Soap Flotation: A Brief Review

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Abstract

Homologues of fatty acids derived from vegetable oils/flats are used as collectors as such or as their soaps in the flotation of silicate/oxide/salt type minerals. Straight chain saturated fatty acid anions are envisaged to form compact adsorbed patches on the mineral surface, which are more effective in imparting surface hydrophobicity to the minerals than the loose/fluffy patches formed by unsaturated fatty acid anions that are bent at the double bonds. Addition of detergents or certain hydrotropes along with fatty acid/soap collectors reduces the consumption of fatty acids/soaps and thereby improves selectivity of mineral separation.

Keywords: Soap, flotation, fatty acid, hydrophobicity, mineral separation

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INTRODUCTION

Concentration of sulphide minerals was a challenging problem in front of the mineral beneficiation scientists in the 90s and beginning of 20th century [1]. Many alternatives were tried based on specific gravity, magnetic separation etc. but were largely failed. In 1900, the flotation as a method of mineral separation emerged, which was improved in 1905 by the Mineral Separation Ltd.—a small London-based company. The process involved addition of small amount of oil drops to the flotation pulp and followed by aeration of the pulp.

Over the period, selective collectors for specific minerals were found, for example, xanthates, dithiocarbamates, dithiophosphates that are very selective collectors for sulphide minerals among which xanthates are widely used in the industry [2, 3].

Fatty acids and their soaps are used as collectors for silicate (e.g. sillimanite), oxide (hematite) and salt type (apatite, fluorite) minerals [2, 3]. In industrial practices what is being used as oleic acid/sodium olate is in fact homologues of fatty acids derived from oils and fats.

Fatty acids are found in nature as esters of glycerol, commonly known as oils, fats [4]. Fatty acids and their soaps are characterised by certain chemical/physical properties such as total fatty matter (TFM), iodine value (IV), and relative measure of unsaturated bonds present in the oil or fat [5]. Titre value (TV) is the solidifying point of the fatty acids.

Fatty acids with double bonds are unsaturated. Unsaturated fatty acids having a bend/kink at double bond are cis-types and unsaturated fatty acids without bend are trans-types [4]. Out of these, trans-types are more stable and are straight chained. Saturated and trans-unsaturated hydrocarbon chains of fatty acids fit together as compact bundle well, which is not the case with cis-types.

Sodium salts of fatty acids are water soluble and at certain concentration known as critical micelle concentration (CMC) of the solute; molecules form into aggregates known as micelles [6]. Micelles are initially spherical with the nonpolar, hydrocarbon chains of the fatty acids oriented towards the core of the micelle and the polar part towards the solvent (water). Sharp change in the physical properties of the solution (surface tension,
viscosity, conductivity, etc.) against the concentration of the solute indicates the CMC formation.

Soap anions having a polar part (carboxylate functional group) attached to a nonpolar part (hydrocarbon chain), fits the conventional way of describing a collector in flotation process. Taggart noted that soap used as collector must be C8 or greater than C8, preferably greater than C12 and should not be greater than C18 or C20 (they are low soluble) [7]. Common oils and fats contain a variety of fatty acids such as caprylic, capric, lauric, myristic palmitic, oleic, linoleic, linolenic, stearic, ricinolic, behenic, archidic, etc., with varying lengths of hydrocarbon chains and varying number of double bonds in the hydrocarbon chain. The driving forces of adsorption of soap anions are electrostatic attraction between the polar part of the collector and surface charge on the mineral, thermodynamic forces, which originate due to the incompatibility of nonpolar part with polar water and the ability of soap anions to chemisorb on the mineral surface [6, 8]. Selective separation of carbonates (calcite, dolomite) from apatite or fluorite using soap is a tough problem. Good results were reported by using N-sarcosine collector in the separation of calcite and phosphate minerals (Sillinjarvi, Finland) [9–12]. Tall oil soaps are used in the flotation of dolomite in acidic conditions while the chamber product is the phosphate concentrate are stringent at Jhamarkotra plant, India [14]. The specifications of Jhamarkotra soap are: TFM, 60–65%; TV, 22–25°C; preferred fatty acid composition: 26–31% saturated fatty acids (stearic, palmitic, myristic and lauric), 37–48% oleic acid; <24% linoleic; <1% linolenic; <1% fatty acids above C18, and so on. The fatty acid composition was analysed by Gas Liquid Chromatography. These specifications were arrived at after due observation of plant flotation performance at phosphate concentrator, Jhamarkotra, India. It is suggested that the patches of adsorbed soap anion formation on the mineral surface will be compact only when sufficient number of soap anions are saturated/straight chained which is a requirement for good flotation of dolomite in acidic pH [14]. Double bonds may be hydrated due to its basic nature particularly in acidic pH. Effective length of kinked molecules is reduced (Figure 1).

