Introduction to Lubricants and Additives for Polymer Compounds

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Discussion of additives that act as:

- Lubricants
- Adhesives
- Surfactants

Which function to:

- Improve dispersion of fillers/pigments
- Improve processability
- Improve functionality of the compound

How, What, Where, Why?

TRIBOLOGY

The science and study of the mechanisms of friction, lubrication and wear of interacting surfaces that are in relative motion.

Not:

The study of the depressing history of the Cleveland Indians!

TRIBOLOGICAL EFFECTORS

- Lubricants
  - Function to minimize frictional forces between moving surfaces
  - Can be classified as internal, external or both
- Adhesives
  - Function to increase interfacial forces created by surface attachment (I.e., mechanical bonding)
  - Increase the energy required to break adhesive bonds causing increased shear
- Surfactants
  - Create a surface active film via polar and non-polar ends
  - Polar end adsorbs/bonds to a surface
  - Wetting of the filler allows for improved low energy dispersion
  - Lubricant-like end effect

LUBRICANTS

Polymers are made of long chain molecules of varying sizes and distributions. These polymers tend to be:

- Relatively viscous above their melt temperature
- “Sticky” above their melt temperature

Lubricants serve to decrease the frictional forces found between:

- Polymer : Polymer
- Polymer : Metal
- Polymer : Filler
- Filler : Filler
- Filler : Metal

ADHESIVES

Adhesive-type additives are highly branched, relatively low molecular weight, low melt temperature (lower than the polymer) materials that disperse within both polymer and filler. The adhesives will form mechanical bonds with:

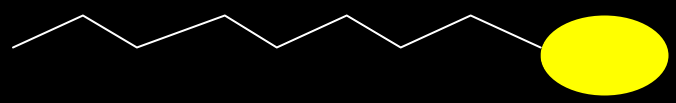
- Polymer : Polymer
- Polymer : Metal
- Polymer : Filler
- Filler : Filler
- Filler : Metal

The adhesion leads to increased shear forces, required to break the mechanical bonds, increased temperatures, therefore dispersion is improved.

SURFACTANTS

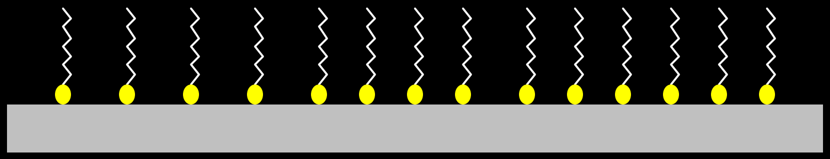
Surfactants = “Surface Active Agents”

Traditional Head-Tail structure:



Tail group is typically soluble in non-polar region (internal).

Head group is typically soluble in polar region or adsorbs to surfaces of polymer, filler or metal. The adsorption is typically via hydrogen bonding. Forms a monolayer with tail group providing lubricating effects.



LUBRICANT CLASSIFICATION

Taken from classical PVC terminology:

- **External = Insoluble**
  - Typically provide lubrication between the polymer and the metal surface of the processing equipment
  - Classic types:

