Advanced CMC Manufacturing & Machining
Process Development

PROBLEM / OBJECTIVE
Improve the fuel efficiency and reduce the weight of the UH-60 Black Hawk and AH-64 Apache helicopters through the use of lighter weight, higher temperature capable, and more durable Stage 1 and Stage 2 ceramic matrix composite (CMC) shrouds, replacing metal components in the T700 family of engines.

ACCOMPLISHMENTS / PAYOFF

Process Improvement: This project demonstrated improved manufacturing and processing of CMCs used in aviation propulsion and power generation. Demonstrated processes include:

- Affordable robust manufacturing processes
- Manufacture full-scale prototype components
- Validate process capabilities to MRL 6+
- Increased efficiency of tow coating for Type S SiC fibers
- Low cost methods for fabricating shroud preform shapes
- Leaner machining fixturing and cutting processes for CMC materials
- Developing Cost Effective Methods for Applying and Repairing Environmental Barrier Coatings (EBC)

Implementation and Technology Transfer:
GE Aviation has conducted a full engine test program which has successfully demonstrated the use of CMC shrouds in a CT7 turboshaft engine. The improved manufacturing parameters and demo shrouds were delivered to PM Common Engine in April 2015. The Navy is funding development to implement CMC shrouds in the T700-401C engine for Seahawk. This program will provide a range of benefits to the Warfighter including weapon systems availability, durability, efficiency, logistical support and O&S costs.

CMC Shroud
SH-60 Seahawk

Benefits and Warfighter Impact:

<table>
<thead>
<tr>
<th>Process</th>
<th>Measure</th>
<th>Program Objective (reductions)</th>
<th>Final Status (reductions)</th>
<th>Final MRL</th>
</tr>
</thead>
<tbody>
<tr>
<td>In-Line Tow Coating</td>
<td>Labor 70%</td>
<td>70%</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Tape Processing</td>
<td>Labor 20%</td>
<td>43%</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Layup &amp; Debulk</td>
<td>Labor 50%</td>
<td>75%</td>
<td></td>
<td>6</td>
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<tr>
<td>Preforming</td>
<td>Labor 50%</td>
<td>75%</td>
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<td>6</td>
</tr>
<tr>
<td>Machining</td>
<td>Labor 20%</td>
<td>20%</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Environmental Barrier Coating</td>
<td>Labor 75%</td>
<td>94%</td>
<td></td>
<td>6</td>
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</tbody>
</table>

In addition to meeting the metrics listed above, there were a number of other potential performance benefits associated with using CMC shrouds in the T700 engine application that were identified at the onset of the program. These achievements include:

- ~0.5% improvement in engine Specific Fuel Consumption
- >1 pound of weight reduction (per engine)
- Reduced engine part count
- Reduced environmental emissions of CO2
- Reduction of front-line fuel transportation convoys

TIME LINE / MILESTONE

Start Date | Sept 2010
End Date   | April 2015

FUNDING

U.S. Army ManTech
$10.65M

PARTICIPANTS

U.S. Army RDECOM Aviation and Missile Research, Development and Engineering Center (AMRDEC)
Redstone Arsenal, AL
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