Roles of Surfactants in Flotation Deinking

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INTRODUCTION

Flotation deinking is a common practice for removing ink from wastepaper, and it is becoming a key process in many recycling paper mills. Flotation deinking was successfully introduced to the paper recycling industry in the 1980s, and its applications in wax removal, sticky control, and fiber fractionation have attracted great research interest. A successful flotation process has three major efficient subprocesses: the detachment of the ink particles from the fibers, the effective adhesion of the ink particles onto air bubble surfaces, and the removal of froth and ink particles from flotation cells. Surfactants can affect these subprocesses either positively or negatively. To understand how a surfactant can positively and negatively affect the flotation deinking process, the basic chemistry of surfactant in solution should be discussed.

KEYWORDS

Deinking, Deinking chemical, Deinking performance, Flotation deinking, Paper recycling, Secondary fibers, Surfactant

WHAT ARE SURFACTANTS AND HOW ARE THEY CHARACTERIZED?

Surfactant is the abbreviation of surface active agents. To be surface active, the chemicals must have a lyophilic (liquid-loving) and lyophobic (liquid-hating) group. For an aqueous solution, these are usually called hydrophilic and hydrophobic groups. From this broad definition, any chemical that has both a hydrophilic and a hydrophobic portion should more or less have surface activity (reducing the surface energy of liquid or solid) and can be called a surfactant in general. By this definition, defoamers, dispersants, foaming agents, and collectors used in flotation deinking are all surfactants. Surfactants from a commercial chemical supplier are often blends of many different functional surface active and nonsurface active agents, such as sodium hydroxide, sodium silicate, etc.

The chemical structure of surfactants used for flotation deinking may differ significantly; they can be cationic, anionic, nonionic, or amphoteric. However, anionic fatty acids and nonionic surfactants are more commonly used. The hydrophile-lipophile balance (HLB) value has gained acceptance in the paper industry for characterizing surfactants (1).

Cloud point is a specific temperature-related phenomenon of surfactants. Below the cloud point, the surfactant molecules can be dissolved in water. As temperature begins to rise, molecules start to associate and come closer together and the surfactant solution becomes cloudy as a result of phase separation and loss of surface activity. For this reason, the cloud point temperature of surfactants used in deinking should be at least 5°C higher than the flotation deinking process temperature (2, 3).

GENERAL ROLES OF SURFACTANTS IN FLOTATION DEINKING

In general, surfactants play three roles in flotation deinking (1,4):

a) as a dispersant to separate the ink particles from the fiber surface and prevent the redeposition of separated particles on fibers during flotation deinking;

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b) as a collector to agglomerate small ink particles to large ones and change the surface of particles from hydrophilic to hydrophobic; and
c) as a frother to generate a foam layer at the top ofa flotation cell for ink removal.
Although surfactants play important roles in deinking, they can also have some adverse effects on ink removal, fiber quality, and water reuse. For example, the adsorption of dispersant and frother (5, 6) on fiber surfaces may reduce fiber–fiber bonding and create foaming problems in paper machines.

Not all types of surfactants are needed in flotation deinking. For instance, no collector is necessary in deinking hydrophobic inks, such as photocopy toner. The dispersant may also be unnecessary if the ink particles can be separated from fibers by other chemicals, such as sodium silicate, sodium hydroxide, and enzyme, or by mechanical actions, such as magnetic and electrical fields and ultrasonic irradiation. However, a frother must be used to obtain a stable foam layer for ink particle removal in flotation deinking.

SURFACTANTS USED IN FLOTATION DEINKING

Although HLB value, cloud point, critical micell concentration (CMC), and detail structure are useful tools for characterizing surfactants, they should not be used as the primary factors in selecting a surfactant for flotation deinking. Deinking conditions, such as furnish, water hardness, pH, and temperature, are different in each paper recycling mill. As a result, a surfactant formulation that works well at one mill may not work at another mill.

Dispersion Agents or Anti-Redeposition Agents

Dispersants assist in separating the ink particles from the fiber surface and preventing the redeposition of separated ink particles on fibers during flotation deinking. Nonionic surfactants, such as ethoxylated linear alcohols, ethoxylated alkyl phenols, ethoxylated fatty acids, oligoethylene-oxide alkyl ether, and polyethyleneoxide alkyl ether, are widely used in deinking mills as dispersants because they can function independently, they are not affected by water hardness, and their hydrophilic–hydrophobic properties can be very easily controlled by synthesis chemistry.

Dispersants can lower the surface tension of the pulping medium, thereby increasing the wettability of ink-coated fiber and improving the ink–fiber detachment. Rao and Stenius (7) and Pirttinen and Stenius (8) suggested that nonionic surfactants, such as polyethyleneoxide alkyl ether and modified compounds of this surfactant type, are capable of assisting the detachment of coldset offset ink particles from newsprint. Dispersants can solubilize the detached ink particles and create a stable emulsion that does not readily redeposit onto the fiber. Because dispersants provide the ink particles with a solubilizing surface chemistry as the surfactant adsorbs, this kind of chemical can adversely affect favorable interactions with hydrophobic calcium soap complexes and result in poor flotation efficiency. Therefore, dispersants should be used with caution in flotation systems that use fatty acid soap as the collector.

