CONFINED FLAME TREATMENT: THE PROCESS AND ITS APPLICATIONS

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SUMMARY

1. Brief introduction to flexible packaging
2. Web surface treatment techniques
3. Confined flame treatment characteristics
5. Confined flame treatment applications
1.1 FLEXIBLE PACKAGING

“Flexible packaging is a packaging having an internal pressure in dynamic balance with total external pressure”

Flexible packaging advantages vs. inflexible one:

- Lower weight;
- Infrangible;
- Cheaper transportation;
- Lower storage overall dimensions;
- Lower production energy cost;
- More effective product promotion;
- Processed by FFS machines.
1.2 FLEXIBLE PACKAGING

Process of Extrusion:
- Flat films;
- Blown films.

Films finishing:
- Stretching;
- Thermal stabilization;
- Surfaces modifications;
- Metallization and coating.
1.3 FLEXIBLE PACKAGING

Typical production process of a metallized BOPP film
2.1 WEB SURFACE TREATMENT TECHNIQUES

In order to increase the attitude of polymerous films to be printed, coated, lacquered, metallized, several techniques can be used. The most common are the followings:

- **PRIMING**
- **CORONA TREATMENT**;
- **COLD PLASMA TREATMENT**;
- **HOT PLASMA (FLAME) TREATMENT**.
2.2 WEB SURFACE TREATMENT TECHNIQUES

- C-H link breaking vs. C-C link breaking;
- OH > O > H >> HO₂

 RH+OH \rightarrow R^o+H₂O; \quad \text{Initiating step}
 RH+H \rightarrow R^o+H₂

 R^o+OH \rightarrow ROH;
 R^o+HO₂ \rightarrow ROOH; \quad \text{Propagating step}
 R^o+O₂ \rightarrow ROO;
 R^o+H₂O₂ \rightarrow ROO+OH
 R^o+O \rightarrow RO
 R^o+H \rightarrow RH; \quad \text{Terminating step}
2.3 WEB SURFACE TREATMENT TECHNIQUES

$\beta$-scission reaction:

$\begin{array}{c}
\text{-C-C-C-} \\
| \\
\text{O} \\
\text{O} \\
\text{alkoxy radicals } \text{RO}^\circ \\
\Rightarrow \text{LMWOM.}
\end{array}$
2.4 WEB SURFACE TREATMENT TECHNIQUES

- O/C RATIO
- IMWOM vs. LMWOM

INCREASED SURFACE ENERGY

- Chain Scission behaviour
- “Aging” behaviour
- Metallizing barrier effect & Improved surface properties
## 2.5 WEB SURFACE TREATMENT TECHNIQUES

<table>
<thead>
<tr>
<th>CORONA TREATMENT</th>
<th>COLD PLASMA TREATMENT</th>
<th>STAND. FLAME TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Depth of treatment</td>
<td>Cannot be used on common BOPP film widths</td>
<td></td>
</tr>
<tr>
<td>Production of LMWOM</td>
<td>Poor treatment levels</td>
<td></td>
</tr>
<tr>
<td>Not selective</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not uniform</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not repeatable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor treatment at higher speeds</td>
<td>Film treated surface aspect at high trt</td>
<td></td>
</tr>
<tr>
<td>Backside treatment</td>
<td>Heat distributed to the surrounding room</td>
<td></td>
</tr>
<tr>
<td>Pin-holes formation</td>
<td>Difficulties in hoods position optimization</td>
<td></td>
</tr>
<tr>
<td>Ozone production</td>
<td>Room conditions influence on flame yield</td>
<td></td>
</tr>
</tbody>
</table>


2.6 WEB SURFACE TREATMENT TECHNIQUES
Lambda value vs. Room Temperature at different relative humidity values.
Natural Gas combustion (d=0.59).
Stoichiometric at 20°C; H% = 0
2.8 WEB SURFACE TREATMENT TECHNIQUES

Thickness meter device measurements vs. lab ones

y = 6E-6x^2 - 0.0042x + 18.776
R^2 = 0.8407
3.1 CONFINED FLAME TREATMENT CHARACTERISTICS
3.2 CONFINED FLAME TREATMENT CHARACTERISTICS
3.3 CONFINED FLAME TREATMENT CHARACTERISTICS

