COALESCING CLARIFIER FOR CRUDE PALM OIL CLARIFICATION

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NEW DEVELOPMENTS IN PALM OIL MILLING TECHNOLOGY

- Sterilization
  - Vertical sterilizer with FFB conveying system
  - Continuous sterilizer with FFB crusher and conveying system
  - Tilted sterilizer with conveying system
  - Spherical sterilizer with conveying system
- Boiler with automated fuel-steam management
- Oil clarification
  - New 2-phase decanter based clarification system (Westfalia, Alfa-Laval, IHI)
  - Coalescing clarifier operating without oil purifier
- Effluent Management
  - Modern biogas plant (complete mixed, baffle reactor, CIGAR)
  - Tertiary/polishing plant (SBR, CAS, MBR, Trickling filter)
  - Integrated anaerobic-aerobic with resource recovery
DRIVERS FOR NEW DEVELOPMENTS

- Process efficiency requirements
  - Reduce cost of production
  - Improve oil and kernel recovery
  - Efficient steam management

- Oil quality improvements
  - Low FFA oil
  - Low PV, high DOBI

- Sustainability and environmental issues
  - Carbon footprint, LCA, BOD 20 mg/l effluent discharge

- Quality system certification requirements
  - ISO quality management
  - RSPO certification
  - Code of Good Milling Practices for palm oil mill
  - Food safety certification
STOKES SETTLING – THE BASIC

- When two liquids are immiscible, or non-soluble in one another, they can form either an emulsion or a colloidal suspension.
- In either of these mixtures, the dispersed liquid forms droplets in the continuous phase. In suspension, the droplets are less than one micron in diameter and the liquids cannot readily be separated with the conventional clarifier/separator.
- Traditionally, gravity separators were used to handle emulsions before the use of coalescing media became applicable.
- In this equipment, differences in densities of the two liquids cause droplets to rise or fall by their buoyancy. The greater the difference in densities, the easier the separation becomes.
- Rising (or falling) droplets are slowed by frictional forces from viscous effects of the opposing liquid.
STOKES SETTLING – THE BASIC

- When the stream is not flowing and the opposing forces of buoyancy and viscous drag balance, the droplet has achieved its Terminal Settling Velocity.
- This vertical velocity is constant because there are no net forces acting upon the droplet. This mechanism of separating liquids by gravity is called Stokes Settling.
- The size of gravity settler is derived from 1) the terminal settling velocity of a minimum sized droplet and 2) the inertial force imparted to the droplet due to the velocity of the emulsion through the vessel. At these conditions, all droplets larger than a minimum will be removed at a quicker rate.
- Typical minimum droplet size is between 75 to 300 µm.
- In order to settle fine droplets and ensure laminar flow, large vessels and long residence times are required. It may take ten, twenty or even hours to make a separation, depending on the physical properties of the stream.
PARTICLE SETTLING (STOKES’ LAW)

- Settling velocity is when fluid drag force equals gravitational force (terminal velocity)

\[ v = gd^2(\rho_s - \rho_l)/18\mu \]

- For small particles and low terminal velocity, fluid flow around particle is laminar \( \rightarrow \) Stokes’ Law applies
- \( V = \) terminal velocity (cm/s), \( g = \) acceleration due to gravity (981 cm/s\(^2\)), \( d = \) particle diameter (cm), \( \mu = \) viscosity of liquid (g/cm-s), \( \rho_s, \rho_l = \) density of solid particle and liquid (g/cm\(^3\))

Note: assuming flow is laminar
\[ v = g d^2 \left( \rho_s - \rho_l \right) / 18 \mu \]

**Terminal velocity, cm/s**

**Oil particle diameter**

**Viscosity, depends on temperature**

What makes oil particle diameter increases:
- create shearing force to combine small particles
- preventing excessive emulsion formation – choose the right pump
- use coalescer plates – increases particle diameter

Increase \( g \)
PARTICLE SETTLING
(Reynold’s Number)

To validate the assumption of laminar flow, calculate Reynold’s Number (Re)

\[ R_e = \frac{\rho dv}{\mu} \]

- \( \rho \) is density of the liquid \((g/cm^3)\)
- \( R_e < 0.2 \) → fluid is laminar (Stokes’ Law is valid)
BASIC DESIGN CONCEPTS – The emulsion

- In selecting and designing a coalescer, it is important to understand and characterize the emulsion that has to be treated. The finer the droplets dispersed in an emulsion, the more stable it is, because buoyancy force diminishes in magnitude as the diameter decreases.
- The manner in which the mixture is created effects the droplet size distribution.
- Centrifugal pumps shear liquid droplets much more severely than progressive cavity pump, thereby creating finer droplets.
- It is important to construct the droplet size distribution curve by plotting the droplet diameters against the volume or mass fraction at the differential diameter. The shape of the distribution is affected by the manner in which the emulsion was formed, and its age.
BASIC DESIGN CONCEPT – Operating Principles of a Coalescer

