Analysis and Comparison of Surface Roughness Effects on Pressure Data from SLS Wind Tunnel Test

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Mission Objective

- Necessary to know flow field characteristics of SLS design configurations
- Does paint application affect signal?
- Does sanding of the paint affect signal?

Shoulder of paint around the Kulite

Sanded paint around the Kulite

[Images of SLS and Kulite courtesy of NASA PSP Team] [Moon and Mars images courtesy of Google Images]
### Timeline of Events

#### Configuration 17

<table>
<thead>
<tr>
<th>Day 0 (Dec. 1(^{st}))</th>
<th>Day 1 (Dec. 4(^{th}))</th>
<th>Day 2 (Dec. 5(^{th}))</th>
<th>Day 3 (Dec. 6(^{th}))</th>
</tr>
</thead>
</table>
| • Clean Model           | • Epoxy, uPSP Base and Topcoat  
  • Test with no sanded Kulites | • Refreshed uPSP Topcoat  
  • Test with 10 Sanded Kulites  
  • 940, 952, 925, 998, 923, 416, 792, 779, 996, 738 | • No refresh of uPSP  
  • Test with 5 sanded Kulites  
  • 414, 773, 763, 419, 404 |

<table>
<thead>
<tr>
<th>All Days Tested at Mach</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.7</td>
</tr>
<tr>
<td>0.8</td>
</tr>
<tr>
<td>0.85</td>
</tr>
<tr>
<td>0.9</td>
</tr>
<tr>
<td>0.95</td>
</tr>
<tr>
<td>1.05</td>
</tr>
<tr>
<td>1.1</td>
</tr>
<tr>
<td>1.2</td>
</tr>
<tr>
<td>1.4</td>
</tr>
</tbody>
</table>

[SLS and Kulite images courtesy of NASA PSP Team]
## Kulite Locations on SLS

### Table

<table>
<thead>
<tr>
<th>#</th>
<th>Kulite</th>
<th>Zone</th>
<th>X</th>
<th>Phi</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>738</td>
<td>13</td>
<td>43.1</td>
<td>283</td>
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<tr>
<td>2</td>
<td>996</td>
<td>77</td>
<td>53.4</td>
<td>270</td>
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<tr>
<td>3</td>
<td>404</td>
<td>77</td>
<td>53.4</td>
<td>180</td>
</tr>
<tr>
<td>4</td>
<td>763</td>
<td>77</td>
<td>55.9</td>
<td>90</td>
</tr>
<tr>
<td>5</td>
<td>773</td>
<td>77</td>
<td>58.5</td>
<td>113</td>
</tr>
<tr>
<td>6</td>
<td>779</td>
<td>77</td>
<td>58.5</td>
<td>293</td>
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<tr>
<td>7</td>
<td>792</td>
<td>78</td>
<td>60.7</td>
<td>225</td>
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<tr>
<td>8</td>
<td>414</td>
<td>78</td>
<td>61.4</td>
<td>45</td>
</tr>
<tr>
<td>9</td>
<td>416</td>
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<td>61.4</td>
<td>182</td>
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<tr>
<td>10</td>
<td>419</td>
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<td>62.2</td>
<td>93</td>
</tr>
<tr>
<td>11</td>
<td>998</td>
<td>79</td>
<td>65.4</td>
<td>270</td>
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<td>12</td>
<td>925</td>
<td>79</td>
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<td>315</td>
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<tr>
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<tr>
<td>15</td>
<td>952</td>
<td>99</td>
<td>72.4</td>
<td>225</td>
</tr>
</tbody>
</table>

### Diagram

- Mach 0.7
- Mach 0.8
- Mach 0.85
- Mach 0.9
- Mach 0.95
- Mach 1.05
- Mach 1.1
- Mach 1.2
- Mach 1.4

