

## **6. Silicones in Household Cleaning Applications**

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Silicones and household cleaning applications have been associated for more than 50 years, particularly in the laundry area, where the main use is foam control in consumer washing machines and fabric softening. But silicones are also used to provide extra benefits such as fabric dewatering, antiwrinkle characteristics, ease of ironing or improved water absorbency. Silicone additives have also been developed to reduce fabric mechanical losses over time or to improve perfume release.

A wide range of foam control agents exists. These foam control agents prevent (antifoams), and knock down (defoamers) foam that occurs in both the manufacture of detergents and during their use by consumers at home, or by professionals.

Antifoams are critical in many consumer applications. For example, in a washing machine, a steady control of foam is needed, rather than its complete elimination or prevention. Correct foam control is essential since consumers are very perceptive about foam levels. Moreover, incorrect foam levels can reduce the detergent's cleaning efficiency.

Silicone foam control agents are based on combinations of polydimethylsiloxane (PDMS) and finely divided silica particles. This particular combination seems most effective.

To optimize antifoam performance, the foam control agent must be properly incorporated into the detergent product with an effective protection system so it will subsequently disperse into the wash liquor in the right form. Silicone antifoams have been developed either as compounds, ready-to-use emulsions for liquid detergents or solid powdered forms that are easy to incorporate in powder detergent formulations. Delivery form and stability of the silicone antifoams (i.e., protection from the detergent under various temperature or humidity conditions) are critical aspects.

Silicone antifoams are also used in the manufacture of detergents to help processing of detergent liquids, to de-air the wet slurry and improve powder density in the spray-drying towers for powdered detergents, or to facilitate all types of bottle-filling operations.

### **Silicones for Delivering Fabric Care Benefits**

Within the textile industry, silicone products have been used for almost 50 years. The primary textile benefits and applications from silicones have been as antistatic agents, fibre and thread lubricants during fabric production, and antifoaming and fabric softening agents during the fabric-finishing step.

It is known from both the textile and laundry industries that the laundry wash cycle process removes most of these fabric finishes. It is considered that about 10 wash cycles are sufficient to remove most of the garment's initial fabric treatment.

With ever-demanding consumers having less time for clothing care, wanting clothing to look better and as new as possible after repeated washings, and expecting clothes to be comfortable directly from the dryer, it became a market need to deliver the known textile industry technology benefits in consumer laundry products.

Key technologies and silicone product parameters in fabric care are:

- Polymer architecture and functionality
- Type of delivery vehicle
- Particle size properties of emulsion vehicles
- Surfactant systems used with emulsion vehicles

The association of a flexible backbone with low intermolecular interactions as limited to methyl groups explains the lubrication characteristics of PDMS. Some methyl groups can be substituted by other groups, such as hydroxy, amino, amido, polyether and longer alkyl, either along the chain (grafted) or at the ends of the chain (end-blocked). These functionalities allow adjustment of the architecture of the polymer to tailor the interactions between these polymers and the fabric during and after laundry. Some polymers can be cyclic, but the majority are linear with various molecular weights, from volatile fluids to high consistency gums. They can also be cross-linked to variable levels to provide higher substantivity, controlled spreading and elastomeric properties.

Depending on the requirements of the application, the above silicone polymers can be delivered as self-emulsified in the formulation (polyethers), emulsified in situ (low molecular weight amino-functional polymers) or pre-emulsified (most polymers). Some formulations may contain volatile silicones as a secondary delivery system within the emulsion.

Silicone emulsions are available either as microemulsions (<100 nm) or macroemulsions (>100 nm), depending on the polymer architecture and functionality selected. The emulsion particle size is often related to the properties ultimately observed on a fabric. Microemulsions are able to penetrate into the yarns and deposit onto the fabric fibers, bringing a soft, dry feel to fabric. Studies suggest that the deposition of silicone is internal, which provides dry lubrication of individual fibers against each other with a very thin coating of silicone, probably reducing the static coefficient of friction. Macroemulsions deposit on the external surface of the fabric, causing superior lubrication through reduction of the dynamic coefficient of friction. They provide relatively good fabric softening performance.

Silicone emulsions may be formulated with adequate anionic, nonionic or cationic surfactants. The choice is driven by the compatibility with the application formula and the mechanism of silicone action or deposition. To provide its benefits, the silicone must generally deposit on the fabric. This deposition is triggered either by the polymer functionality and/or by the emulsion surfactant system used in synergy with the application formulation.

*Fabric Softening.* Numerous patents have been filed [1-2] on this application since 1976, and many commercial product implementations exist [3], mainly in fabric softeners but also in liquid detergents. The fundamental properties of silicones behind this application benefit are their low surface tension, low intermolecular interactions, high spreading and nonadhesive characteristics. Some studies have demonstrated high levels of silicone deposition onto fabric when delivered from fabric softeners.

