F-35 Lightning II
ASETSDefense 2009
Replacing Cu-Be Bushings

Scott Fetter
F-35 ESOH Lead
**Report Documentation Page**

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

<table>
<thead>
<tr>
<th>1. REPORT DATE</th>
<th>2. REPORT TYPE</th>
<th>3. DATES COVERED</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEP 2009</td>
<td></td>
<td>00-00-2009 to 00-00-2009</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>4. TITLE AND SUBTITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replacement for Cu-Be Bushings</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>6. AUTHOR(S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lockheed Martin Aeronautics, F-35 Materials and Processes, Pinellas Park, FL, 33782</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>13. SUPPLEMENTARY NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASETSDfense 2009: Sustainable Surface Engineering for Aerospace and Defense Workshop, August 31 - September 3, 2009, Westminster, CO. Sponsored by SERDP/ESTCP.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>16. SECURITY CLASSIFICATION OF:</th>
<th>17. LIMITATION OF ABSTRACT</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. REPORT</td>
<td>Same as Report (SAR)</td>
</tr>
<tr>
<td>unclassified</td>
<td></td>
</tr>
<tr>
<td>b. ABSTRACT</td>
<td></td>
</tr>
<tr>
<td>unclassified</td>
<td></td>
</tr>
<tr>
<td>c. THIS PAGE</td>
<td></td>
</tr>
<tr>
<td>unclassified</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>18. NUMBER OF PAGES</th>
<th>19a. NAME OF RESPONSIBLE PERSON</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td></td>
</tr>
</tbody>
</table>
Timeline

• 2003-LM Hazardous Materials Management Program made Copper-Beryllium (Cu-Be) plain bearings (bushings) Restricted Materials
  – Any new LM designs have to investigate/implement alts
  – F-35 granted continued use while alternatives investigated/implemented to replace ~350 bushings
  – F-35 Static/Fatigue/Durability Test Articles immediately changed

• 2004 – Five phase test series and Collaborative MAI
  – Toughmet AT/TS and Nitronic 60 CW initial promising candidates
  – Found Mil-B-81820 Navy Bushing Qualification testing rig in San Antonio

• 2005 - Based on initial test series, F-35 changed all <2.5”OD airframe bushings to Nitronic 60CW to new LM specification
  – Continued testing on biomedical Cobalt-Chrome-Moly alloy based on outstanding bushing test rig results

• 2006 – Completed initial and enhanced test series, direction to continue development of BioDur CCM as a wrought aerospace qualified material
  – Far superior wear properties and comparable strength
Mil-B-81820 Qual Test Rig

Cantilevered Beam Applies Constant Load

440C Paddle

Test Bushing

440C Insert

440C Support Pin

Load Cell

Load
Sub Scale Bushing Test

• COMPONENTS
  – BUSHING - press fit; candidate material
  – PIN - slip fit; MP 35N steel (pictured) and 440C steel

• LOAD
  – normal to bushing ID / pin OD interface
  – + / - 25 degrees steady rotation while under load
  – starts at 2000 pounds (all loads are actual); increases 500 pounds every 100 cycles; max is 10,000 pounds reached at 1600 cycles; run-out at 2000 cycles
Sub Scale Bushing Test Cont’d

• RESULTS
  – The following specimens (pictures on next pages) all reached 10,000 pounds at 1600 cycles, but only one material would continue to ‘run-out’.
  – CCM showed no negative signs at run-out so load and cycles were increased; failure did not occur.
  – Higher performance for all candidate materials was seen when using 440C pins due to less spalling and galling.

• DISCUSSION
  – Both Nit 60 and CCM performed excessively better than Cu-Be even though both have less compressive yield strength than Cu-Be. Different grades (strengths) of the same material showed very little performance differences. For ‘wear’ applications tribology is far more important than strength as long as the compressive yield strength is not exceeded.
Sub Scale Bushing Test Cont’d

Cu-Be Bushing; MP 35N Pin
1725 cycles total
125 cycles at 10,000 lbs

ToughMet 3TS Bushing; MP 35N Pin
1600 cycles total
Stopped at one cycle of 10,000 lbs
Sub Scale Bushing Test Cont’d

CW Nitronic 60 Bushing; MP 35N Pin
- 1850 cycles total
- 250 cycles at 10,000 lbs

CCM Bushing; MP 35N Pin - After run-out, ran at 12,000 pounds (2000 additional pounds) to 5000 cycles without failure. There was minimal (0.004-0.005”) wear.
Current CCM Status

• Carpenter Alloy finalized alloy content for wrought material to new name ACUBE100
• Match Cu-BeTF00 properties
  – *Will not match the more rarely used TH04 but still superior wear*
• Verification complete up to 4”
• Qualification billets fabricated and waiting approved plan
• Gradual implementation including replacing Nitronic 60CW on an as-touched basis
Questions?