HIGH VISCOSITY TECHNOLOGY

An Extruder Made to Measure

Without halobutyl rubber there would be no tubeless tires. However, its production is energy-intensive. In collaboration with Bayer Technology Services, Lanxess was able to improve its manufacturing process substantially – thanks to, among other things, a customized extruder.

The name of the manufacturer is clearly visible on the steel, and yet the unit located at the Lanxess site in Zwijndrecht near Antwerp in Belgium cannot be ordered from the company's product catalogue – at least not the inner workings of this steel cylinder several meters long. "We changed quite a bit," Dr. Thomas König explains, and it was indeed necessary. "Nowhere in the world is it possible to order an extruder like the one needed for the task at Lanxess," says the process engineer working at Bayer Technology Services. For this reason, König and his team purchased a commercially available extruder and then modified it with the help of a further partner so that it was able to do the job.

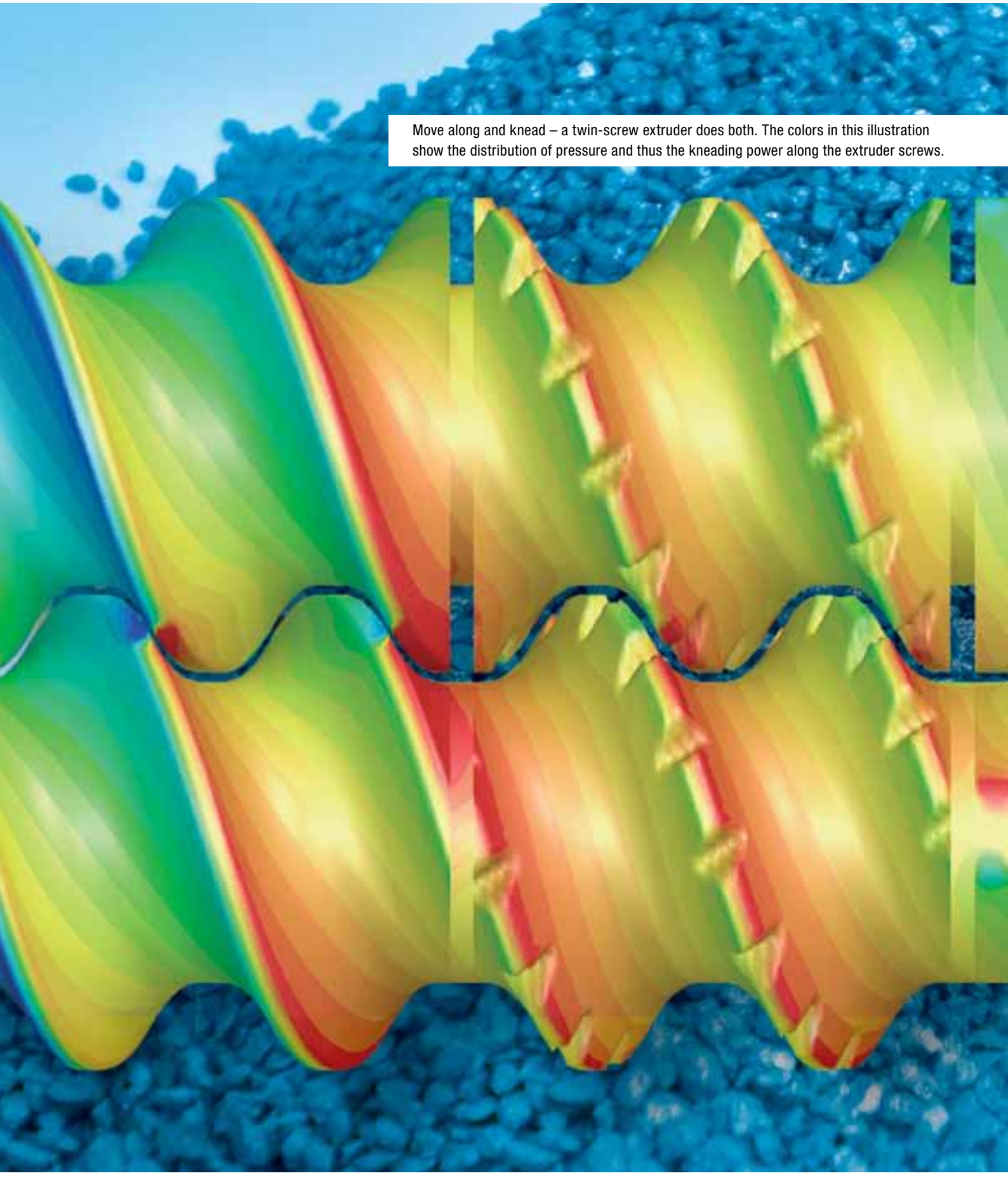
The usual task of an extruder is to knead a more or less viscous material while conveying it, thus homogenizing it, or, as the case may be, to thoroughly mix two different components in the process. Thermoplastic melts are often processed in this way. One or several screw-like shafts rotate, thus moving the material to be processed from one end to the other. The basic principle of this technology was discovered by the Greek scholar Archimedes more than 2000 years ago. However, he had other applications in mind. With his Archimedean screw, he succeeded in transporting low-viscosity water upwards against the force of gravity.

