4. Silicones in the Pulp and Paper Industry

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Organosiloxane materials can be found throughout the processing of pulp and paper, from the digestion of wood chips to the finishing and recycling of papers. Some examples are:

- As digester additives, silicones improve the impregnation of active alkali in the wood chips and improve the cooking
- As antifoams, silicones help de-airing or drainage in the pulp washing and papermaking processes
- As additives, silicones contribute in the finishing process of paper and tissues
- In the recycling of papers, silicones act as de-inking aids

Some specific examples are developed here to demonstrate how the properties of silicones can bring benefits as antifoams in the paper pulp-washing process and as softening agents in the treatment of tissue fibers.

Antifoam in the Pulp-Washing Process or Brownstock Washing

Kraft or sulfate pulping remains the most common chemical process used to produce bleached and unbleached pulp of high quality [1]. The wood chips are impregnated with an alkaline liquor containing NaOH and Na_2S and digested at high temperatures. During this process, delignification and degradation of esters from fatty acids, resin acids and sterols occurs. This generates surface-active molecules that create excessive foam during the pulp-washing process. The presence of foam is a serious problem for the paper mill operator since it dramatically reduces washing efficiency, and in extreme conditions, can lead to an overflow from the filtrate vat spilling onto the washroom floor. In some cases, such an event can cause the shutdown of production.

Both organic and silicone antifoams are used and subjected to harsh conditions of pH (11 to 12.5) and temperature (80 to 95 °C). Antifoams are typically based on a combination of a hydrophobic and insoluble oil formulated with hydrophobic solid particles. These mixtures are generally called antifoam compounds [1]. Organic antifoam compounds are generally based on mineral, paraffin or vegetable oils and particles made of amide waxes like ethylene-bis-stearamide (EBS) or hydrophobized silica. Silicone antifoams are usually made of polydimethylsiloxane (PDMS) fluids compounded with hydrophobized silica.

Silicone antifoam compounds are sometimes combined with more hydrophilic organic polyethers or silicone polyethers, which can help the emulsification of the silicone compound and act as co-antifoam agents if their cloud point is below the application temperatures.

To control foaming over a long enough period of time, organic antifoam must generally be added at higher dosage levels (0.5 to 5 kg/t, expressed as kg of antifoam per ton of dried pulp) if compared to silicone-based antifoams (0.2 to 0.8 kg/t).

In the most modern paper mills designed to run at high production rates but also with minimum water consumption, the washing of fiber stocks containing high soap levels as from Scandinavian softwoods or from birch is done under such harsh conditions that only silicone antifoams give the required level of performance. Silicone antifoams contribute to various effects in the process: as defoamers, they reduce the amount of foam immediately after their addition (this is called the “knock down” effect), but as antifoams they also prevent further foam formation and maintain their activity over a long period of time (this is called “persistency”). Silicone antifoams also help drainage and improve washing efficiency by reducing the level of entrapped air in the pulp mat [3].

Silicone antifoams for pulp and paper applications can be seen as a combination of polydimethylsiloxane (PDMS) chemistry, silica chemistry (as silica surface treatment is critical), and emulsion technology, as emulsions are sometimes the preferred route of delivery for the antifoam. Since its introduction in the pulp market in the early 90s, the technology of silicones as antifoams and drainage aids has dramatically evolved. Key improvements worth noticing in recent years are two-fold:

- Improvement in persistency, which allowed a dramatic reduction in dosage level
- Optimization of the way the antifoam active is delivered and dispersed in the processing media

Both are critical for reducing the risks of undesired antifoam hydrophobic deposits from these foam-control agents. Lower dosage reduces the amount of hydrophobic particle present, and improved delivery from specific emulsions (particle size, stability) reduces the risk of agglomeration of such insoluble components.

The persistency of silicone-based antifoams has been improved using PDMS polymers of very high molecular weight that are more resistant towards deactivation [4], less prone to emulsification upon use and have less tendency to liberate the hydrophobic silica particle if submitted to high shear. Careful selection of the silica used (structure, surface area, particle size, porosity) is key to achieving optimum performance of the silicone-based antifoam.

Silicone-based antifoams are used at very low levels and generally formulated as self-dispersible concentrates or even more commonly as water-based emulsions. This allows a dramatic reduction in problems of pitch deposits that are commonly encountered with nonaqueous mineral oil/EBS-based antifoams [5].

Finally, over and above any technical requirements, antifoams for paper and pulp applications must meet acceptance under FDA Indirect Food Contact Guidelines 21 CFR 176.170, 180 or 210 and compliance with BGA Recommendations XV.1.A. and XXXVI.B.C1. These regulatory requirements are fulfilled by many silicone-based materials.

Silicone Finishes in Tissue Converting

Silicone materials are used as a surface treatment for tissue softening to enhance the performance of bath, toilet and facial tissues; paper towels, napkins and tablecloths; wet and dry wipes; and other consumer and commercial paper products [6].

Similar to other applications such as textile finishing, fabric treatment or hair care, a wide range of performance results from the use of silicones. Most new products for tissue converting are water-based, solventless emulsions. Silicones provide softening by reducing the coefficient of friction without reducing wet or dry strengths, providing antistatic properties and reducing dust and lint during use. More hydrophilic silicone polyethers can also enhance water and liquid absorbency.

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