[Run Log data courtesy of NASA PSP Team]
Tools for Mission Success

1. Notes, Pictures, and Run Log from Test

2. Reduced Kulite and uPSP Pressure Time History Data

3. Matlab $\rightarrow$ Plot 3D and Modified uPSP Example Code

4. Dots

5. Requirements of SLS Customers

[SLS image courtesy of NASA PSP Team]
Processing the Kulite Data
Locating Kulites on SLS using Dots

• Began with studying documentation taken during Kulite sanding (photos, notes, test run log)
• Using Dots, was able to determine location of these Kulites on SLS model

Kulite names can be featured beside their location

[Dots image courtesy of NASA PSP Team and Thomas Steva of MSFC]
[Kulite images courtesy of NASA PSP]
Data Processing Method for Kulites

• 15 Kulites, 9 Mach Numbers, 4 Days of Testing

Enter Desired Run Number
Enter Desired Sequence #
Enter Desired Kulite

Input working directory

Result is FPL of Kulite at that Mach number and Model Orientation
Comparing the Kulite Data

• Combined the plots for all four days for each Mach number
Results of Sanded Kulite Data
11 DDS Results Along SLS at Mach 0.7, $\alpha=0$ $\beta=0$

Flow

[Dots image courtesy of NASA PSP Team and Thomas Steva of MSFC]
11 DDS Results Along SLS at Mach 0.95, $\alpha=0 \ \beta=0$

[Dots image courtesy of NASA PSP Team and Thomas Steva of MSFC]
11 DDS Results Along SLS at Mach 1.4, $\alpha=0$ $\beta=0$

Flow

[Dots image courtesy of NASA PSP Team and Thomas Steva of MSFC]
Results: Mach 0.7 @ $\alpha=0$, $\beta=0$

K998  KA738  KA996

KA779  K404  KA979

K498  KA925  KA998

KA940  KA763  KA773

K416  K414  K419
Results: Mach 0.95 @ $\alpha=0$, $\beta=0$
Results: Mach 1.4 @ $\alpha=0$, $\beta=0$
Results with Large Differences in FPL, $\alpha=0 \ \beta=0$

- Mach 0.7: 414, 763, 773
- Mach 0.95: 414, 763, 779
- Mach 1.4: 414, 773, 779
11 DDS Results Along SLS at Mach 0.7, \(\alpha=0 \ \beta=4\)
11 DDS Results Along SLS at Mach 0.95, α=0 β=4

Day 0
Day 1
Day 2
Day 3

[Dots image courtesy of NASA PSP Team and Thomas Steva of MSFC]
11 DDS Results Along SLS at Mach 1.4, $\alpha=0$ $\beta=4$

Flow

[Dots image courtesy of NASA PSP Team and Thomas Steva of MSFC]
Results: Mach 0.7 @ $\alpha=0$, $\beta=4$
Results: Mach 0.95 @ $\alpha=0$, $\beta=4$
Results: Mach 1.4 @ $\alpha=0$, $\beta=4$
Results with Large Differences in FPL, $\alpha=0$ $\beta=4$

Mach 0.7

Mach 0.95

Mach 1.4
Processing the uPSP Data
Locating Nodes on SLS using Dots

- SLS is defined by PSP grid ➔ each grid has multiple zones ➔ each zone has nodes
- Selected a 3x3 section of nodes near a sanded Kulite using Dots grid

Each node has an i and j coordinate:
- i coordinate goes around from 1-361 for every line of nodes in the grids for the larger parts of the model
- J=1 at the start of every zone from left to right

[Dots image courtesy of NASA PSP Team and Thomas Steva of MSFC]
Data Processing Method for uPSP