The customized extruder in Zwijndrecht has a very different function. Its job is to free freshly synthesized butyl rubber from the solvent in which the synthesis has previously taken place. Until now Lanxess had used a stripping technology at this stage of the process. Here, hot steam is fed through a mixture of rubber crumbs and liquid, and the steam then carries away the solvent. However, this process is extremely energy-intensive. In fact, it is the main reason why nearly nine metric tons of steam are required per metric ton of synthesized butyl rubber. With the demand for butyl rubber increasing from year to year (see the adjacent box), Lanxess is striving to improve the energy balance of its production. In collaboration with Bayer Technology Services, the chemical company in Leverkusen has succeeded in optimizing its process in recent years. The result of this development is the large-scale pilot plant now located on the River Schelde in Zwijndrecht. The customized extruder that removes the last of the solvent is part of this new plant.

As the solvent evaporates at the temperature conditions in the extruder, this process is also referred to as degassing. Degassing polymers in extruders is not really new, but there are always additional challenges involved in degassing rubber. The more solvent removed, in other words, the higher the rubber content of the remaining mixture,

Popular rubber

Tubeless tires were first introduced in the 1950s. Ever since virtually every tire available on the market has been lined with a coating of butyl rubber. Lanxess is one the world's two leading manufacturers of this special polymer made from isobutene and isoprene. More than three quarters of the some 300,000 metric tons produced every year end up in the tire industry. This industry's demand for gastight rubber is increasing – especially in the booming economies of Asia. Experts calculate that by 2020 China, for instance, will require an average of 8.8 percent more tires every year. Incidentally, another application for butyl rubber is chewing gum.



Move along and knead – a twin-screw extruder does both. The colors in this illustration show the distribution of pressure and thus the kneading power along the extruder screws.

"An extruder like the one required for the task at Lanxess cannot simply be ordered somewhere in the world. That is why we took a model that is commercially available and further developed it to meet our needs."

Dr. Thomas König, Principal Expert High Viscosity Systems, Bayer Technology Services

It may come as a surprise, but pure (butyl) rubber is white (left). Tire manufacturers are the main users of the dried crumbs. All modern radial-ply tires are coated with halobutyl rubber (right).

the more viscid and sticky it will be. When using the term viscid, a consistency something like honey may come to mind. But pure butyl rubber is almost like a solid. If a glass with butyl rubber were to be turned upside down, it would take ages before something would run out.

As a lot of energy is added to the rubber through kneading, its temperature increases along the length of screw-like shaft in the extruder. "This is a problem because at some point it can become so hot that the rubber would chemically decompose," explains Thomas König. Clearly this is undesirable.

