Measurement, Identification, and Evaluation of Airport Runway Grooving

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◆ Jeff Rapol, FAA (retired).
◆ Qiang Wang, SRA International.
◆ Al Larkin, FAA Airport Technology R&D Branch.
Outline

1. Need for grooving.
2. Grooving and groove measurement equipment.
3. FAA construction and maintenance guidelines.
4. Profile measurement and data processing for grooving evaluation.
5. Software for groove evaluation.
6. Example results.
7. Summary.

Example in NWT, Canada

Timeline

1. Paved in 2006
   - High fines content in aggregate
   - High asphalt content -> smooth surface
   - Paver left ruts along wheel paths
2. May 05, 2007 - B737 hydroplaned
3. Summer 2007 - paving contractor patched ruts
4. April 22, 2010 - B737 hydroplaned
5. July 2010 – conducted runway friction and texture testing
6. Researched remediation options
7. July 06, 2011 - B737 hydroplaned
8. July 14, 2011 - B737 hydroplaned
9. July 26, 2011 started cutting grooves

Presented at the SWIFT 2012 Conference, Banff, Alberta, Canada
Example in NWT, Canada

User Concerns

Hydroplaning/Wet Friction

Example in NWT, Canada

Friction Improvement Options

<table>
<thead>
<tr>
<th>CYVQ Improvement Options: Cost Comparisons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
</tr>
<tr>
<td>cost estimate</td>
</tr>
<tr>
<td>recurrence</td>
</tr>
<tr>
<td>cost/ year</td>
</tr>
</tbody>
</table>

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Braking on a Puddled Asphalt Pavement

Water Spray on an SMA Surfaced Runway Pavement, Beijing Capital International Airport, Ungrooved
Hydroplaning Video

Grooving Equipment
Manual Groove Measurement With Caliper and Micrometer Depth Gage

Manual Groove Measurements To Compare With Profiler Measurements at ACY
**FAA Construction Guidelines**

- Item P621, Saw Cut Grooves

  a. Alignment tolerance. The grooves shall not vary more than ±1-1/2 inch (38 mm) in alignment for 75 feet (23 m) along the runway length, allowing for realignment every 500 feet (150 m) along the runway length.

  b. Groove tolerance. Depth. The standard depth is 1/4 inch (6 mm). At least 90% of the grooves must be at least 3/16 inch (5 mm), at least 60% of the grooves must be at least 1/4 inch (6 mm), and not more than 10% of the grooves may exceed 5/16 inch (8 mm).

  c. Width. The standard width is 1/4 inch (6 mm). At least 90% of the grooves must be at least 3/16 inch (5 mm), at least 60% of the grooves must be at least 1/4 inch (6 mm), and not more than 10% of the grooves may exceed 5/16 inch (8 mm).

  d. Center-to-center spacing. The standard spacing is 1-1/2 inch (38 mm). Minimum spacing 1-3/8 inch (34 mm). Maximum spacing 1-1/2 inch (38 mm).

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**FAA Maintenance Guidelines**


  **3-5. GROOVE DETERIORATION.** Periodically, the airport operator should measure the depth and width of a runway’s grooves to check for wear and damage. When 40 percent of the grooves in the runway are equal to or less than 1/8 inch (3 mm) in depth and/or width for a distance of 1,500 feet (457 m), the grooves’ effectiveness for preventing hydroplaning has been considerably reduced. The airport operator should take immediate corrective action to reinstate the 1/4 inch (6 mm) groove depth and/or width.
**FAA Inertial Profiler Setup To Measure Grooves For Comparison With Manual Measurements**

LMI Selcom vertical non-contact displacement sensor with accelerometer mounted along its line-of-sight

The data acquisition equipment is located inside the vehicle

**PTS Inertial Profiler**

Wheel-speed sensor to measure longitudinal distance traveled

LMI Gocator vertical non-contact displacement sensor

Vertical accelerometer
Schematic Of a Typical Inertial Profiler

Signal Acquisition Unit
+/- 5V Analog 16 Bit Serial 1 Pulse per 25 mm

Laptop Computer
Stores 3 Bytes/Sample in Expanded Memory 8,000 Samples/Second

Typical Processing for Highway Profile and Runway Grooving Measurements

Accelerometer Signal
High-Pass Filter 300 ft cutoff
Profile
Displacement Signal

Errors from vehicle acceleration (sine), roll and pitch (cosine).
Screenshot Of Data Acquisition Program Showing Vertical Displacement (top), Acceleration (middle), and Distance Pulses

Screenshot Of Data Acquisition Program With Signals Zoomed To Show Fine Detail (Signals Are Shown With Respect To Time)
Screenshot of Data Acquisition Program After Processing the Accelerometer and Distance Signals (Signals Are Still Shown With Respect To Time). Maximum Speed is 59 ft/s (40.2 mph).