• Converted the 3 x 3 section of chosen nodes into a virtual Kulite

```matlab
% Read HDF5 file
file = '132506_trans.h5';
zone = 13;

obj.X = h5read(file, '/X'); % retrieves all X data for h5 file
obj.Y = h5read(file, '/Y'); % retrieves all Y data for h5 file
obj.Z = h5read(file, '/Z'); % retrieves all Z data for h5 file
obj.GridSizes = h5read(file, '/Grid_Sizes');
jmax = obj.GridSizes(1,zone);
kmax = obj.GridSizes(2,zone);

nodes = 0;
for i = 1:zone-1
    nodes = nodes + (obj.GridSizes(1,i)* obj.GridSizes(2,i));
end
node_start = nodes + 1;
nodes_zone = obj.GridSizes(1,zone)* obj.GridSizes(2,zone);
node_end = node_start + nodes_zone - 1;
numOfNodes = node_end - node_start + 1;
clear nodes;
X = obj.X(node_start:node_end,1);
Y = obj.Y(node_start:node_end,1);
Z = obj.Z(node_start:node_end,1);
dim1 = 176; % j-value or i-value in DOTS
dim2 = 25; % k-value or j-value in DOTS

NZone = [(jmax+1) + dim1];
NZone = [(kmax*(dim2-1)) + dim1];
KuliteNode = node_start + NZone - 1;

KuliteX = obj.X(KuliteNode);
KuliteY = obj.Y(KuliteNode);
KuliteZ = obj.Z(KuliteNode);
```

Specified h5 file and zone of nodes

Extracted h5 file information and Grid Sizes;
“jmax” is max of “i” and “kmax” is max of “j” in Dots program for specified zone

Extracting Node Information:
- `node_start` ➔ first node in zone in relation to all nodes
- `nodes_zone` ➔ number of nodes in specified zone
- `node_end` ➔ last node in zone in relation to all nodes
- `numOfNodes` ➔ `nodes_zone`

Specified (i,j) location of node to obtain node number in specified zone and in relation with all the nodes in Dots program
Data Processing Method for uPSP Cont.

- Extract the Frame x Node Data from h5 file
- Isolate chosen nodes in columns perpendicular to flow for 3 vectors
- Reshape these into 3x1xtime matrices
- Combine the matrices into one 3x3xtime matrix
- Average matrix to create virtual Kulite, now a 1x1xtime matrix
- Reshape into 2D matrix (1xtime)
- Processed uPSP data to obtain Power Spectral Density plot
  - Sampling Rate ➔ 10kHz
  - FFT size ➔ 512
  - Overlap ➔ 0.75
  - Detrended virtual Kulite (although not needed)
  - Normalized by variance of detrended data
- Plotting PSD in semilog fashion
Conclusions Gathered to Help Complete the Mission

• No right or wrong answer
• Changing the roughness of a model will affect the flow
• Positive Note: uPSP not creating tones $\Rightarrow$ not translating to design change
• uPSP surface roughness does affect flow, magnified at areas of high fluctuating pressures (do see offset but consistent across days)

Future Work Towards Mission Accomplishment

• Process uPSP data for same runs
• Prepare for September uPSP demonstration
  • Only sanding in areas of high fluctuation
  • Painting over Kulites $\Rightarrow$ does uPSP damage the Kulite?
Thank You! Any Questions?

Power of Pink!
Results

\( M = 0.7 \)

\( \alpha = 0, \beta = 0 \)
Results
M=0.7  \alpha=0, \beta=0

[Dots image courtesy of NASA PSP Team and Thomas Steva of MSFC]
Results

$M=0.95$

$\alpha=0$, $\beta=0$

[Dots image courtesy of NASA PSP Team and Thomas Steva of MSFC]
Results

$M = 1.4$

$\alpha = 0, \beta = 0$

[Dots image courtesy of NASA PSP Team and Thomas Steva of MSFC]
Results

$M=0.7$

$\alpha=0$, $\beta=4$
Results

$M=0.95$

$\alpha=0$, $\beta=4$

[Dots image courtesy of NASA PSP Team and Thomas Steva of MSFC]
Results

M=1.4

α=0, β=4

[Dots image courtesy of NASA PSP Team and Thomas Steva of MSFC]