In conventional automobile designs, a radiator and a condenser are typically configured and mounted independently of each other. We have developed a smaller and more powerful cooling module by integrating these two products into one unit. The new cooling module has been designed to share the fin material and to have an insulating slit and other means for effective prevention of heat loss that occurs due to thermal conduction between the radiator and the condenser. In addition, as one of the key techniques for integrating fins, we studied thermal spraying of a brazing filler to the tube material and were able to achieve a practical-level cooling module through use of high-performance fins, and thus contribute largely to the efforts to create a more compact, higher performance cooling module.

**Key words**: Radiator, Condenser, Cooling module, Thermal spraying, Brazing filler, Tube material
Table 1 Relation between fin material and product’s performance

<table>
<thead>
<tr>
<th></th>
<th>Radiator</th>
<th></th>
<th>Condenser</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fin electrical</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>conductivity</td>
<td>type</td>
<td>performance</td>
<td>type</td>
<td>performance</td>
</tr>
<tr>
<td>38% IACS</td>
<td>Clad fin</td>
<td>97%</td>
<td>Clad fin</td>
<td>100%</td>
</tr>
<tr>
<td>50% IACS</td>
<td>Bare fin</td>
<td>100%</td>
<td>Bare fin</td>
<td>103%</td>
</tr>
</tbody>
</table>

- Current material

Fig.2 Properties of Al-Fe-Ni alloy

Fig.3 The structure of cooling module
Table 2  Comparison of thermal spraying process

<table>
<thead>
<tr>
<th>Thermal spraying process</th>
<th>Characteristic of braiding filler metal</th>
<th>Registration of thermal spraying</th>
<th>Equipment cost</th>
<th>Sprayed property</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shape</td>
<td>Chemical composition freedom</td>
<td>Flame temperature (°C)</td>
<td>Grain speed (m/s)</td>
</tr>
<tr>
<td>DJ method High velocity oxygen fuel (Powder)</td>
<td>○ (50%)</td>
<td>× (60%)</td>
<td>2800</td>
<td>960</td>
</tr>
<tr>
<td>Plasma spraying Powder</td>
<td>○ (60%)</td>
<td>×</td>
<td>1600</td>
<td>450</td>
</tr>
<tr>
<td>Electric arc spraying Wire</td>
<td>× (20%)</td>
<td>○</td>
<td>5000</td>
<td>250</td>
</tr>
</tbody>
</table>

Table 3  Operating conditions for DJ method

<table>
<thead>
<tr>
<th>Condition</th>
<th>Oxygen</th>
<th>Propylene</th>
<th>Air</th>
<th>Nitrogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure (MPa)</td>
<td>1.0 ~ 1.1</td>
<td>0.45 ~ 0.55</td>
<td>0.50 ~ 0.55</td>
<td>1.0 ~ 1.1</td>
</tr>
<tr>
<td>Flow (FMN)</td>
<td>40 ~ 45</td>
<td>42 ~ 46</td>
<td>54 ~ 58</td>
<td>27 ~ 31</td>
</tr>
</tbody>
</table>
Fig. 5  Relation between partial diameter and covering situation

Photo. 2  Surface and cross section situations after spraying  
(Particle diameter : 20~70µm)

Fig. 6  Relation between Si content and brazing filler amount for constant fillet length

Fig. 7  Brazing mechanism of Al-Si alloy
Fig. 8 Relation between Si content in filler Al-Si alloy and erosion depth

Fig. 9 Thermal spraying mass production

Photo. 3 Thermal spraying mass production equipment
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