*Fabric Dewatering.* There is an interest in terms of consumer convenience to accelerate fabric drying, matching wash and drying cycle times, and also to contribute to a reduction of electricity consumption when tumble dryers are used. Reducing the amount of water left in

the fabric after the wash and spin cycle directly correlates with a reduction of drying time and energy. Studies have shown that when dosed at 1% active silicone in the softener, up to a 13% further reduction of water content can be achieved with the tested silicones over fabric rinsed with organic quaternary ammonium salts, which already reduce water content by 23% over the water-rinsed fabric. It is believed that the fundamental silicone properties behind this benefit are hydrophobisation of the fabric surface and its subsequent dewetting, as well as its low surface tension, which allows fast spreading. Several patents were issued and are commercially practiced [4-5].

*Ease of Ironing.* The ease of ironing benefit can be subjectively assessed through paired comparison panel tests but can also be objectively measured by coefficient of friction measurements. Several patents exist and are practiced in the fabric softener market [6-7]. The fundamental properties behind this application benefit are the same as softening, with the proviso of higher levels and external deposition of the silicone.

*Wrinkle-Related Benefits.* Perhaps the most critical objective of fabric care is to reduce garment wrinkling after the wash cycle and during ironing, and also to improve wrinkle resistance during wear. This is a difficult technical challenge, because the mechanism of wrinkle formation is complex and not easy to access from a laundry application perspective. The textile industry has been able to meet this challenge to some extent through the application of “easy care” finishes. These treatments are based on a high-temperature cure of crease resist resins (dimethylol-dihydroxyethyleneurea or DMDHEU), organic quaternary ammonium salts and silicones. However, this is not compatible with consumer washing processes and safety. The current opportunity is great for technical improvements that would bring satisfactory performance. Many patents [8-9-10-11] have been published in this field for various product formats (e.g., sprays, fabric softeners and detergents), and they always combine silicone with other ingredients or polymers. It is suspected at this stage that fibre lubrication is most likely to be the added benefit in this process together with the silicone softening touch.

*Water absorbency.* Fabric softeners have the down side effect of hydrophobizing fabric. This is a concern for consumers who want a soft, bulky towel with good absorbing properties. Surprisingly, in the middle 1980s, it was found that the addition of silicone polymer in a fabric conditioner composition actually improves the water absorbency of the fabric. Water absorbency is evaluated by a Drave’s wetting test, which measures the time required for a fabric sample to sink to the bottom of a beaker filled with demineralised water. Measurements are relative to a given organic quaternary ammonium salt type and are arbitrarily stopped after 300 s.

Several patents [12] were issued from the mid 80s until recently for a variety of silicone structures and compositions, but so far no clear, convincing interpretation of this phenomenon has been proposed. Because low molecular weight PDMS is known to be the most effective in water absorbency studies, we suspect that the versatile orientation of the silicone molecule and its ability to modify surface hydrophobicity/hydrophilicity as well as its low viscosity and high spreading rate are involved.

*Modification of the Mechanical Properties of Fabric.* Sophisticated investigation found that particular silicone products formulated in a fabric softener have a positive impact on the

fabric's mechanical strength compared to water-rinsed or pure softener-rinsed fabric. This was observed using the "tear crack propagation" method as described in the DIN ISO 13937-1:2000 standard. It is suspected that the elastomeric nature of the silicone polymer and its lubrication properties are involved in this phenomenon. It is also believed that treating fabric with silicone lubricants can reduce fabric wear abrasion and consequently improve color definition, reduce pilling and fuzziness, and help retain original fabric shape.

*Silicones as Perfume Release Modifiers.* Perfumes are present in almost all consumer surfactant-based products in the household and cleaning segments. Perfumes are added to cover residual odours from raw materials but also for more subjective purposes. Both protection and controlled release of perfumes have been areas of development in recent years in household and cleaning products. Silicones are being considered here because of their high permeability to gas and low molecular weight organic molecules and also because this property can be reduced and adjusted (e.g., by using bulky alkyl side groups). Silicone can also easily be formulated under different product forms: from volatile dispersions, emulsions, or particles to devices made from a cured elastomer [13-14-15-16-17].

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This article has been published in the chapter "Silicones in Industrial Applications" in *Inorganic Polymers*, an advanced research book by Nova Science Publishers ([www.novapublishers.com](http://www.novapublishers.com)); edited by Roger De Jaeger (Lab. de Spechtrochimie Infrarouge et Raman, Univ. des Sciences and Tecn. de Lille, France) and Mario Gleria (Inst. di Scienze e Tecn. Molecolari, Univ. di Padoa, Italy). Reproduced here with the permission of the publisher.