Bottom Burner version
3.4 CONFINED FLAME TREATMENT CHARACTERISTICS

Top Burner version
3.5 CONFINED FLAME TREATMENT CHARACTERISTICS

Confined flame treatment advantages:

- Higher surface quality at higher treatment levels;
- Improved after treatment web surface properties;
- No radiating heat to the surrounding room;
- Access easiness to the burner body;
- Possibility to control the combustion room conditions;
- Possibility to add inert gases to the combustion area.
3.6 CONFINED FLAME TREATMENT CHARACTERISTICS

FLAME SPEED
Mallard-LeChatelier Theory

\( S_L \sim (\beta \times RR)^{1/2} \)

\( \beta = \text{Thermal Diffusivity} = \lambda / \rho c_p \)
4.1 CONFINED FLAME TREATMENT APPLICATIONS
4.2 CONFINED FLAME TREATMENT APPLICATIONS
4.3 CONFINED FLAME TREATMENT APPLICATIONS

Upstream hood - Exhaust gases temperatures at different speed and mixture flow values

- Speed 100 m/min
- Speed 300 m/min
- Speed 500 m/min
4.4 CONFINED FLAME TREATMENT APPLICATIONS

Downstream hood - Exhaust gases temperatures at different speed and mixture flow values

Exhaust temperature [°C]

Mixture flow [Nm³/h]

- speed 100 m/min
- speed 300 m/min
- speed 500 m/min
4.5 CONFINED FLAME TREATMENT APPLICATIONS

- Energy to the treater roll: 40 - 45%
- Energy to the web (1%):
- Energy to the exhausts: 40 - 45%
- Energy to the burner: 15 - 20%
4.6 CONFINED FLAME TREATMENT APPLICATIONS

CONFINED FLAME TREATMENT DISTRIBUTION ENERGY MAP

Energy to the treater roll
35 - 40%

Energy to the web (1%)

Energy to the burner
10 - 15%

Energy to the exhausts
50 - 55%

COMBUSTION ENERGY
4.7 CONFINED FLAME TREATMENT APPLICATIONS

A) Metallized Coex films

- Layer "C" – Heat Seal
- Layer "B" – PP Structural
- Layer "A" – Al deposition receptive
- Al layer (deposition under vacuum)
- Anti-blocking particles
## 4.8 CONFINED FLAME TREATMENT APPLICATIONS

<table>
<thead>
<tr>
<th></th>
<th>STANDARD FLAME TREATMENT</th>
<th>CONFINED FLAME TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixture flow per web meter [Ncm/(h m)]</td>
<td>70,5</td>
<td>45</td>
</tr>
<tr>
<td>Air Gap [mm]</td>
<td>5,0</td>
<td>3,8</td>
</tr>
<tr>
<td>Mixture lambda value</td>
<td>1.020</td>
<td>1.020</td>
</tr>
<tr>
<td>Treatment Roll</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature [°C]</td>
<td>27</td>
<td>30</td>
</tr>
<tr>
<td>Line Speed [m/min]</td>
<td>335</td>
<td>277</td>
</tr>
<tr>
<td>Treatment level</td>
<td>46/48</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4.9 CONFINED FLAME TREATMENT APPLICATIONS

Metallized film properties: Confined vs. Standard flame treatment

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<table>
<thead>
<tr>
<th></th>
<th>Standard Flame Treatment</th>
<th>Confined Flame Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>OTR [cc/day, dry 22.8°C]</td>
<td>108</td>
<td>229</td>
</tr>
<tr>
<td>Transversal Rexam [g/cm]</td>
<td>82</td>
<td>176</td>
</tr>
<tr>
<td>Longitudinal Rexam [g/cm]</td>
<td>108</td>
<td>235</td>
</tr>
<tr>
<td>OTR [cc/mq day, dry 22.8°C]</td>
<td>320</td>
<td>320</td>
</tr>
<tr>
<td>Transversal Rexam [g/cm]</td>
<td>229</td>
<td>229</td>
</tr>
<tr>
<td>Longitudinal Rexam [g/cm]</td>
<td>176</td>
<td>176</td>
</tr>
</tbody>
</table>
4.10 CONFINED FLAME TREATMENT APPLICATIONS

