Rapid Vacuum Plasma Spray (VPS) Closeout of Liquid Rocket Engine Combustion Chamber Cooling Channels for Both Time and Cost Savings

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VPS Forming MoRe Cartridge to Safely Contain Tungsten Alloy at 1600°C
• VPS GRCop-84 Liner Development

• MSFC CDDF Task
  • Developed FGM
  • with VPS process
  • for Space
  • Furnace Cartridges
  •+ GRC Task
  • Developed Superior Copper Alloy, GRCop-84
  • (VPS = vacuum plasma spray
  • FGM = functional gradient material)

• NRA8-21 Task
  • Fabricated midsize chamber liners for higher thrust levels
  • FY01-03

• FY98-99

• MSFC CDDF + NRA8-21 Tasks
  • Applied technology to subscale chamber liners
  • FY99-01

• FY02-03

• NGLT
  • Demonstrating technology for large, “engine class” liners
  • (SSME MCC size)

• FY97

• Combined VPS, FGM, & GRCop-84 on small chamber liners

• FY01-03

(VPS = vacuum plasma spray
FGM = functional gradient material)
5K Hardware Fabrication

- VPS Applied Material to Mandrel
- As-sprayed liner
- Coolant channels machined Mandrel removed
- Channels filled
- VPS Closeout Applied & Machined
- Manifolds Attached PMC Jacket Applied (by Aerojet)
5K Hardware Testing

220 Hot-fire Tests Performed to date
1100 seconds accumulated
$P_c$ range: $750 – 1100$ psig
Oxygen/hydrogen propellants
Liner Coolant: liquid hydrogen, water
GRCop-84 temperatures = $900 – 1250$ F

No degradation observed for GRCop-84 liner or NiCrAlY hot wall layer
Alternate Material & Process

Functional Gradient Material (FGM)

- Hot wall layer: NiCrAlY
- Gradated to ----
- Liner Material: GRCop-84
- Formed with ----

Vacuum Plasma Spray (VPS)

Advantages

- NiCrAlY layer offers maximum blanch protection
- No distinct bond joint between material layers
- Near net shape part
- Reduced fabrication schedule
- Higher operating temperatures
- Higher reliability, longer life
# 5K Hardware Performance

## Subscale Cycle Test Comparison

<table>
<thead>
<tr>
<th>VPS GRCop-84 Liner</th>
<th>NARloy-Z Liner</th>
</tr>
</thead>
<tbody>
<tr>
<td>108 Cycles (520 sec, total)</td>
<td>118 Cycles (353 sec, total)</td>
</tr>
<tr>
<td>Max. GRCop-84 temp = 1250 F</td>
<td>Max. NARloy-Z temp = 1100 F</td>
</tr>
<tr>
<td>No hot wall cracks or surface roughening ever initiated – no liner degradation at all</td>
<td>Cycles &lt; 30, Hot wall cracks &amp; Surface roughening initiated</td>
</tr>
<tr>
<td>Cycle ~ 55, heat load decreased 30% less coolant required</td>
<td>Cycle ~ 70, heat load increased Surface polishing required</td>
</tr>
</tbody>
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NARloy-Z avoids $O_2/H_2$ ratios of 8:1 due to blanching.

VPS GRCop-84 liner: 9 tests at 8:1 with no signs of blanching!
Material Testing Results

0.2% YIELD STRENGTH

- VPS -270 HIP+Braze/Age
- VPS -325 HIP+Braze/Age
- NARloy-Z
Material Testing Results

UTS

- VPS -270 HIP+Braze/Age
- VPS -325 HIP+Braze/Age
- NARloy-Z

Temperature (°F)

UTS (ksi)

0.0  10.0  20.0  30.0  40.0  50.0  60.0  70.0  80.0  90.0

-500  -200  100  400  700  1000  1300  1600  1900
Material Testing Results

% ELONGATION

- VPS -270 HIP+Braze/Age
- VPS -325 HIP+Braze/Age
- NARloy-Z

Temperature (F)
40K Thruster with Cooling Channels
Cut Circumferentially
40K Thruster to being Tested
as a Calorimeter
Hot Fire Testing 40K Thruster as Calorimeter
Summary

• Demonstrated high performance of VPS FGM with hot-fire cycle testing
• Demonstrated Rapid Closeout of Combustion Chamber Cooling Channels for Reduced Time and Reduced Costs
• Increased VPS material database
• Currently testing 40K thruster as a Calorimeter

Further Information

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References


• Holmes, R.R., Ellis, D., McKechnie, T., Hickman, R., Microsturcture and Mechanical Properties of Vacuum Plasma Sprayed Cu-8Cr-4Nb. For presentation at 10th JPL/MSFC/AIAA Advanced Propulsion Research Workshop, Huntsville, AL, April 5-9,1999.


References (Concluded)