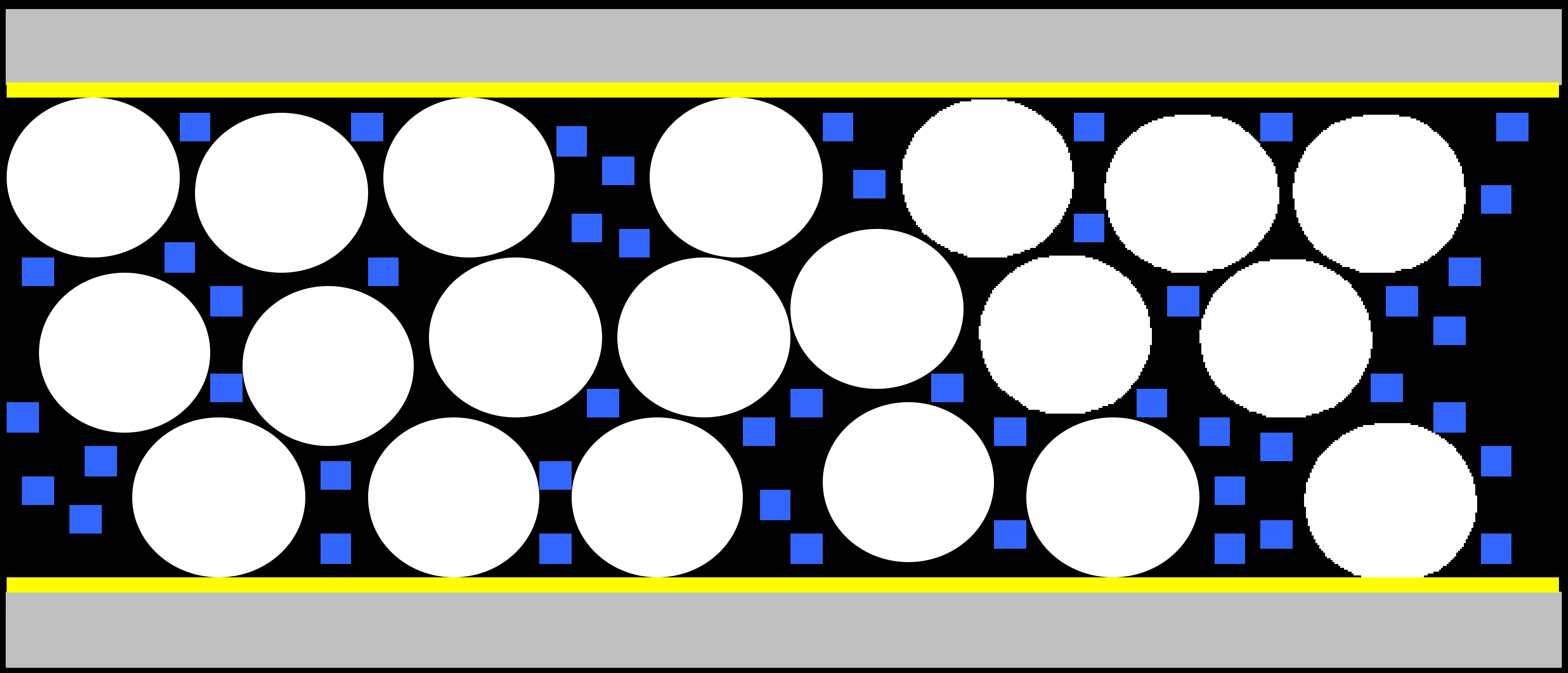
    Polyethylene waxes, Oxidized Polyethylene waxes, Paraffins, Metal Soaps, Esters (high esterification), Amides, Fatty Acids
- **Internal = Semi-Soluble (Plasticizer)**
  - Typically reduce bulk viscosity through partial compatibility with the polymer, thus opening the polymer chain with the lubricant's soluble component while providing intermolecular lubrication with the less soluble portion of the molecule.
  - Classic types:

    Fatty alcohols, Esters (low esterification), EVA Wax, others

GENERAL EFFECTS OF LUBRICANTS

- Internal Lubricants
  - Promote flow
  - Exhibit good clarity
  - Promote weld line strength
  - Minimize sink marks
  - Improve die filling
  - Reduce die swell
  - Reduce head and back pressure
  - Lower HDT
- External Lubricants
  - Provide metal release
  - Help reduce process temp
  - Can plate out
  - Slow fusion/recrystallization
  - Can cause delamination
  - Can lower weld line strength
  - Can cause surging

POLYMER + FILLER/PIGMENT + LUBRICANT/ADHESIVE



REMEMBER!

Most lubricants provide a combination of internal and external effects. It is the balancing of these effects in the formulation that will determine the ultimate and overall effectiveness of the lubricant!

AND

Lubricants will act differently in different polymer compounds due to chemical solubility. The solubilities change relative to polymer chemistry and other additive (Pigment!) chemistries!