And there is another factor that complicates the degassing of butyl rubber: its low gas permeability. This is actually considered a desirable property from the point of view of the main users of the rubber: tire manufacturers. After all, it is the coating of butyl rubber on the inside of all tires that makes them airtight. However, it is easy to imagine that this very gas impermeability can also be a real obstacle, if you want to remove the existing gaseous solvent from the rubber mixture.

König and his team colleagues were exactly the right people to work out a solution despite this problem. Principal Expert High Viscosity Systems is the title on König's business card. Highly viscous systems are what experts describe as substances which are so viscid that they can hardly be called liquids at all – just like synthetic rubbers. König has worked in highly viscous technology for more than 15 years.

In fact, Bayer has amassed expertise in this field over decades. But that is not all: the company has even shaped this area of process technology through its own pioneers and innovations. "Device for the kneading, gelatinizing and pressing of plastic masses" is the title of a patent specification that was first drafted in 1944 and granted at the beginning of the 1950s. The authors were Bayer employees, and the "device" to which they referred was none other than a "co-rotating twin-screw extruder", i.e. an extruder with two intermeshing screws, both of which rotate in the same direction. In certain applications, this

"This process is not only attractive for the manufacture of butyl rubber. We intend to successively make use of this technology in the production of other elastomers as well."

Dr. Hanns-Ingolf Paul, Head of Global Technology Butyl Rubber, Lanxess

type offers some advantages compared with the other existing version in which the two screws rotate in opposite directions.

A co-rotating twin-screw extruder was also the favored solution for degassing butyl rubber. Unfortunately, however, the models that were commercially available were not suitable for the task. "The increase in temperature resulting from this method would simply have been too high," says König. So, König and his team proceeded to modify the inner workings of the extruder to meet their needs. For this, there are two basic regulating possibilities: one for the geometry of the screw and the other for the size of gap between the two screws. The mixture is kneaded in this space, and it is also transported through this space. The smaller the space, the greater the built up of pressure – and thus the degasification effect. But the friction and temperature also increase as the compound is conveyed along the screws, and therefore the whole process is an extremely sensitive balancing act for engineers.

Fortunately, König and his team colleagues had a small scale version of twin-screw extruder at their disposal in the pilot plant in Leverkusen. During the course of the project, they tested a wide variety of geometries for the screw elements in this Center. "All of them were custom-built models, for which we commissioned another supplier," says König.

In order to ensure the model dimensions were not random choices, practical tests were conducted hand in hand with theoretical considerations. Bayer Technology Services colleagues from Computational Fluid Dynamics helped in these efforts. They are well-versed in the flow simulations of liquids and gases. Although it is true that simulations of rubbers are extremely difficult, as König explains, computer modeling has nevertheless provided important services in terms of coming up with the specific configurations of screw elements.

For obvious reasons, König does not want to reveal exactly how the optimal screw elements will look. However, the fact remains that they are now able to almost completely remove the solvent from the rubber mixture, without the rubber becoming too hot. This was confirmed on a small scale in a pilot plant operated by Lanxess near Zwijndrecht. After this came the conversion to a large pilot plant in full-scale industrial production. The extruder for this operation is nearly eight meters long. The still gel-like rubber-solvent mixture is fed into the top at one end of the apparatus, and the white, viscid crumbs come out at the other end. These crumbs are then processed into pellets. At its maximum operating performance, up to several metric tons of rubber pass through the extruder per hour. Despite the long distance, the respective residence time in the extruder is in the range of just a few minutes.

Experts at Lanxess are also pleased with the results. The first tests have shown that, with the new process, the chemical company can save more the 70 percent of the amount of steam required using the conventional method. And the CO_2 emissions resulting from production are reduced proportionately. Both are nice contributions to protecting the climate.

With this success, the Project Manager for Lanxess, Dr. Hanns-Ingolf Paul, is already thinking ahead: "This process is not only attractive for butyl rubber. We intend to successively make use of such technology in the production of other elastomers as well." Lanxess manufactures many additional types of rubber in its Performance Polymers Segment. Steam stripping is currently still the common practice for a number of these rubbers, but there is now the energy-saving alternative found for the production of butyl rubber.