Additive Components
Multifunctionality...
Drawing Parallels...

Lubricants dealing with different tasks

- Friction
- Wear
- Oxidation

Multifunctional mixture

Thanks to additives
Introduction

Reliability

Performance

Performance you can rely on.
Agenda

01 | Destructive processes. The necessity for additives

02 | Functions of additives

03 | Types of additives

Enhance lubricant performance
Minimise destructive processes in the engine
Extend engine and oil life time
Balance of Additives and Base Oil

Key is balancing the additives for the application.

- Base Oil: 60-90%
- Viscosity Modifier & flow improver: 5-15%
- Additive Package: 5-25%

Dispersant
Detergent
Antiwear
Antioxidant
Friction Modifier
Others

Lubricant
Commercially available product
Destructive Processes

These processes affect both the engine and the lubricant
Both caused by relative motion between surfaces

Friction
loss of energy – dissipated as heat
• Types – sliding, rolling, static

Wear
loss of material
• Types – abrasion, adhesion, corrosion, fatigue
• Changes geometry of contacts
• Changes equipment performance
• Introduces metal oxidation catalysts
Destructive Processes

Rust
to ferrous (iron) metals
- Oxidative process
- Catalysed by water and acids

\[ 2\text{Fe} + 1.5\text{O}_2 \rightarrow \text{Fe}_2\text{O}_3 \]

Corrosion
to non-ferrous metals
- Chemical attack
- Examples include:

\[ \text{Cu} + \text{S} \rightarrow \text{CuS} \]
\[ \text{Pb} + \text{acid} \rightarrow \text{Pb-salt} \]

Performance you can rely on.

© INFINEUM INTERNATIONAL LIMITED 2019. All Rights Reserved.
Destructive Processes

Fuel combustion

**Ideal situation**
Complete combustion

Fuel + O\textsubscript{2} → Energy + CO\textsubscript{2} + H\textsubscript{2}O

**Reality**
Incomplete combustion

Fuel + Air → Energy + CO\textsubscript{2} + H\textsubscript{2}O + NO\textsubscript{x} + SO\textsubscript{x} + CO + HC + Particulate Matter (PM-Soot) + Radicals

**Result**
Acceleration of oil oxidation and degradation, viscosity increase, acid build-up, corrosive wear and deposits
Destruction of molecules by exposure to oxygen at elevated temperatures

Initiated by radicals

- attack and ‘pull apart’ base stock molecules
- To pair their lone electron
- Process can produce more radicals leading to a chain reaction

The process can be catalysed by metals

Consequences
Balance of Additives and Base Oil

- Solubilisation of different moieties
- Inhibition of deposit formation
Dispersants and Detergents
Properties

Molecules with a polar and a non-polar section

Non-polar tail  Polar end

Tend to aggregate forming polar or non-polar core micelles
Dispersants and Detergents
Aggregation

Micelles

In Oil

Polar core

In Water

Non-polar core

Performance you can rely on.
Metal-containing Detergents

Colloidal particles with two discrete sub-sections

Organic Stabilising Surfactant (Soap)

Inorganic Metal Carbonate Core (Base)

Performance you can rely on.

© INFINEUM INTERNATIONAL LIMITED 2019. All Rights Reserved.
Metal-containing Detergents

<table>
<thead>
<tr>
<th>Function</th>
<th>Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutralise acidic blow-by gases</td>
<td>Prevent corrosive wear</td>
</tr>
<tr>
<td>Solubilise engine combustion products</td>
<td>Reduce lacquer, carbon and varnish deposits on pistons</td>
</tr>
<tr>
<td>Inhibit high-temperature deposit formation</td>
<td>Prevent ring sticking under severe operating conditions</td>
</tr>
<tr>
<td>Provide supplementary anti-oxidancy</td>
<td>Reduce base oil degradation</td>
</tr>
</tbody>
</table>

Typical compositions – colloidal
- Alkylated metal sulphonates, sulphurised phenates, salicylates
- “Neutral” or “overbased “ (Excess base)
General Dispersant Structure

- Oleophilic (hydrophobic) tail and hydrophilic head group
- Sometimes contains a bridge for ease of attachment
- Can have multiple tails or multiple heads or both
## Ashless Dispersants