Groove Definition Improves as Test Speed Decreases

<table>
<thead>
<tr>
<th>Test Speed</th>
<th>Groove Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 ft/s</td>
<td></td>
</tr>
<tr>
<td>20 ft/s</td>
<td></td>
</tr>
<tr>
<td>30 ft/s</td>
<td></td>
</tr>
<tr>
<td>40 ft/s</td>
<td></td>
</tr>
<tr>
<td>50 ft/s</td>
<td></td>
</tr>
<tr>
<td>58 ft/s</td>
<td></td>
</tr>
</tbody>
</table>
The Profile After Conversion to Distance-Based At a Sample Spacing of 1 mm (0.039 in)

Required Sample Rates

- A high enough sample rate has to be used in order to get good definition of the groove shapes.
- The LMI Selcom sensor used on the FAA profiler has a sample rate of 62,500 Hz.
- The LMI Gocator on the PTS profiler has a sample rate of 32,000 Hz.
- Lower sample rates require lower speeds to get satisfactory definition of the groove shapes.
**Groove Measurement For Roughness-Scale Profiling**

- The grooves must be measured when using small spot-size sensors even if the final sample spacing is for roughness analysis.
- This is to avoid severe aliasing.
- Roughness profiles are normally reduced to 1-inch to 6-inch sample spacing.
- The required sequence is: sample fast enough to define the groove shapes, low-pass filter, subsample to the final rate.

**Groove Identification and Evaluation**

- The FAA has an unpublished program for groove identification and evaluation called ProGroove.
- PTS has a program called Groovy which is based on the same methodology as used in ProGroove.
- The original procedure for groove identification was developed by Jeff Rapol using macros in an Excel spreadsheet.
Distance-Based Profile Read Into Groovy and Grooves Identified

Profile

Idealized Groove Shapes As Identified

Distance-Based Profile and Identified Grooves After Zooming

Baseline for groove identification
Three Different Filters are Implemented in Groovy

- Standard Butterworth low-pass filter.
- FAA beam bridging filter.
- UMTRI bridging filter.
- The FAA and UMTRI filters both perform better than the low-pass filter, but take considerably longer to run.
More Information on the Groove Identification Procedure


Three Baseline Filters

- Low-Pass Filter
- UMTRI Filter
- FAA Beam Filter
Three Baseline Filters, Second Example

Low-Pass Filter

UMTRI Filter

FAA Beam Filter

Probability Distribution Functions Over the Full Profile Length
Bar Chart Over Profile Sections

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Bar Chart Over Profile Sections

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Bar Chart Over Profile Sections

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Bar Chart Over Profile Sections

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Text Summary of Width Results

Summary of Groove Depth Results
Profile file = E:\Sample Files\Rwy 10R 1 immgrv.csv
Surface type = Asphalt
Profile total length = 0.0 ft
Profile step length = 0.003281 ft
Baseline filter type = Beam Bridging Filter, length = 10.0 in

Minimum value over full profile length = 0.022200 in
Maximum value over full profile length = 0.320980 in
Average value over full profile length = 0.193287 in
Standard Dev. over full profile length = 0.039843 in
Percent of grooves identified = Infinity %
Percent less than the specified limit = 3.33 % < 0.125

Groove Depth results summarized over each profile section.

<table>
<thead>
<tr>
<th>Section No.</th>
<th>Length (ft)</th>
<th>Maximum Depth</th>
<th>Minimum Depth</th>
<th>Average Depth</th>
<th>Std. Dev.</th>
<th>% Identified</th>
<th>% &lt; Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>150</td>
<td>0.288780</td>
<td>0.022200</td>
<td>0.164667</td>
<td>0.052168</td>
<td>58.75</td>
<td>18.01</td>
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<tr>
<td>2</td>
<td>150</td>
<td>0.315880</td>
<td>0.097115</td>
<td>0.226889</td>
<td>0.032454</td>
<td>69.11</td>
<td>0.48</td>
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<tr>
<td>3</td>
<td>150</td>
<td>0.313755</td>
<td>0.101135</td>
<td>0.226499</td>
<td>0.037834</td>
<td>72.69</td>
<td>0.34</td>
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<tr>
<td>4</td>
<td>150</td>
<td>0.293740</td>
<td>0.071280</td>
<td>0.190445</td>
<td>0.037464</td>
<td>68.00</td>
<td>3.80</td>
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<tr>
<td>5</td>
<td>150</td>
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<td>0.114945</td>
<td>0.214563</td>
<td>0.036017</td>
<td>71.49</td>
<td>0.81</td>
</tr>
<tr>
<td>6</td>
<td>150</td>
<td>0.296850</td>
<td>0.109120</td>
<td>0.195506</td>
<td>0.035113</td>
<td>70.94</td>
<td>1.41</td>
</tr>
</tbody>
</table>

Etc.

FAA Maintenance Guidelines


3-5. GROOVE DETERIORATION. Periodically, the airport operator should measure the depth and width of a runway’s grooves to check for wear and damage. When 40 percent of the grooves in the runway are equal to or less than 1/8 inch (3 mm) in depth and/or width for a distance of 1,500 feet (457 m), the grooves’ effectiveness for preventing hydroplaning has been considerably reduced. The airport operator should take immediate corrective action to reinstate the 1/4 inch (6 mm) groove depth and/or width.
Example of Joints in Need of Sealing

Summary

◆ Equipment is available for measuring groove geometry using a high-speed inertial profiler.

◆ Calculation procedures and personal computer power are available for defining the geometry of airport runway grooves.

◆ The groove measurements can be used for pavement acceptance screening, followed by physical measurements in problem areas.
Summary (Continued)

◆ Summaries of the groove geometry can be used to track groove deterioration over time for use in pavement management.

◆ Other possible uses of the procedures after suitable modification are:
  ◆ Joint seal evaluation.
  ◆ Evaluation of rubber removal.
  ◆ Slab curling.

Thank you for your attention.