Heat Exchanger Innovations – Design and Application

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Contents

- Innovation Drivers
- Micro-Tube: Development Practices and Benefits
- Active Maintenance
- Research Areas
Innovation Drivers in heat exchangers for heating and cooling can be summarised as:

- Legislation Changes: Such as F-Gas or ErP
- Competitive Landscape: Improving competitive position through innovation
- Social Changes: Increasing population density
- Materials Sustainability: Availability of raw material
- Environmental Sustainability: Use of energy in production and in application
- Application Demands: Challenging applications often lead to innovations which may then be applied more widely
‘Micro-Tube’ / 5mm Configuration

• The development of a new configuration using 5mm tube

• This provides opportunities for:
  - Reducing refrigerant charges
  - Radically improving capacity density
  - Less materials to achieve the same capacity
  - Less air volume / power input / noise to achieve the same capacity
  - Ideally suited for the construction of natural refrigerants, such as CO2

• Reflecting the most common innovation drivers, it facilitates an R&D project and potential manufacturing investments
• Rapid prototyping used for the first time in the optimisation of a tube configuration

• LSBU assisted in expertise and production of prototyped fin samples

• Greater flexibility to optimise configurations than previously possible

• Previous CFD analysis completed in conjunction with Brunel University had established the dead areas that can exist behind tubes
• Airflow testing helped to validate early stage CFD for flow paths

• Combined with commercial review, a tube pattern of 20mm x 12mm was fixed upon, in order to focus on enhancement developments

• Fin enhancement optimisation considered a number of variations
• Validating against known results for existing patterns helped to refine the model to improve accuracy

• Critical balance between heat transfer coefficients and airside pressure loss

• The most effective option then needs to be balanced against what is possible for manufacture
- Fin press purchased after development project
- Complex press die to produce fin enhancements
- Example of improvements in capacity for specified surface area
• Test results for final coil
  - 2.12mm Fin Spacing
  - Slit Enhancements
  - 4 Rows Deep

16% Increase in external heat transfer coefficient
• Selection examples showing potential for:
  - Reduced material consumption
  - Application benefits, i.e. smaller footprint and lower sound level
  - Reduction in energy use

<table>
<thead>
<tr>
<th>Tube Pattern</th>
<th>Duty (kW)</th>
<th>Area (m²)</th>
<th>Noise Level (dBA)</th>
<th>Power Input (kW)</th>
<th>Cu Qty (kg)</th>
<th>Al Qty (kg)</th>
<th>Cu % Diff</th>
<th>Al % Diff</th>
<th>Area % Diff</th>
<th>Sound Diff (dBA)</th>
<th>Power Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>G-Fin (8mm)</td>
<td>98.8</td>
<td>3.9</td>
<td>31</td>
<td>0.38</td>
<td>87</td>
<td>195</td>
<td>-47%</td>
<td>-45%</td>
<td>0%</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>F-Fin (5MM)</td>
<td>95.8</td>
<td>3.9</td>
<td>31</td>
<td>0.38</td>
<td>46</td>
<td>108</td>
<td>-21%</td>
<td>-18%</td>
<td>0%</td>
<td>-4</td>
<td>-34%</td>
</tr>
<tr>
<td>G-Fin (8mm)</td>
<td>293.9</td>
<td>12.5</td>
<td>30</td>
<td>1.03</td>
<td>304</td>
<td>678</td>
<td>-37%</td>
<td>-35%</td>
<td>-22%</td>
<td>1</td>
<td>6%</td>
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<tr>
<td>F-Fin (5MM)</td>
<td>295.3</td>
<td>12.5</td>
<td>26</td>
<td>0.68</td>
<td>238</td>
<td>553</td>
<td>-37%</td>
<td>-35%</td>
<td>-22%</td>
<td>1</td>
<td>6%</td>
</tr>
</tbody>
</table>

• Manufacturing innovations and investments also required to realise full commercial potential
Active Maintenance

- Combination of increased air pollution and changes in fan operation logic leading to varying levels of heat exchanger fouling

- Traditional scheduled / preventative cleaning cycles not reflecting requirements across estates

- Incorporation of IoT offers opportunity to monitor and visualise operational characteristics

- Building relationships between power consumption and fouling allows for algorithm development for possibility of alarm output for cleaning cycles
<table>
<thead>
<tr>
<th>8 Fan Condenser</th>
<th>RPM</th>
<th>Air Volume (m³/s)</th>
<th>Power Input (W)</th>
<th>Capacity</th>
<th>Power Input Change (%)</th>
<th>Capacity Change (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean Coil</td>
<td>600</td>
<td>34.56</td>
<td>5400</td>
<td>386</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>20 Pa Fouling</td>
<td>600</td>
<td>32</td>
<td>5640</td>
<td>370</td>
<td>4.44%</td>
<td>-4.02%</td>
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<tr>
<td>40 Pa Fouling</td>
<td>600</td>
<td>28.24</td>
<td>5840</td>
<td>345</td>
<td>8.15%</td>
<td>-10.51%</td>
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<tr>
<td>40 Pa Fouling, design capacity</td>
<td>690</td>
<td>34.56</td>
<td>8400</td>
<td>386</td>
<td>55.56%</td>
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</tbody>
</table>
- Operating cost reductions possible

<table>
<thead>
<tr>
<th>Clean Coil</th>
<th>Fouled Coil (40 Pa)</th>
<th>Comparisons – 6 months operation</th>
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<tbody>
<tr>
<td>Duty</td>
<td>Air Vol</td>
<td>Power Input</td>
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<tr>
<td>386.0</td>
<td>34.56</td>
<td>5.4</td>
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</tbody>
</table>

- Costs of pre-mature failure even more significant
Continued Areas of Research

- Continued application simulation and optimisation
- Active equipment, with auto defrosting and auto cleaning
- Reduction in use of conventional materials, with target of alternative materials
- Reduction in operating costs, through optimised control strategies and high efficiency coils / air movement
- Accurate selection and application of heat exchangers to reduce operating energy / costs

<table>
<thead>
<tr>
<th>Capacity</th>
<th>Air On</th>
<th>Fluid In</th>
<th>Fluid Out</th>
<th>Condensing Temp</th>
<th>Pressure</th>
<th>Fluid Pressure Drop</th>
<th>Fan Speed</th>
<th>Air Volume</th>
<th>Power Input</th>
<th>Sound Power</th>
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<tbody>
<tr>
<td>kW</td>
<td>°C</td>
<td>°C</td>
<td>°C</td>
<td>°C</td>
<td>Bar A</td>
<td>kPA</td>
<td>RPM</td>
<td>m3/s</td>
<td>kW</td>
<td>dB(A)</td>
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<tr>
<td>230</td>
<td>32</td>
<td>115</td>
<td>35</td>
<td>N/A</td>
<td>92.0</td>
<td>120</td>
<td>680</td>
<td>28.2</td>
<td>3.71</td>
<td>82</td>
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<tr>
<td>60</td>
<td>12</td>
<td>60</td>
<td>15</td>
<td>16</td>
<td>52.1</td>
<td>11</td>
<td>680</td>
<td>28.2</td>
<td>3.71</td>
<td>82</td>
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<tr>
<td>75</td>
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<td>94</td>
<td>950</td>
<td>38.4</td>
<td>9.50</td>
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Example of application modelling to ensure appropriate selection / operation