<table>
<thead>
<tr>
<th>Function</th>
<th>Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absorbs to particle surfaces preventing agglomeration/ controlling viscosity growth</td>
<td>Rheology control</td>
</tr>
<tr>
<td>Surface adsorption</td>
<td>Forms protective layer altering friction/wear properties</td>
</tr>
<tr>
<td>Inhibits sludge formation and phase separation</td>
<td>Solubilisation</td>
</tr>
<tr>
<td>Inhibits deposit formation/suspends soot</td>
<td>Keep engine parts clean</td>
</tr>
<tr>
<td>Delivers other moieties e.g. boron</td>
<td>Enhances overall efficiency of lubricant</td>
</tr>
</tbody>
</table>

**Diagram:**
- **Tail:** PolyIsoButylene (Oleophile)
- **Bridge:** Succinic Anhydride
- **Polar Head:** Polyalkylene Amine

**Chemical Structures:**
- PolyIsoButylene
- Succinic Anhydride
- Polyalkylene Amine

**Note:**
- Performance you can rely on.
Balance of Additives and Base Oil

‘Finished Oil’

Base Oil 60-90%

Viscosity Modifier & flow improver 5-15%

Additive Package 5-25%

Dispersant

Detergent

Antiwear

Antioxidant

Friction Modifier

Others

Wear is the process of physical loss of material from a metal surface
Wear and Antiwear Agents

Process of physical loss of material from a metal surface

**Adhesive:** metal extremities fuse together and motion pulls them apart

**Abrasive:** hard material in the contact abrades the metal surface

**Corrosive:** loss of material by chemical reaction; water, combustion acids, excess antiwear or EP additives

**Fatigue:** high stress deforms the metal structure below the surface

50% of engine friction is between piston rings and liner.
Antiwear Agents

**Zinc-based: zinc dialkyldithiophosphates (ZDDP)**
Engine oils

**Molybdenum-based: molybdenum dithiocarbamates (MoDTC)**

**Phosphorus-based: tri-cresyl phosphate**
ATF, gear, aviation

**Extreme pressure: highly reactive sulphur-phosphorus compounds**
Gear oils

- Improved Stability
- Better Wear Protection
- Molecular Weight
Antwear Agents
Protection mechanism

Mechanism of antiwear protection by ZDDP

Moving surface

Hydrodynamic contact
- Thick oil film
- No metal/metal contact
- Phosphate layers will not form but would be maintained if formed previously

Boundary contact
- Oil film insufficient to separate surfaces
- Glassy poly-phosphate film forms as high temp/pressure increase contact
- Phosphate layer liquefies at high temperature
- Phosphate layer is lost sacrificially to protect the metal surface

Performance you can rely on.
Balance of Additives and Base Oil

Oxidation is one of the major destructive processes the lubricant experiences.
Oxidation and Consequences

Consequences

- Degradation of base oil and its additives
- Acidification through carboxylic acid generation
- Chain cleavage and volatilisation of light ends
- Increased polarity and viscosity
- Loss of performance - Hardware damage
**Consequences**

- Degradation of base oil and its additives
- Acidification through carboxylic acid generation
- Chain cleavage and volatilisation of light ends
- Increased polarity and viscosity
- Loss of performance - Hardware damage
- Deposit formation, poor pumpability, oil starvation

**Affecting parameters**

- Base stock
- Additive package
- Biofuel contamination
- Operating temperature
- Presence of wear metals
Oxidation

Mechanistic Overview

Decomposition products (carbonyl and hydroxy compounds) are the major oxygenated components of used oils
Types of Antioxidants

**Primary antioxidants:** Act as radical traps, interrupting oxidation process

- Hindered Phenols
- Alkylated DiPhenyl Amines (DPA)

![Diagram showing the mechanism of antioxidants](image-url)
Types of Antioxidants

Secondary antioxidants: Peroxide/hydroperoxide decomposers

\[
\begin{align*}
R-S-S-R + R'-O-O-H & \rightarrow R-S-S-R + R'-O-H \\
R'SS'R & \leftrightarrow R'SH + S=\overline{R''} \\
R'SH + R'-O-O-H & \rightarrow R'SO\overline{H} + R'-O-H \\
R'SO\overline{H} & \xrightarrow{heat} R-H + O=S=O
\end{align*}
\]