GENERAL CHEMISTRIES OF LUBRICANTS

- Acid Amides
  - Primary Amides: Erucamide, Oleamide, Stearamide
  - Secondary Amides: EBS, EBO
- Acid Esters
  - PEMS, PEDS, PETS, PEAS, GMS, GMO, Montan Wax, Stearyl Stearate, Distearyl Pthalate
- Fatty Acids
  - Saturated: Lauric (C12), Myristic (C14), Palmitic (C16), ***Stearic (C18)***
  - Unsaturated: Oleic (C18), Erucic
- Hydrocarbon Waxes
  - Polyethylene, Polypropylene, OPE, Paraffin
- Metallic Soaps
  - Calcium, Zinc, Magnesium, Lead, Aluminum, Sodium, Tin, Barium, Cobalt, etc. Stearate

CHEMICAL STRUCTURE OF LUBRICANTS

- Acid Amides

Oleamide

$$
\begin{array}{l} \qquad\qquad\qquad\qquad\qquad\qquad\qquad O \\ \qquad\qquad\qquad\qquad\qquad\qquad\quad /\!/ \\ CH_3\text{-}(CH_2)_7\text{-}CH = CH\text{-}(CH_2)_7\text{-}C \\ \qquad\qquad\qquad\qquad\qquad\qquad\quad \backslash \\ \qquad\qquad\qquad\qquad\qquad\qquad\qquad NH_2 \end{array}
$$

Erucamide

$$
\begin{array}{l} \qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad O \\ \qquad\qquad\qquad\qquad\qquad\qquad\qquad /\!/ \\ CH_3\text{-}(CH_2)_7\text{-}CH = CH\text{-}(CH_2)_{11}\text{-}C \\ \qquad\qquad\qquad\qquad\qquad\qquad\qquad \backslash \\ \qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad NH_2 \end{array}
$$

- Acid Esters

Stearyl Stearate

$$
\begin{array}{l} \qquad\qquad\quad O \\ \qquad\qquad\quad \| \\ CH_3\text{-}(CH_2)_{16}\text{-}C\text{-}O\text{-}CH_2\text{-}(CH_2)_{16}CH_3 \end{array}
$$

PEDS

$$
\begin{array}{l} \qquad\quad OH\text{-}CH_2 \qquad\quad O \\ \qquad\qquad\quad | \qquad\qquad\quad \| \\ OH\text{-}CH_2\text{-}C\text{-}CH_2\text{-}O\text{-}C\text{-}(CH_2)_{16}CH_3 \\ \qquad\qquad\quad | \\ \qquad\qquad\quad CH_2\text{-}O\text{-}C\text{-}(CH_2)_{16}CH_3 \\ \qquad\qquad\qquad\qquad\quad \| \\ \qquad\qquad\qquad\qquad\quad O \end{array}
$$

- Fatty Acids

A large number of lubricants discussed today are based on a reaction of “stearic” acid with a metal ion, alcohol or amide. Stearic acid is a long chain fatty acid:

$$CH_3(CH_2)_{16} - \overset{\overset{\displaystyle O}{\|}}{C} - O - H$$

- Metallic Soaps

<u>Zinc Stearate</u>

$$ZnO + CH_3(CH_2)_{16} - \overset{\overset{\displaystyle O}{\|}}{C} - O - H \longrightarrow \begin{matrix} CH_3(CH_2)_{16} - \overset{\overset{\displaystyle O}{\|}}{C} - O \diagdown \\ \qquad\qquad\qquad\qquad\qquad\quad Zn \\ CH_3(CH_2)_{16} - \underset{\underset{\displaystyle O}{\|}}{C} - O \diagup \end{matrix} + H_2O$$

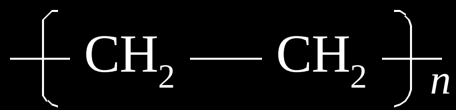
WHY "STEARIC" ACID?