**SPECIFICATIONS OF SOAP COLLECTOR**

Soaps and fatty acids used in the mineral industry as collectors are rather poorly specified. Usually the specifications are limited to TFM, IV and Titre Point/ TV and sometimes unsaponifiable matter, free alkali and moisture are also specified for soaps. These specifications hardly give any idea about the fatty acid composition of the soap.

Specifications of soap used in the flotation of dolomite in acidic conditions while the chamber product is the phosphate concentrate are stringent at Jhamarkotra plant, India [14]. The specifications of Jhamarkotra soap are: TFM, 60–65%; TV, 22–25°C; preferred fatty acid composition: 26–31% saturated fatty acids (stearic, palmitic, myristic and lauric), 37–48% oleic acid; <24% linoleic; <1% linolenic; <1% fatty acids above C18, and so on. The fatty acid composition was analysed by Gas Liquid Chromatography. These specifications were arrived at after due observation of plant flotation performance at phosphate concentrator, Jhamarkotra, India. It is suggested that the patches of adsorbed soap anion formation on the mineral surface will be compact only when sufficient number of soap anions are saturated/straight chained which is a requirement for good flotation of dolomite in acidic pH [14]. Double bonds may be hydrated due to its basic nature particularly in acidic pH. Effective length of kinked molecules is reduced (Figure 1).

**PROMOTERS IN SOAP FLOTATION**

Some plants use soap–light diesel oil (LDO) emulsion instead of soap alone [15, 16]. LDO acts as an extender of the hydrocarbon chain of the collector. Use of soap–LDO emulsion helps in collecting coarse particles. But addition of LDO reduces selectivity to some extent or the other. It is reported that Jhamarkotra soap–LDO emulsion performed better as compared to tall oil soap–LDO emulsion in the direct flotation of phosphate mineral from Eshidiya mine, Jordan at bench scale testing [13].

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**Fig. 1:** (a) Compact Layer of Adsorbed Saturated Fatty Acid Anions on a Mineral Surface; (b) Fluffy Layer of Adsorbed Mixed Fatty Acid Anions on a Mineral Surface.
Soap molecules serve dual purpose in the flotation process, i.e., they act as both frother and collector. Using methyl isobutyl carbinol (MIBC)—a known frother—is reported to have improved the process efficiency of soap flotation with both oleate and stearate [17]. In the same study, it is also reported that stearate is more efficient than oleate with or without MIBC. The double bond in the hydrocarbon chain is polar, basic and undergoes reactions such as hydration [4].

Detergents such as sodium petroleum sulfonate (SPS) and alfa olefin sulfonate (AOS) are used in the phosphate concentrators at Phalaborwa, Foskor, South Africa and Jhamarkotra, RSMML, India, respectively along with soaps [18, 19]. Introduction of 150–200 g of AOS per ton of ore reduced the consumption of oleate from 2.25–2.5 kg per ton of ore to 1.15–1.25 kg per ton of ore.

HYDROTROPES IN SOAP FLOTATION

Much recently hydrotropes such as urea, sodium benzoate etc., reagents that enhance the dissolution of nonpolar solutes in water were shown to act as promoters in soap flotation in that they improve flotation efficiency [20–22]. Hydrotropes are similar to surfactants but with smaller hydrocarbon chain. It is noted from the earlier studies that pure zinc sulphide in cubic form showed flotability in concentrated solution of urea without activation by copper ions and without xanthate collector [23]. The exact reasons why urea enhances the flotation of minerals are not known.

SUMMARY

1. The specifications of Jhamarkotra soap that prescribes a minimum content of saturated fatty acids is built on the finding that stearate is more efficient than oleate as a flotation collector and that the double bonds in the hydrocarbon chains might get hydrated in acidic flotation circuits.

2. Presence of fatty acids with double bonds might form fluffy adsorbed layer on the mineral surface whereas straight chain fatty acids in the soap form compact adsorbed layer of fatty acid molecules on the mineral surface. The low solubility of stearate warrants its use as hot solution, if used alone.

3. Using detergents, frothers along with the soap collectors increase the separation efficiency and also reduce the consumption of soap.

4. Hydrotropes such as benzoate/urea act as promoters when used with soap collectors.

REFERENCES


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