Kobe Steel Develops High Heat Transfer Titanium Sheet for Plate Heat Exchangers

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Contents

✓ Titanium sheet and plate heat exchangers
✓ High heat transfer titanium sheet
✓ Results of heat transfer measurement
✓ Application of high heat transfer titanium
✓ Summary
Plate Heat Exchanger (PHE)

Major applications

- Central cooling system in power & chemical plants, etc.
- Engine cooler for ships

Working principle of PHE

Courtesy of Alfa Laval
Plate Heat Exchanger (PHE)

is a device for

ermal energy transfer

Energy PHE Transfer
Heat Transfer and Loss of Energy

To make effective use of energy, Kobe Steel developed high heat transfer titanium sheet

Image of heat transfer in PHE

Inlet → PHE → Outlet

Loss
High Heat Transfer Titanium Sheet for PHE

- Warm Liquid
- Liquid + Gas
- Normal surface
- Special surface for enhancement of boiling heat transfer
- Cool Liquid
- Ti Sheet
Special Surface Treated Sheet

Special surface
(for boiling heat transfer)

Normal surface
(back face)

Special surface treated sheet
Grade : 1
Thickness : 0.4~0.6mm

Pat. No.
P4638951, P4964327 (Japan)
WO2011/136278, WO2010/143564 (International)
**Heat Transfer Measurement**

Schematic diagram of experiment apparatus
Heat Transfer Measurement

Appearance of experiment apparatus
**Results of the Experiment**
(Overall heat transfer coefficient)

**Experimental conditions and results**

<table>
<thead>
<tr>
<th>Working fluid</th>
<th>R134a</th>
<th>NH$_3$</th>
<th>HFC-245fa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area of heat transfer in PHE [m$^2$]</td>
<td>0.0075</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Mass flux [kg/m$^2$ s]</td>
<td>25</td>
<td>5</td>
<td>10 - 20</td>
</tr>
<tr>
<td>Enhancement of overall heat transfer coefficient [%]</td>
<td>&gt;10</td>
<td>15</td>
<td>20</td>
</tr>
</tbody>
</table>
Results of the Experiment
(Overall heat transfer coefficient)

Overall heat transfer coefficient for mass flux

Mass flux \[ kg/m^2 \cdot s \]
Results of the Experiment

(Local heat transfer coefficient)

Comparisons of local boiling heat transfer coefficient on quality at different surface conditions
**Effect of High Heat Transfer**

\[ Q = U A \Delta t_m \]  \hspace{1cm} (1)

\[ Q = c_p m \Delta t \]  \hspace{1cm} (2)

- \( Q \): heat exchange  \[ \text{[J/s]} \]
- \( U \): overall heat transfer coefficient  \[ \text{[W/m}^2\text{K]} \]
- \( A \): heat transfer area  \[ \text{[m}^2\text{]} \]
- \( \Delta t_m \): logarithmic mean temperature difference  \[ \text{[K]} \]
- \( c_p \): specific heat  \[ \text{[J/kg K]} \]
- \( m \): mass flow rate  \[ \text{[kg/s]} \]
- \( \Delta t \): temperature difference of heat source  \[ \text{[K]} \]

\[ \Delta t_m = \frac{(t_{W1} - t_{WF2}) - (t_{W2} - t_{WF1})}{\ln((t_{W1} - t_{WF2}) / (t_{W2} - t_{WF1}))} \]

*Image of PHE*
### Study of Applications for High Heat Transfer Titanium

Titanium sheet for heat transfer and PHE applications

<table>
<thead>
<tr>
<th>Application fields</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High heat transfer sheet</strong></td>
</tr>
<tr>
<td>Applications for recovering energy</td>
</tr>
<tr>
<td><strong>Normal sheet</strong></td>
</tr>
<tr>
<td>Applications for emitting energy</td>
</tr>
</tbody>
</table>
Application of High Heat Transfer Titanium in “Ocean Thermal Energy Conversion (OTEC)”

Warm Seawater at Surface

⑤ Warm Seawater pump

① Evaporator

② Turbine

③ Condenser

④ Working fluid pump

Cold Seawater in Depth

⑥ Cold seawater pump

PHE using titanium plates for evaporator and condenser
Okinawa Prefecture

has decided to construct a demonstration OTEC plant on Kume Island and start operation by March next year. (July 2012)

Image of OTEC plant on Kume Island (Detailed design may change)
**Purpose of OTEC Project on Kume Island**

**Potential site for OTEC in Japan**

<table>
<thead>
<tr>
<th>Energy resource by OTEC [MW]</th>
<th>2,797</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present power capacity [MW]</td>
<td>1,905</td>
</tr>
</tbody>
</table>

(NEDO, 2011)
Titanium PHE for OTEC Plant

If the heat transfer coefficient in PHE increases,

Increase of net power by reduction of pressure loss in PHE
Effect of High Heat Transfer
(increase in net power of OTEC)

Net Power \( (W_{\text{NET}} = W_G - W_{WS} - W_{CS} - W_{WF}) \) (1)
Titanium PHE for OTEC Plant

If the heat transfer coefficient in PHE increases,

- Increase of net power by reduction of pressure loss in PHE
- Downsized floating structure and intake pipes by smaller PHE

the power generation efficiency of OTEC also increases
## Future Products Coming Up

Development of high heat transfer titanium for heat exchangers

<table>
<thead>
<tr>
<th>Grade</th>
<th>Completed</th>
<th>Coming up next</th>
</tr>
</thead>
<tbody>
<tr>
<td>JIS</td>
<td>Class 1</td>
<td>Class 2</td>
</tr>
<tr>
<td>ASTM</td>
<td>G1</td>
<td>G 2</td>
</tr>
<tr>
<td>Form</td>
<td>sheet</td>
<td>tube</td>
</tr>
</tbody>
</table>

Kobe steel plans to accelerate development for effective use of energy
Summary

1) Kobe Steel’s high heat transfer titanium sheet has minute convex-shaped bumps on the surface, which increase heat transfer.

2) Using this new sheet increases the boiling heat transfer coefficient by more than 10% without changing the equipment design.

3) Due to higher heat transfer, the number of titanium heat transfer plates can be reduced. At the same time, as the volume of fluid can be decreased, a smaller pump can be used to circulate the fluid.
Thank you for your kind attention!