One of the most commonly used surfactants in the flotation deinking process is fatty acid soaps. Generally, fatty acids react with calcium ions in the system to form calcium soaps which can adsorb onto the ink surface and provide the collector action (9). The fatty acid soap system is not a good dispersant in general. It can function as a dispersant only if there are free fatty acids in the pulp suspension.

Collectors

As the name implies, the function of a collector is to aggregate very small ink particles that have been released from the fibers by the pulping action. The particles are then more efficientlyremoved by the uprising air bubbles injected by the flotation unit. The optimal particle size range for flotation deinking is 10 to 100 µm. However, before collectors are added, most ink particles are much smaller than 10 µm. Collectors can be made from naturally occurring materials, such as fatty acid soaps, synthetics such as polyethylene oxide and polypropylene oxide copolymers, and blends such as ethoxylated fatty acids. It is always necessary to balance the effects of a collector with those of a dispersant in flotation deinking, if dispersant is used.

Fatty acids are often used as a collector due to their ability to form ink-affinitive soaps with calcium ions. These 16- to 18-carbonchain amphoteric molecules are produced during NaOH-mediated ester hydrolysis (that is, saponification) of triglycerideadditives. The acidic end groups readily complex with calcium ions present within a pulper to form calcium soap precipitates. These soaps will eventually associate with detached ink particles, thereby rendering them hydrophobic. Additional calcium ions within the pulping medium contribute to charge neutralization of the ink particles. These ink–soap complexes will heterocoagulate with similar complexes and can ultimately form ink particle aggregates within the floatable size range of 10 to 100 µm. However, the overall size of the heterocoagulated aggregate is also a function of the shearing forces present within the pulper. These forces serve to disrupt larger aggregates and thereby establish an average particle size within a particular system. It has been found that the absence of double bonds in the carbon chain of fatty acid, such as stearic acid, helps in ink removal from the fiber (dispersion function) while the presence of double bonds, such as linoleic acid, helps with flotation (collector function) (9, 10). It has also been reported that a formulation with a high percentage of stearic acid gives the best flotation deinking results (4).

Currently, fatty acid soaps are widely used in old newspaper–old magazine (ONP–OMG) deinking. The fatty acid–calcium soap formulation is considered to be the most prevalent collector system in the industry today, and most commercially available deinking agents are founded upon this chemistry. Although fatty acid soap formulation is widely used in flotation deinking, it still has some unfavorable effects on deinking performance. Generally, calcium ions need to be added to convert the fatty acid soaps to the calcium soaps. However, the calcium ions are believed to cause scaling and deposition problems on paper machines and other equipment in a deinking plant.

Frother

The function of the frother is to generate a foam layer at the top of the flotation cell for ink removal. A frother must be used to obtain a stable foam layer to remove ink particles. Nonionic surfactants are widely used as frothers in flotation deinking because they have excellent foamability and function independently of water hardness. A fatty acid system could serve not only as the collector but also as the frother and dispersant in a flotation deinking operation only when there are free fatty acids in the pulp suspension.

Ink removal efficiency depends on several factors such as the ability to separate the ink particles from the fibers, the collision probability between ink particles and air bubbles, the interfacial energy between ink particles and the air bubble surface, the specific contact surface area between ink particles and air bubbles, the stability of the froth for final ink removal, etc. It is well known that surface chemistry plays a key role in flotation deinking. It has also been shown that froth stability is critical for ink removal. Ink removal efficiency increases with an increase in froth stability. Unfortunately, the increase in frother concentration in the pulp suspension may increase the adsorption of surfactant by ink particles, resulting in a reduction in surface hydrophobicity of the ink particles and therefore low ink removal (5). Therefore, there is an optimum frother concentration for efficient ink removal.

In our recent studies (11, 12, 13), we found that both physical entrapment of fibers in an air bubble network and adhesion of hydrophobic parts of fiber surfaces on air bubble surfaces contribute to the total fiber loss in flotation deinking. However, physical entrapment is the major contributor. We also found that fiber and water losses are directly related to the froth stability and froth structure. The fiber entrapment is dictated by the gravitational, buoyant, fluid dynamic drag and surface or capillary forces. In general, a froth with a structure consisting of small bubbles causes high fiber and water losses due mainly to the low water and fiber drainage in the small diameter of the plateau board channels. These channels are formed where the neighboring liquid films between the faces of the polyhedral bubbles meet.

Because mechanical entrapment of fiber and water in the froth is the major reason for fiber and water losses, effectively controlling the stability, structure, and fluid dynamics of froth is critical for reducing fiber and water losses. It is understood that an effective mechanical control of the froth properties and production rate can be achieved by controlling surfactant concentration and distribution in the froth.

Defoamer or Antifoamer

Because froth stability, froth structure, and froth dynamics are critical to ink removal and fiber and water losses, sometimes defoamer is added into the flotation pulp slurry to control froth stability and structure. Also, adding a defoamer could suppress the formation of foams during the papermaking process. Low HLB surfactant and finely divided hydrophobic silica particles dispersed in silicone oil are effective defoamers (14, 15).