Metallized Film WVTR: Confined vs. Standard Flame Treatment
4.11 CONFINED FLAME TREATMENT APPLICATIONS

Metallized BOPP film aging curves

Days after treatment

Treatment level [dynes/cm]

Confined Flame Treatment

Standard Flame Treatment
## 4.12 CONFINED FLAME TREATMENT APPLICATIONS

### B) White Opaque films / Synthetic Paper

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Standard Flame Treatment</th>
<th>Confined Flame Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixture flow per web meter [Ncm/(h m)]</td>
<td>62.5</td>
<td>40</td>
</tr>
<tr>
<td>Air Gap [mm]</td>
<td>4.0</td>
<td>3.5</td>
</tr>
<tr>
<td>Mixture lambda value</td>
<td>1.020</td>
<td>1.020</td>
</tr>
<tr>
<td>Treatment Roll Temperature [°C]</td>
<td>20</td>
<td>18</td>
</tr>
<tr>
<td>Line Speed [m/min]</td>
<td>250</td>
<td>260</td>
</tr>
<tr>
<td>Treatment level [dynes/cm]</td>
<td>40/42</td>
<td>46/48</td>
</tr>
</tbody>
</table>

**STANDARD VS. CONFINED FLAME TREATMENT PARAMETERS**
4.13 CONFINED FLAME TREATMENT APPLICATIONS

Confined vs. Standard Flame treatment on white opaque films: sealing strength

Sealing Strength [g/cm]

Standard Flame Treatment

Confined Flame Treatment

SIT 105°C
SIT 115°C
SIT 105°C
SIT 115°C
4.14 CONFINED FLAME TREATMENT APPLICATIONS

Confined vs. Standard Flame Treatment: aging curves

Days after treatment

Treatment level [dynes/cm]

- Standard Flame Treatment
- Confined Flame Treatment

### 4.15 CONFINED FLAME TREATMENT APPLICATIONS

#### C) Sealable Coex films

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixt. [m³/h*m]</td>
<td>27</td>
<td>32</td>
<td>32</td>
<td>42</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>Gap [mm]</td>
<td>3.2</td>
<td>3.5</td>
<td>3.5</td>
<td>3.8</td>
<td>3.5</td>
<td>3.5</td>
</tr>
<tr>
<td>T Jono [°C]</td>
<td>812</td>
<td>795</td>
<td>795</td>
<td>820</td>
<td>820</td>
<td>810</td>
</tr>
<tr>
<td>Speed [m/min]</td>
<td>300</td>
<td>280</td>
<td>280</td>
<td>300</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>Roll Temp.[°C]</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>20</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Dynes/cm</td>
<td>52</td>
<td>48</td>
<td>48</td>
<td>48</td>
<td>44</td>
<td>42</td>
</tr>
<tr>
<td>Film aspect (stripes)</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>SIT-Delta T[°C]</td>
<td>112°C, 0°C</td>
<td>116°C, +2°C</td>
<td>114°C, 0°C</td>
<td>124°C, +6°C</td>
<td>122°C, +4°C</td>
<td>121°C, +3°C</td>
</tr>
</tbody>
</table>
4.16 CONFINED FLAME TREATMENT APPLICATIONS

Confined vs. Standard Flame Treatment: sealing strength

Sealing Strength [g/inch]

- SIT: 122°C; 46 dynes/cm
- SIT: 116°C; 50 dynes/cm

- Standard Flame Treatment
- Confined Flame Treatment
CONFINED FLAME TREATMENT APPLICATIONS

- Higher treatment levels with improved web surface properties;
- Improved final properties on metallized, white opaque and sealable treated films;
- No corrugation/deformations on white opaque films;
- Simple system to run;
- Costs-saving technology;
- Room friendly technology.