

Improving profitability through innovative technologies and processes

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Performance material usage is increasing in the manufacture of tires. These materials are composed of various additives with different properties that require a high level of expertise to maintain their properties throughout the production process and to deliver the desired, consistently high level of required quality. This is just one aspect that increases complexity in the manufacturing process. Market demands for more cost-effective products are also constantly increasing. Operating costs deserve special attention because process optimization is paramount on every manufacturer's agenda. Specialty chemicals group Evonik Industries and plant automation supplier Zeppelin Systems are working closely together to show how the use of innovative products and processes can both improve the performance properties of tires, while making their manufacture even more economical.

In order to optimize a production process, various factors must be accounted for. These include minimizing both CAPEX (capital expenditures) and OPEX (operating expenses), sustainable management of pollutants and emissions, and avoiding waste.

A typical green tire recipe is shown in table 1. The use of materials in conjunction with the appropriate process technology reduces operating costs and ensures consistent, or even improved product quality. For example, liquids make up a portion of a typical formulation in the rubber and tire industry. Liquids reduce viscosity during processing or can be used as functional additives that make an important contribution to improved tire properties. Up until now, liquid raw materials have mainly been used as processing aids in the form of oils. With a content of up to 15%, they serve predominately as plasticizers to improve the compound's processing properties. However, performance and safety relevant properties in affected tire compounds, such as braking grip, can deteriorate. For this reason, many tire manufacturers use liquid butadiene rubber (LBR) as an alternative. Due to its chemical structure, LBR can be reactively incorporated into the compound during vulcanization, forming solid, permanent, covalent chemical bonds. This prevents the risk of material migration, which delays tire embrittlement and main-

tains their quality. The driver thus uses the tire longer, and subsequently minimizes environmental impact. In addition to the sustainable aspect of LBR, its use improves important performance criteria, such as grip on snow and ice, and in cold weather. For the manufacturing process itself, the use of LBR continues to provide advantages in the mixing process, as it reduces viscosity in the initial mixing steps and has a positive influence on mechanical properties. The resulting advantages allow the rubber compounds to be tailored to optimal specific requirements, as proven in numerous laboratory studies.

High productivity thanks to an innovative dosing system

In terms of cost-effectiveness, liquid polybutadienes have a distinct advantage: Not only can they be mixed faster and more evenly, but also, with the correct dosing system, can save up to four seconds per mixing cycle. This enables the manufacturer to run up to 20 additional batches per day, while improving the dispersion quality and reproducibility of each formulation. In terms of plant technology, polymeric liquid raw materials such as LBR place high demands on their precise handling. This is because the compounder needs to mix many different raw materials in the right sequence, safely and precisely, to afford the desired quality. Concurrently, the total mixing time must be minimized to ensure production lines of different compounds remain as efficient as possible. Particularly challenging are the limitations of precise metering of the liquid raw materials by means of conventional oil scales and pumps into the mixer.

Since the demands on rubber compounding systems are continuously increasing, and functional additives or LBR are being used in ever greater quantities, automated plant supplier Zeppelin Systems has developed an innovative solution specifically to meet these requirements: the Liquid Dosing System. This fully automatic and sealed system has a special injection valve and a volumetric dosing system that guarantees the exact proportioning of the liquid raw materials and ensures consistent properties of the compounds. This increases repeatability and, when compared to conventional systems, reduces the need for adding excess material to ensure the achievement of mechanical properties, and thus reduces the total usage of expensive additives.

A special injection valve on the mixer allows up to six fluids of either low or high viscosity to be injected into the mixer, one after the other, with virtually no cross-contamination or back-flow. The liquids are stored within a closed system, eliminating external cross-contamination and employee contact with the liquids and their off-gases. This provides the operator a very high level of environmental safety in the work environment.

Functionalized polybutadienes: Demonstrably better performance

The German specialty chemicals group Evonik Industries is setting another trend in the production of liquid raw materials: the use of silane functionalized polybutadienes as specialty ad-

Table 1 - typical green tire recipe

Reference: S-SBR (oil extended) 96.3 phr; BR 30 phr; silica (Ultrasil 7000 GR) 90 phr; sulfur-silane (Si 266) 6.53 phr; Polyvest EP ST-E 60 0.0 phr; process oil (TDAE) 8.75 phr; sulfur 2.0 phr

+PV ST-E 60: +5.0 phr Polyvest ST-E 60

+PV ST-E 60 - TDAE: 5.0 phr Polyvest ST-E 60; -5 phr process oil

ditives for rubber production. The new technology, based on Polyvest ST, combines the already positive properties of classic LBR with even higher performance characteristics. Functionalized polybutadienes are liquid polybutadienes with terminal silane groups. Polyvest ST is typically used in tread compounds, and supports the distribution of the filler in the rubber matrix in silica filled tires.

Chemically, the terminal silane groups bond to the surface of the hydrophilic silica particles, while the hydrophobic polymer chain ensures excellent compatibility with the rubber matrix. Optimizing filler-rubber compatibility improves important core properties, such as rolling resistance, and reduces abrasion. The reduction in rolling resistance in turn has a positive effect on energy consumption, improves the range of electric vehicles, and lowers the release of carbon dioxide which is harmful to the climate. Extensive laboratory tests by Evonik have shown that the use of Polyvest ST significantly reduces typical indicators such as $\tan \delta$ (60°C) and abrasion (figure 1). These positive effects become even more apparent the higher the proportion of filler. The use of natural rubber as the main or partial component in combination with Polyvest ST also has a positive effect. In addition to the performance benefits, the use of functionalized liquid polybutadienes also results in tangible advantages for the compounder, especially the partial substitution of oil, improving aging resistance and extending scorch time (figure 2).

