The new RFL-free adhesion promoters offer several advantages in the production of seals and moulded parts. (Image: iStock.com/Henadzi Pechan)

RFL-Free Adhesion Promoters for Textile-Reinforced Seals

Design Considerations
RFL-free adhesion promoters provide high bond strength without resorcinol, formaldehyde or isocyanates.

Production Considerations
Pre-dipping and solvent-based methods for positioning the reinforcement can be eliminated. This simplifies the process chain and reduces exposure to substances of concern.

Quality Management Considerations:
The formulations contain no resorcinol, formaldehyde, isocyanates or solvents, helping manufacturers meet increasingly stringent material and emission safety requirements.

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New Approaches to Textile Reinforcement in Rubber Applications and to Safer, More Efficient Processes

Resorcinol-formaldehyde latex (RFL) has long been established as an adhesion promoter in textile-reinforced seals. However, it is coming under increasing scrutiny because of health concerns. A new approach does more than replace RFL with a chemical system of lower health concern. It combines high bond strength with tangible benefits for the production process, providing a decisive advantage in industrial rubber processing.

Resorcinol-formaldehyde latex (RFL) is an adhesion promotion system that has been used successfully for decades. It addresses one of the rubber industry's key challenges: creating a durable bond between rubber and reinforcing materials such as polyester, polyamide, aramid or glass fibres. These fibres offer high strength but naturally adhere poorly to elastic rubber compounds. Once cured, RFL forms a functional interlayer that reliably bonds the two materials.

RFL is used in applications including seals, tyres, conveyor belts and hoses. Although RFL delivers excellent chemical performance, it must be viewed critically from a health perspective. The main concern is formaldehyde, which has been classified as carcinogenic by the European Union. Workers may be exposed to formaldehyde during the production of RFL systems, the coating of textiles in dipping processes and subsequent thermal processes. This results in strict requirements for occupational safety, emission control and the monitoring of production facilities.

Resorcinol is also increasingly subject to regulatory scrutiny. The substance is considered a health concern and is being monitored for its potential effects on people and the environment. As a result, the search for alternatives that pose fewer health risks has intensified in recent years. The desire for greater sustainability has also accelerated this technological shift.

High Requirements for Adhesion Promoters

These developments led Collano to pursue a new approach. The development team did not simply want to replace RFL.
Its goal was to develop an adhesion promoter that would also be safer, easier and more efficient to use.

The primer effect, meaning improved adhesion between the reinforcing fibres and the rubber, is only the first and most obvious requirement. The material combination consists of high-strength, rigid fibres and fabrics on the one hand and soft, elastic rubber compounds on the other. The adhesion promoter must bond to both materials and provide high resistance to tensile, peel and vibration loads. It must transfer forces between the materials and compensate for stress concentrations at the interfaces. Ideally, the bond to the substrates should be stronger than the cohesion of vulcanised rubber itself. In the event of failure, the rubber should tear rather than the materials delaminate at the interface. The requirements are particularly demanding for highly stressed components such as seals, which may be exposed to millions of load cycles during continuous use. These dynamic loads must not cause microcracks or delamination.

A further challenge is that rubber is not a uniform substance but a chemically diverse group of materials. The most commonly used rubber types include natural rubber (NR), styrene-butadiene rubber (SBR), nitrile rubber (NBR) and ethylene-propylene-diene rubber (EPDM). Vulcanisation takes place through the formation of sulphur bridges or by peroxide-induced radical polymerisation. SBR and NBR can also be vulcanised using heat alone. Vulcanisation temperatures range from 120 °C to 180 °C, and the materials may also be exposed to high temperatures during service. This places additional demands on the temperature stability of the adhesion promoter.

The New Development Approach

Collano has succeeded in combining the requirements for technical performance and increasingly stringent regulations in a new adhesion promoter. The formulations are based on aqueous acrylate or ionomer dispersions while avoiding ingredients of toxicological concern. The dipping solutions are therefore free from solvents, resorcinol, formaldehyde and isocyanates.

The crosslinking required for durability and resistance to continuous loading is ensured by the use of multifunctional acrylates. Thanks to the acrylate chemistry of the adhesion promoter, formulations for peroxide vulcanisation can be produced without adding peroxide. As a result, both the adhesion promoter and the impregnated reinforcing fibres and fabrics remain stable in storage for several months. Crosslinking takes place during vulcanisation itself and is initiated by radicals in the rubber.