COMPLEX ROLES OF SURFACTANT IN FLOTATION DEINKING

Although surfactants used in deinking can be categorized as frother, dispersant, collector, and defoamer, most surfactants often play multiple roles (for example, dispersants can generate foams in general) that can either positively or negatively affect the deinking process. Therefore, surfactant suppliers should take all these aspects into consideration in surfactant formulation. Figure 1 shows the possible impacts that surfactants may have in flotation deinking.

SUMMARY

The function of surfactants or surfactant systems is to release ink particles from the fibers, stabilize liberated particles, aggregate dispersed particles and/or modify the surface properties of released ink particles, and improve the overall ink removal of a flotation line. Although dispersants and collectors may not be necessary for some pulps, a frother must be used to obtain a stable foam layer to remove ink particles.

Although surfactants used in deinking can be categorized as frothers, dispersants, collectors, and defoamers, most surfactants play multiple roles and can affect the deinking process either positively or negatively. Therefore, surfactant formulation for flotation deinking should take all aspects into consideration.

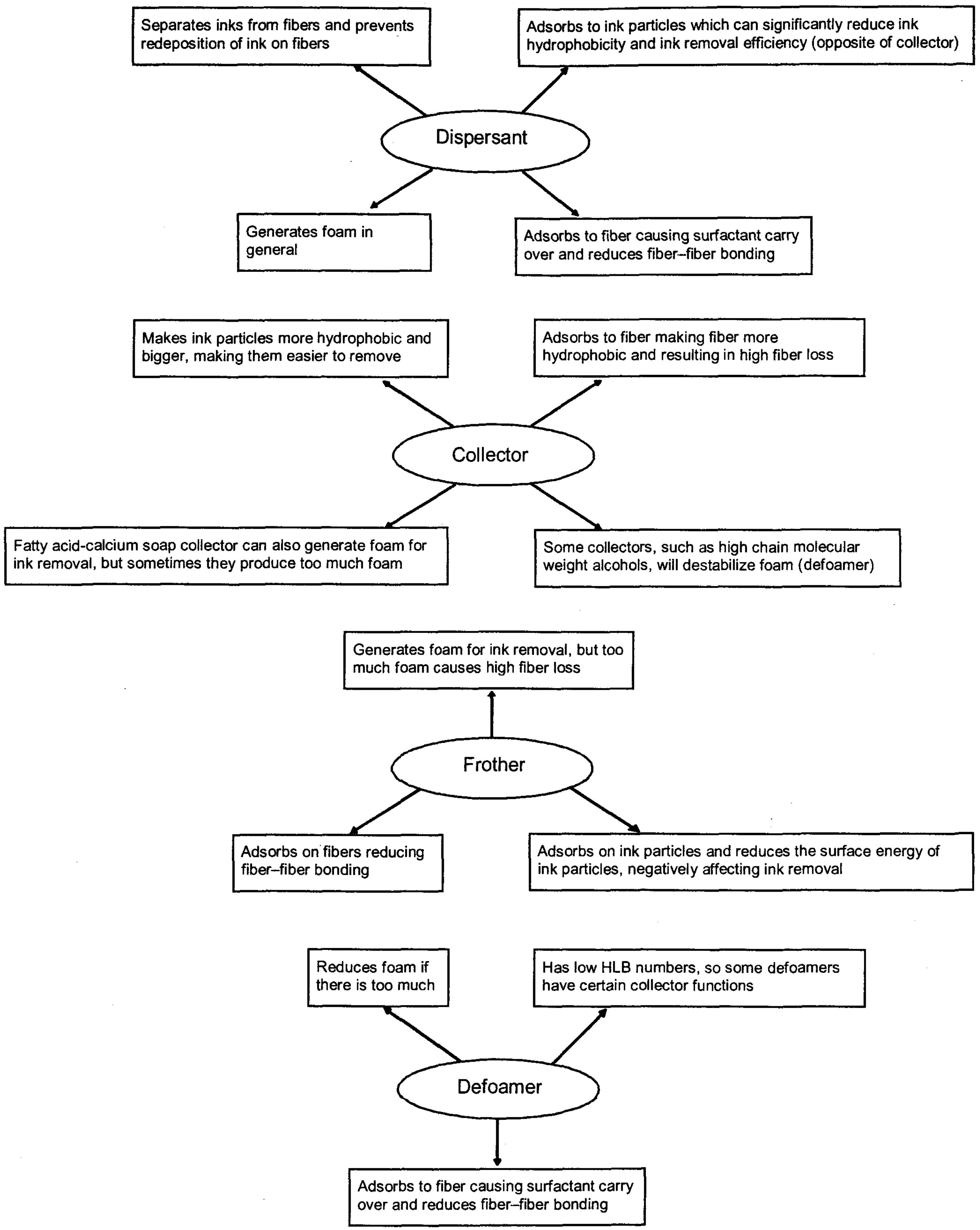

Figure 1. **The complex roles of surfactants in flotation deinking.**

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