

# On-line profile monitoring keeps rubber extrusion on the straight and narrow

The importance of on-line monitoring of rubber profile dimensions is described by Dennis Reynolds, vice president of sales and marketing at Bytewise Measurement Systems.

**R**UBBER extruders can risk scrap rates approaching 10 per cent because of the unexpected behaviour of the compound due to processing variations or even inconsistencies in the same batch of material. Warning that things are going wrong can manifest itself in dimensional change in the extruded profile, so watching for profile variation is a key factor in activating process control.

Large amounts of scrap can be generated during the start-up of a run while the process reaches stability. And off-spec material can be generated by variations in the physical properties of the rubber compounds both within a batch and between batches. Often variations in material properties and equipment can conspire to make good profiles behave badly.

## Start-up behaviour

The objective of extrusion control is to deliver the rubber compound to the die at a uniform viscosity, with a uniform heat history, and under a uniform die pressure. During start-up the extruder barrel and screw temperatures come into equilibrium as the rubber starts acquiring heat.

Once equilibrium is achieved the rubber can acquire a uniform heat-history as it passes through the machine. Uniform heat history assures uniform viscosity at the die which in turn assures uniform flow characteristics through the die. Any change in viscosity will result in changes in die flow which will result in non-uniform profiles.

This is fine for simple profiles. But life isn't always simple, and flow through a non-symmetrical profile die can be extremely complex.

Given a constant pressure distribution across the die, rubber will tend flow faster through a large opening in the die than through a small opening. Many rubber products comprise several different compounds extruded through a single die. Tyre treads are often extruded with four components in a quadraplex extruder – one with four screws. Automotive door seals are often extruded with two compounds; a dense base and a sponge bulb. Set-up and control of multiple durometer compounds introduces an additional parameter of ratio control.

Small changes in viscosity and pressure can have large effects on the flow rates through different parts of the die, and it is difficult to strike the balance where pressure, viscosity and die flow geometry result in an ideal profile extrusion shape coming out of the die.

This is where on-line monitoring comes in. By observing the real-time optical comparator the user can immediately see the dimensional result

of process and equipment set point changes. Figure 1 illustrates how four dimensions come into specification at different times in the start-up process. Some companies that have implemented start-up optimisation programmes reckon to have halved start-up scrap.

## Batch behaviour

Rubber products are manufactured from rubber compounds that most commonly combine natural rubber and carbon black with additives that enhance processability, ageing, flexibility, and environmental resistance, particularly oxidation. Rubber is compounded to craft special properties for a multitude of applications. In spite of well understood chemical behaviour, rubber compounds exhibit considerable variation in their physical properties, due in large part to variations in the chemical makeup of natural rubber, and variations in the molecular structure of carbon black.

The visco-elastic properties of natural rubber vary considerably with the temperature, humidity, and overall climate of the rubber plantation. Carbon black exhibits considerable variation in particle size and molecular structure, owing to the propensity of carbon to bond with itself.

After mixing, the ideal rubber compound should have a highly uniform chemical dispersion. But in practice there is considerable non-uniformity in the dispersion. This is due to several causes, including hot and cold spots in the mixer housing and rotors, excessive rotor clearance, rotor wear, and poorly-circulating flow paths. As a result, there can be a little more carbon black here, and a little less there; along with few clumps of carbon black elsewhere,

Bytewise Measurement Systems introduced the on-line profile geometry measurement system, Profile360, in 2002. Profile360 uses laser line projectors and CCD cameras to digitise the outside shape of profile extrusions to monitor the profile uniformity. Profiles are digitised at rates up to 12 Hz, compared to CAD templates, analysed with software calipers, and visualised in an optical-comparator display. When caliper measurements exceed the user-specified control limits, an alarm alerts the operator to take corrective action. The equipment is sold in Britain by Nortest.

[www.nortest.co.uk](http://www.nortest.co.uk)  
Factfinder 115

that are not well mixed with the rubber or the additives.