✓ Zinc Dialkyl Dithiophosphates
✓ Molybdenum Dithiocarbamates
✓ Thioethers
**Synergy** is the phenomenon where the performance of two additives is greater than the sum of their individual appearances, common in antioxidants

- **Homosynergism** – two additives working by the same mechanism
- **Heterosynergism** – two different mechanisms operating

Once antioxidant is used up, autoxidation results in rapid lubricant degradation
Balance of Additives and Base Oil

‘Finished Oil’

- Base Oil: 60-90%
- Viscosity Modifier & flow improver: 5-15%
- Additive Package: 5-25%

- Dispersant
- Detergent
- Antiwear
- Antioxidant
- Friction Modifier
- Others

Friction coefficient reduction allows **better fuel economy**
General Aspects

Give a low coefficient of friction by providing a low shear surface

Defined as...
Surface active chemicals that affect friction coefficient
Almost all additive components fit this broad definition!

For our purposes...
Chemicals at less than 1% concentration in lubricating oil significantly affect friction coefficient

Long chain hydrocarbons with polar end groups (surfactants)

Molecules designed to:
• Adhere/adsorb to metal surfaces
• ‘Stand’ upright into bulk oil

Friction coefficient is affected by:
• Temperature, speed, load

Performance you can rely on.
• Molecular geometry similar to detergents (surfactant)
• Act “intact” (not chemically transformed at the surface)
• e.g. oleic acid and glycerol monooleate
• Molecular geometry describes a “flat plate”
• Act after chemical transformation at the surface
• Examples include molybdenum disulphide (MoS$_2$) from molybdenum trimer (MoDTC)
Balance of Additives and Base Oil

‘Finished Oil’

Base Oil 60-90%

Viscosity Modifier & flow improver 5-15%

Additive Package 5-25%

Dispersant
Detergent
Antiwear
Antioxidant
Friction Modifier
Others

© INFINEUM INTERNATIONAL LIMITED 2019. All Rights Reserved.
Other Additives

**Anti-foamant**
High viscosity silicone fluid to prevent foaming

![Chemical Structure of Anti-foamant](image)

**Demulsifiers**
Various surfactant chemistries to stop emulsions forming if water gets into the oil (condensation or coolant leaks)

**Emulsifiers**
Typically used in metal-working applications to form an emulsion

Performance you can rely on.
Other Additives

**Rust inhibitors**
Surface coating or improving acid neutralisation
– especially in factory-fill oils

**Corrosion inhibitors**
Film-forming agents as toyl triazole

**Seal compatibility agents**
Control oil polarity
Relative Sizes

Performance you can rely on.

© INFINEUM INTERNATIONAL LIMITED 2019. All Rights Reserved.

Log (Meters)
Conclusion

Benefits

✓ Enhanced lubricant performance
✓ Minimisation of destructive processes
✓ Extended engine and oil life time
Permissions

Permission is given for storage of one copy in electronic means for reference purposes. Further reproduction of any material is prohibited without prior written consent of Infineum International Limited.

The information contained in this document is based upon data believed to be reliable at the time of going to press and relates only to the matters specifically mentioned in this document. Although Infineum has used reasonable skill and care in the preparation of this information, in the absence of any overriding obligations arising under a specific contract, no representation, warranty (express or implied), or guarantee is made as to the suitability, accuracy, reliability or completeness of the information; nothing in this document shall reduce the user’s responsibility to satisfy itself as to the suitability, accuracy, reliability, and completeness of such information for its particular use; there is no warranty against intellectual property infringement; and Infineum shall not be liable for any loss, damage or injury that may occur from the use of this information other than death or personal injury caused by its negligence. No statement shall be construed as an endorsement of any product or process. For greater certainty, before use of information contained in this document, particularly if the product is used for a purpose or under conditions which are abnormal or not reasonably foreseeable, this information must be reviewed with the supplier of such information.

Links to third party websites from this document are provided solely for your convenience. Infineum does not control and is not responsible for the content of those third party websites. If you decide to access any of those websites, you do so entirely at your own risk. Please also refer to our Privacy Policy.

INFINEUM, 润英联 and the interlocking ripple device are Trade Marks of Infineum International Limited. © 2019 Infineum International Limited. All rights reserved.