- Liquid-liquid coalescers are used to accelerate the merging of many droplets to form a lesser number of droplets, but with greater diameter.
- This increases the buoyant forces in the Stokes Law equation.
- Settling of the larger droplets downstream of the coalescer element then requires considerably less residence time.
- Coalescers exhibit a three-step method of operation:
  - Collection of individual droplets
  - Combining of several small droplets into larger ones
  - Rise/fall of the enlarged droplets by gravity
- Coalescers work better in laminar flow for several reasons:
  - Droplets will stay in the streamlines around a media
  - High fluid velocities overcome surface tension forces and strip droplets out of the coalescer medium
  - Slower velocities result in greater residence time in the media and therefore more time for droplet-to-target impact, droplet-to-droplet collision, and intra-media Stoke Settling
BASIS FOR SIZING AND SELECTION

- For liquid-liquid coalescers, as with any process equipment, successful sizing and selection is always a combination of empirical observation/experience and analytical modeling.
- Of the three steps in coalescing – droplet capture, combining of the collected droplets, and gravity separation of the enlarged droplets – the first and the last can be modeled with good accuracy and repeatability. The modeling the middle and the actual coalescing step is a complex function of surface tension and viscous effects, droplet momentum, and the dynamics of sizes of the droplets in the dispersion.
CRUDE PALM OIL CLARIFIER

Current Oil Clarifier

Vertical clarifier

Eco-D decanter - two phase without dilution

New Oil Clarifier

Coalescing clarifier (Oilsep) without purifier

OIL PURIFIER

| YES | NO |
---|---|

PIPOC 2009
COALESCING CLARIFIER (OILSEP) – 1ST GENERATION (INDONESIA)

2 units designed for 60 tonnes FFB/hr operating as primary clarifier. Material of construction: SS316 inserts and mild steel casing with Insulation, temperature control and flow control.
COALENCING CLARIFIER (OILSEP) AT VICHITBHAN OIL MILL
<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>R&amp;D with MPOB. Tested pilot unit at Krau Palm Oil Mill</td>
</tr>
<tr>
<td>2002</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; unit installed in a mill in Indonesia. 1&lt;sup&gt;st&lt;/sup&gt; Generation</td>
</tr>
<tr>
<td>2005 - 2008</td>
<td>3 units in operation in Thailand</td>
</tr>
<tr>
<td>2009</td>
<td>2 unit installed in Thailand for mill upgrading</td>
</tr>
<tr>
<td>2009</td>
<td>Discussed with interested parties: UNIVANICH (Thailand), PAPUA NEW GUINEA, KECK SENG (Malaysia), WEST AFRICA</td>
</tr>
<tr>
<td>2010</td>
<td>Planning to conduct testing on OILSEP without dilution</td>
</tr>
</tbody>
</table>
OIL IN UNDERFLOW OF COALESCECR CLARIFIER - VICHITBHAN OIL MILL

(May 2008 av. 7.72)

(April 2008 av. 6.82)
TYPICAL PERFORMANCE OF A SLUDGE SEPARATOR

- Average flow rate: 11,800 kg/hr with 1.8 mm nozzle
- Strong correlation between oil content in feed and oil content in centrifuge heavy phase
COMPARISON OF OIL CONTENT IN UNDERFLOW OF OIL CLARIFIER

INFEED OIL CONTENT - CONVENTIONAL CLARIFIER

Average 11.7%

OIL IN UNDERFLOW OF COALESCER CLARIFIER - VICHTBAN OIL MILL

Average 6.82%

Average 7.72%
MATERIAL BALANCE OF CONVENTIONAL CPO CLARIFIER

CRUDE SLURRY
Flow 36000 kg/h
Oil 35%
VM 58%
NOS 7%

OIL
Flow 10551 kg/h
Oil 98.9%
VM 85.0%
NOS 0.28%

VERTICAL CLARIFIER
T= 95oC min
RT = 4 – 7 hrs
Automation: dilution, sludge interface

SLUDGE
Flow 25449 kg/h
Oil 8.5% (2163.2)
VM 81.7%
NOS 9.8%

DECANTER/ CENTRIFUGAL SEPARATOR

RECOVERED OIL
1946.7 kg/h oil
(0.9 X 2163.2)

WASTEWATER/SOLID
216.3 kg/h oil (3.6 kg/tFFB)