Simplified Processing

Moving away from conventional RFL and isocyanate chemistry provides further technical benefits. Fibres with low surface energy, such as polyester and aramid fibres, normally require pre-dipping to achieve sufficient bond strength in combination with an RFL solution. With the new solution, this processing step is no longer necessary for these fibre types. The adhesion achieved by the adhesion promoter alone meets the requirements. The ability to formulate the adhesion promoter with a slight permanent tack offers another opportunity to simplify the process. In geometrically complex seals in particular, the reinforcing fibres must be fixed in position on the uncured rubber blank. This is usually done by making the rubber blank tacky with solvents such as toluene or hydrocarbon solvent blends, allowing the reinforcing fibres to be positioned. The new, slightly tacky adhesion promoter enables the fibres to be positioned without using solvents. It also makes it possible to pre-fix multiple layers of rubber and fabric.

Proven Effectiveness

The performance of the adhesion promoters was evaluated using the H-pull-out test in accordance with ASTM D 4776-18. A peroxide-cured EPDM rubber was selected as the rubber component, while a three-ply twisted polyester cord with a linear density of 1,100 dtex was used as the reinforcing material.

Various Collano adhesion promoters were compared with a conventional RFL solution [1] and the commercially available Cokoon dipping solution [2].

Performance comparison of various adhesion promoter systems and test results

Pull-out force at different temperatures	**Pull-out force** at 20 °C	**Variation**	**Pull-out force** at 120 °C	**Variation**
RFL solution	194 N	± 9 N	117 N	± 8 N
Cokoon dipping solution	127 N	± 9 N	58 N	± 4 N
Adhesion promoter 1	170 N	± 15 N	70 N	± 5 N
Adhesion promoter 2	129 N	± 5 N	60 N	± 6 N
Adhesion promoter 3	168 N	± 22 N	77 N	± 12 N
Adhesion promoter 4	191 N	± 15 N	95 N	± 6 N
Adhesion promoter 5	120 N	± 17 N	82 N	± 7 N
Adhesion promoter 6	99 N	± 18 N	78 N	± 19 N

The proprietary adhesion promoters investigated [3] are based on an aqueous ionomer dispersion, a multifunctional acrylate monomer and a surfactant. Depending on the formulation, additional aqueous dispersions or a peroxide were used. The dispersions can contribute to the formation of a slight permanent tack, while the peroxide accelerates crosslinking when vulcanisation times are short. Six variants were developed and tested under identical conditions to systematically investigate the influence of the formulation. The adhesion promoter dispersions were diluted with water so that the impregnated polyester cords had a dry add-on of 250 ± 40 mg per linear metre. Adhesion promoters 1 to 3 produced slightly tacky cords, while adhesion promoters 4 to 6 produced dry cords. The RFL and Cokoon dipping solutions were applied as described in the literature. The impregnated cords were then embedded in a peroxide-cured EPDM rubber. The test specimens were vulcanised at 160 °C for 30 minutes under a pressure of 35 bar.

The pull-out strength was measured at both 20 °C and 120 °C. Testing at 20 °C determines adhesion under standard conditions, while testing at 120 °C simulates typical continuous service temperatures. It also distinguishes between purely thermoplastic adhesion promoters and systems that chemically crosslink before or during vulcanisation.

As expected, the established RFL system continues to achieve the highest pull-out forces. It is noteworthy, however, that several of the newly developed adhesion promoters already achieve values between those of RFL and the commercially available Cokoon system. This demonstrates that a completely RFL- and isocyanate-free approach is technically feasible. The performance at 120 °C is particularly significant. Several Collano formulations retain a considerably higher proportion of their bond strength than the Cokoon system. This indicates that crosslinking takes place successfully during vulcanisation and that adhesion is maintained even at elevated service temperatures.

Conclusion and Outlook

The results show that completely RFL- and isocyanate-free adhesion promoter systems are technically feasible today. In addition to eliminating resorcinol, formaldehyde and isocyanates, this approach offers further potential for simplifying the process chain. Examples include eliminating the need for pre-dipping and enabling solvent-free positioning of textile reinforcements. The approach therefore goes beyond simply replacing one chemical system with another. Alongside improved environmental protection and occupational safety, it provides tangible benefits for industrial applications.

Development is not yet complete. Rubber is not a uniform material but encompasses a wide range of rubber types, fillers and vulcanisation systems. While the initial development work focused on peroxide-cured EPDM rubber, initial tests have shown that sulphur vulcanisation and other rubber types require adjustments to the formulation. The challenge in each case is to align chemical compatibility with the relevant vulcanisation parameters without compromising adhesion.

References

[1] A. Louis et al., KGK, March 2016, p. 30 ff., Table 2
[2] S. Bas et al., US10145034B2, Table 1
[3] P. Frei et al., patent pending, European patent application no. 25182543.6

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