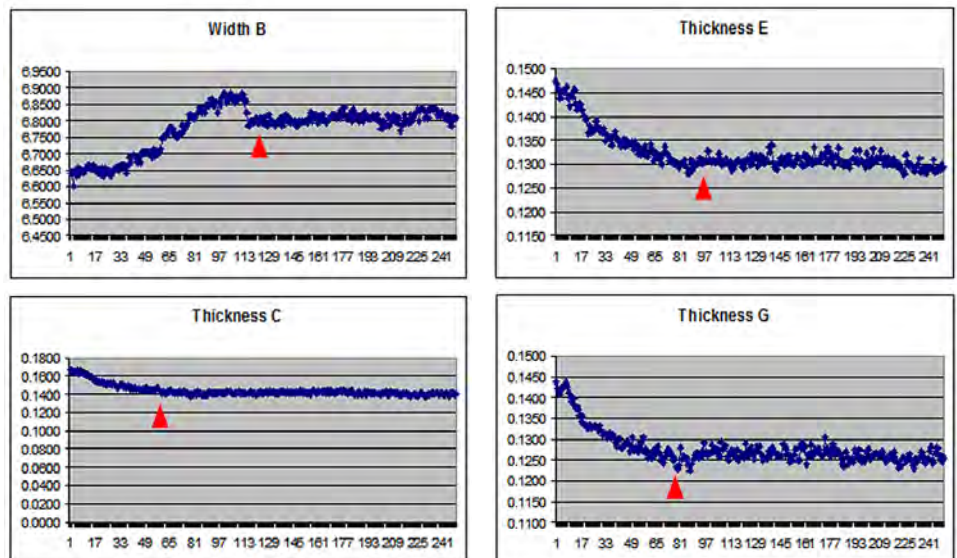
It is no surprise that two batches from the same mixer can exhibit very different physical properties. Variations in visco-elastic properties can be seen even with a single batch.

The diagrams show dimensions can change over time. In figure 1, key dimensions of a profile settle down to stability after start-up, but not all in the same time, so measurement of all key dimensions is crucial to know when production is really on spec. In figure 2, a switch to a different batch of compound has an abrupt effect on a key dimension, while figure 3 shows that inconsistencies within the same batch can change important dimensions.

The start-up behaviour is to some extent predictable. You know the product is going to reach equilibrium, it's just not certain when. But changes between batches, or worse, within the same batch of compound, can switch output from good to bad. And you need to know what's going on.

On-line profile measurement has been implemented to various degrees at nine of the top 10 global automotive sealing systems makers, eight of the top 10 tyre makers, and numerous other custom profile makers. On-line monitoring is a key component in programmes aimed at reducing start-up time and the associated scrap. It has also proven effective at alarming immediately when the

Figure 1 – Various dimensions come into specification at different times during start-up (▲ denotes the time at which the dimension is stable).



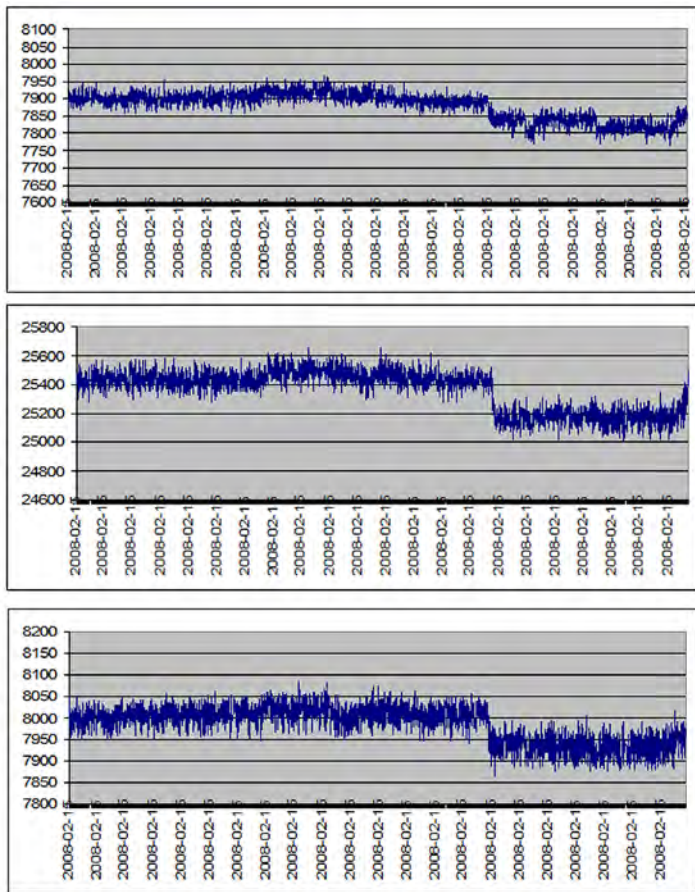


Figure 2 – Two batches of the same compound exhibit different visco-elastic flow properties resulting in different profile dimensions.

profile geometry exceeds control limits and alerting the operator to take corrective action, thus averting costly scrap and quality problems that would otherwise go unnoticed.

These benefits are particularly attractive in rubber extrusion due to the inherent variations in the material properties of rubber compounds and the variations introduced by the extrusion processes.

On-line measurement is an alternative to periodic off-line sampling methods, and is favoured because of its immediate recognition of process changes. It can provide rapid and accurate feedback of production conditions, but human interpretation is still the norm for process correction due to the complexities of extrusion control and the variations inherent in rubber compounds.

Figure 3 – Even within a single batch there can be variations in physical properties that have a bad influence on die-flow and the resulting dimensional values.