BASIS: 60 TFFB/HR, NORMAL DILUTION, DXP
MATERIAL BALANCE OF COALESCING CLARIFIER (OILSEP)

**OILSEP**

**Oil**
- Flow: 11985.6 kg/h
- 98.9% 10985.6 kg/h

**CRUDE SLURRY**
- Flow: 36000 kg/h
- Oil: 35% 12600 kg/h
- VM: 58% 20880 kg/h
- NOS: 7% 2520 kg/h

**SLUDGE**
- Flow: 24958.3 kg/h
- Oil: 8.5% 1614.4 kg/h
- VM: 81.7% 20827.4 kg/h
- NOS: 9.8% 2516.5 kg/h

**RECOVERED OIL**
- 1453 kg/h oil

**WASTEWATER/SOLID**
- 161.4 kg/h oil (2.6 kg/tFFB)

BASIS: 60 TFFB/HR, NORMAL DILUTION, DXP
### COMPARISON BETWEEN OILSEP & VERTICAL CLARIFIER

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>OILSEP</th>
<th>VERTICAL CLARIFIER</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Oil recovery</td>
<td>12438 kg/h</td>
<td>12383.7 kg/h</td>
<td>54.9 kg/h</td>
</tr>
<tr>
<td>2</td>
<td>Oil content (underflow)</td>
<td>5% - 7%</td>
<td>8.0% - 12%</td>
<td>OILSEP very consistent</td>
</tr>
<tr>
<td>3</td>
<td>Feeding &amp; temperature control</td>
<td>Automatic 90 °C ± 2 °C</td>
<td>Normally non-auto 95 °C – 98 °C</td>
<td>Low temperature minimize quality deterioration</td>
</tr>
<tr>
<td>4</td>
<td>Oil quality*</td>
<td>DOBI 2.6 – 2.8</td>
<td>DOBI 2.0 – 2.5</td>
<td>Consistent</td>
</tr>
<tr>
<td>5</td>
<td>Retention time</td>
<td>1 – 1.5 hrs</td>
<td>4 – 7 hrs</td>
<td>Oil flow out within 45 minutes</td>
</tr>
<tr>
<td>6</td>
<td>Foot print for oil room</td>
<td>9 m X 6.5 m X 6 m (H)</td>
<td>Much bigger</td>
<td>Depends on tank size</td>
</tr>
<tr>
<td>7</td>
<td>Material of construction</td>
<td>Housing – 304 SS Inserts – 316 SS</td>
<td>304 SS lining</td>
<td>Comply to CoP of milling. Long life</td>
</tr>
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* Depends on FFB Quality
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<tr>
<td>8</td>
<td>Maintenance and cleaning</td>
<td>Very easy</td>
<td>Time consuming</td>
<td>High pressure water jet for inserts cleaning</td>
</tr>
<tr>
<td>9</td>
<td>Purification requirement</td>
<td>Not required</td>
<td>YES</td>
<td>Cleaner oil</td>
</tr>
<tr>
<td>10</td>
<td>Automation</td>
<td>Fully auto, flow control, temp control</td>
<td>Partial in some installation</td>
<td>Ensuring laminar flow for better oil coalescing</td>
</tr>
<tr>
<td>11</td>
<td>System performance</td>
<td>Dynamic constant shearing of crude slurry</td>
<td>STATIC, no barrier for solid movement</td>
<td>Oilsep is a dynamic system</td>
</tr>
<tr>
<td>12</td>
<td>Total surface area</td>
<td>150 m² surface for shearing action</td>
<td>No shearing surface</td>
<td>Oilsep surface area is equivalent to 200 MT vertical clarifier</td>
</tr>
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<tr>
<td>13</td>
<td>Investment cost</td>
<td>RM 1.4 mil.</td>
<td>RM 600,000</td>
<td>RM 800,000</td>
</tr>
<tr>
<td>14</td>
<td>Return on investment</td>
<td>0.86 yrs new mill compared to vertical clarifier 1.52 yrs if installed in existing oil room</td>
<td>Overall oil recover = 54.9 kg/hr or 1098 kg day at 20 hr/d 1098 kg X 350 d/yr = 384.3 t/yr X RM 2400/t = RM922,320</td>
<td></td>
</tr>
</tbody>
</table>
CONCLUSION

• OILSEP utilizes coalescing principle to enhance Stokes gravity settling. It helps in aggregating small droplets resulted as a result of emulsification of crude oil slurry – BETTER OIL RECOVERY IN SHORT RETENTION TIME

• It comply to the requirement of Code of Good Milling Practices for palm oil milling (MPOB) as all parts in contact with oil are made of SS