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Modern Approaches to Rubber Processing Problems*

Rubber processing is nowadays considered with a sound scientifical approach to the problems involved, namely by taking into consideration the heterogeneous nature of rubber compounds, their strong viscoelastic character and the pecularities of their flow process. It is now recognised that, within an uncured rubber compound, besides the free mobile rubber molecules whose entanglement level is known to control the flow behaviour, it exists a soft three-dimensional network of fibrous elements of carbon black and bound rubber, which brings singular rheological properties. The flow mechanisms of rubber compounds therefore involve a number of concomitant phenomena, certains common to all macromolecular systems, certains typical of such heterogeneous materials. When submitted to the appropriate strain field, a rubber compound flows through disentanglement processes of macromolecules in the free mobile rubber region and the displacement of complex rubberfiller flow units.

The motion of such flow units not only requires the disentangling of the interface but also involves various stretching/relaxation processes of the filaments arising from rubber-filler interactions. Such an interactive network description of rubber compounds allows to understand their particular flow properties.

Progress in rubber processing has benefited from the unit operation analysis of the overall process, which considers the various stages as a sequence of unit steps, in order to establish the relationships between the input and output flux of material, by understanding the various physical, chemical and rheological phenomena involved. Despite its complexity, this approach allows major processing steps such as mixing and extrusion to be analysed in details and the key operational factors to be identified.

When the key operational factors have been identified, the appropriate testing equipments can be developed in order to specifically address the relevant processing properties. Internal mixers are now being equipped with control systems to measure and record all relevant mixing parameters.

Experiments with various compounds demonstrate that the actual position of the ram is a key factor of the process. It has been observed that the higher the fill factor, the longer this time, with clear differences due to the nature of the filler. An important consequence of observations is that, at the beginning of the process, only a part of the total batch volume is involved in the mixing, since a significant portion remains in the inlet duct until the ramp has reached its equilibrium position. The actuel mixing energy must then be corrected for the effective batch volume concerned. When such a correction is applied, it is seen that the true specific mixing energy is not depending on the fill factor but is a characteristic of the batch nature (and depending on the other mixing parameters).

By analysing the extrusion process as a series of sequential unit operations, two major parts are identified, i.e. the screw component and the die component. The later can be studied via experiments with capillary rheometers. The screw component can only be approached using instrumented extruders. For instance, it has been used to study the extrusion behaviour of various rubber compounds by paying a particular attention to the process stability over long period of time.

Results so far obtained show that the feeding of the extruder has a strong effect, as well as the set temperature profile along the barrel. It is clear that such information cannot be obtained using standard laboratory test equipment.

Modern approaches of rubber processing problems consist thus in correctly addressing the particular aspects of rubber compounds, the filler-elastomer interactions and the resulting viscoelastic character combine as to give significant slippage and elastic memory effects, which monitor the processing performances of rubber compounds. Using the appropriate unit operation analysis of the various processing stages, the most likely sources of variation can be identified and the suitable controls installed with respect to the desired process stability. In order to study the relevant aspects of rubber processing rheology, appropriate testing instruments are now being developed to consider real flow situation rather than the ideal conditions generally achieved in classical test equipment.

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The Use of New Thermo-Dynamic Methods in the Rubber Industry*

Many rubber processing technologies are connected with exchange of thermal energy as well as with changes of the thermal state. There also many rubber products used in conditions different from the ambient temperature. Therefore, it is surprising that relatively

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