Most "stearic" acid is a blend of fatty acids, with the grade determining the stearic (C18) acid volume percent:

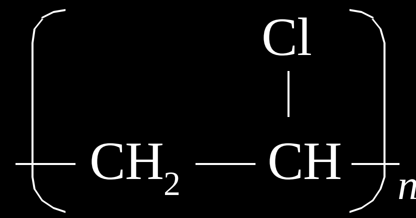
	Fatty Acid, %							
	Lauric	Myristic	Pentadecanoic	Palmitic	Margaric	Stearic	Arachidic	Oleic
Pure				7	2	90	1	
Single-Pressed		2	1	52	2	38		5
Double-Pressed		2	1	52	2	39		4
Triple-Pressed		*2*	*1*	*52*	*2*	*43*		
Hydrogenated Tallow		2	1	29	1	66		
Rubber Grade	2	9	1	21	1	60	1	5
Stearic Palmitic		4	1	21	1	72	1	

POLYMERS

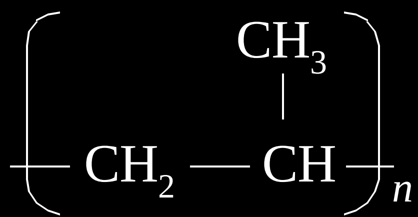
Polyethylene



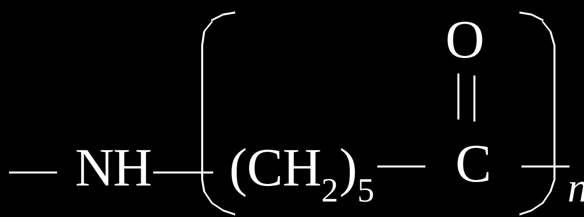
PVC



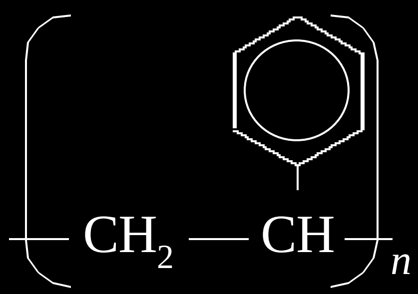
Polypropylene



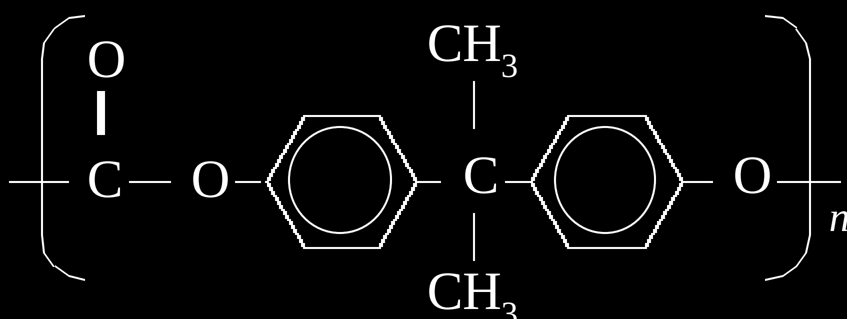
Nylon 6



Polystyrene



Polycarbonate



WHAT ABOUT COLOR CONCENTRATES?!

The selection of lubricants depends on:

- Polymer
- Pigment Chemistries
- Pigment Levels
- General Dispersability of the Pigments

The most common dispersion aids/lubricants are:

- EBS (Acrawax C, Advawax 280, TR-EBS, etc.)
- Stearates
- Hydrocarbon waxes

WHAT ABOUT COLOR CONCENTRATES?!

Goals:

- Optimum dispersion of the pigment
- Processability of the concentrate
- Optimum color development/dispersion in the end use
- Color stability in the end use

For lubricants:

- Aid/improve all of the above
- Do not interfere with the function of the colorant
- Examples:
  - Highly acidic lubes degrade Cadmium pigments
  - Zinc stearate yellows Red 2B