Liquid rubber: High demands on handling

Zeppelin Systems Plant Engineering has conducted extensive studies and tests on the metering and injection behavior of Polyvest ST in its Technology Center for Liquid Dosing (figure 3). The modular Zeppelin Liquid Dosing System can also very precisely meter a wide variety of other liquids, such as oils, waxes and chemical additives. The liquids are stored in heated tanks, IBCs, drums or storage containers. When charging the dosing cylinder, the technology allows the cylinder to fill with material without gas inclusion caused by cavitation. After the filling process, an air check is performed by way of the cylinder

Figure 1 - improved fuel efficiency as indicated by loss factor at 60°C

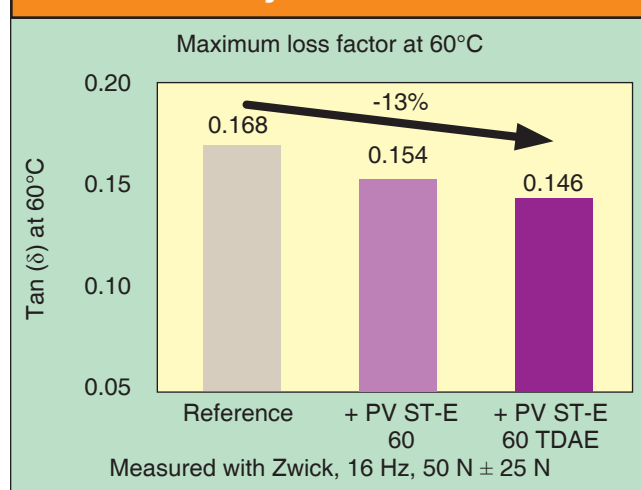
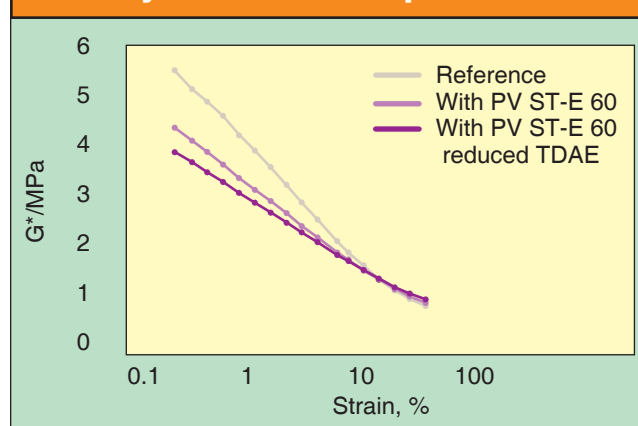


Figure 2 - reduced Payne effect as shown by RPA strain sweep at 60°C



automatically checking that no air is trapped in the liquid by compressing the material. Fine feeding to meet accuracy requirements then takes place. Online density measurement in the feeding pipe precisely measures the material density, and the system adjusts volumes accordingly to meet accuracy, despite temperature fluctuations. During the subsequent injection process, the material injects via the injection valve into a container on a high resolution scale. This demonstrates that, in a production environment, the quantity injected into the mixer can be controlled to the gram, and any deviations can be detected immediately.

An integral part of every liquid dosing test at Zeppelin's Technical Center includes capability process index (Cpk) tests of various performance parameters. These provide meaningful results of the accuracy and repeatability of the system at differ-

Figure 3 - liquid rubber Polyvest ST in the Technology Center for Liquid Dosing



ent target weights. Polyvest ST consistently achieved excellent Cpk results on the Zeppelin Liquid Dosing System of >1.67.

The tests with Polyvest ST showed that it is possible to dose the material precisely and inject it completely into the mixer without any difficulties. Throughputs of up to 90 liters per minute can be achieved via a single injection valve.

Conclusion: Optimized processes and procedures influence operating costs

Liquid polybutadienes, such as Polyvest ST, offer great advantages for high performance rubber compounds, but place high demands on handling, dosing and injection equipment. Not only do high viscosities create challenges, but high polymer liquids also exhibit special rheological properties that make precise and rapid handling difficult. Safe handling of these materials is particularly successful when using sealed systems, such as the Zeppelin Liquid Dosing System.

If an efficient Zeppelin Liquid Dosing System is available, liquid additives stabilized with filler, referred to as dry liquid

concentrates, can be eliminated, and more cost-effective and reactive pure liquid chemicals without carriers or waxes can be used. Not only does this significantly reduce the cost of chemicals, but it avoids disposal costs by reducing waste packaging. A very high level of safety exists with the Liquid Dosing System, and a pre-installed, factory tested modular Skid system is available. The Skid system not only reduces assembly time, but it can very easily be relocated to another site by forklift truck to meet production demands.

Zeppelin Systems is focused on process optimization and customer satisfaction, and has supplied in excess of 80 complete plant projects at well known tire manufacturers around the world. The company offers interested industrial companies starter packages to give them the opportunity to test the Liquid Dosing System in production, at their factories. The starter package includes four modules that are compatible with any mixer. Via plug-and-play, the system can be installed quickly and easily, and demonstrate its fast, safe and accurate dosing in real production environments.



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