tension in N/m.

The rate of dripping also depends on the surface tension of the liquid. In the case of polymer melts, there is a further complication. Polymer melts exhibit resistance to extensional flows. Enhanced polymer dripping therefore requires an effective reduction in combination of surface tension and elongational viscosity effects.

When the fibres are spun, they are stretched according to a specific draw-down ratio that can be as high as 10 to 1. This enhances the strength and crystallinity of the fibre. This stretching orients the polymer chains in the direction of the fibre axis. This unnatural conformation of the polymer chains is locked in place by subsequent recrystallisation. When the fibre melts the polymer chains become mobile and reorient themselves into random coil conformations. This process sets up a retractive force in the fibre. This retractive force of the fibre was clearly demonstrated in both the bottom edge and face ignition tests.