Ultrasonics Equipped Crimp Tool-
A New Technology for Aircraft Wiring Safety

William T. Yost (William.T.Yost@nasa.gov)
Daniel F. Perey (Daniel.F.Perey@nasa.gov)
Elliott Cramer  (K.E.Cramer@nasa.gov)

Nondestructive Evaluation Sciences Branch
NASA-Langley Research Center
Hampton, VA 23681-2199
Introduction
Overview of Crimp Quality and Possible improvements with this technology

- Crimp Failures occur for many reasons.
  - At installation
    - Wrong connector, wire size or tool used
    - Improper technique
    - Crimp tool failure (worn jaws), etc.
  - During service life
    - Corrosion effects
    - Wire under stress
- Crimp installation are clearly indicated with the Ultrasonics Equipped Crimp Tool (*patent applied for*).
- Recertification of existing crimps (during service life) is possible
Present Practices

• Procedures
  – Detailed crimping procedures, with QA verification on procedures, are used to ensure good initial crimp quality

• Certification / Calibration
  – Destructive pull-testing of similarly crimped connectors is used to certify tools and procedures
  – There is no direct verification of a good crimp

• Verification
  – No crimp recertification is possible
The Concept
Basic Concept of Ultrasonic Equipped Crimp Tool

Crimp Connector

Ultrasonic Wave Transmitter

Wire

Ultrasonic Wave Receiver

\[ A(t) \] is the ultrasonic wave amplitude as a function of time

Operational Signals

Input to crimp

Output from crimp
Basic Concept – A Good Crimp!

Input
(plane ultrasonic wave)

Multiple Output wavelets

Ultrasonic Features Of a Good Crimp:

1. Multiple signal paths thru crimp
2. Higher amplitude on time record
3. Low spectral variation in Fourier Transform
Basic Concept – A Bad Crimp!

Ultrasonic Features Of a Bad Crimp:

1. Single (or no) signal paths thru crimp
2. Low amplitude on time record
3. High spectral variation in Fourier Transform
Test of Concept
Test of Concept Arrangement

Oscilloscope
(Agilent 54832B)

Crimp Tool Jaws

Ultrasonic Pulser-Receiver
(GE Panametrics 5900PR)

Simple Electronics that can easily be miniaturized to produce a self contained ultrasonics equipped crimp tool
Test of Concept
Instrumented Crimp Tool

Wedges (for ultrasonic transmit and receive)

Transducers, 1/4 inch dia (Panametrics A-series)

Crimp Tool (Raychem AD 1377)
Test of Concept Results

- Based on using 10 Mhz transducers
- 16-20 gauge wires used for connections
Test of Concept:  
Typical Oscilloscope Waveforms of Good Crimp

Received Signal Waveform

Destructive Pull-Test Confirmation
Wire gage - 20 AWG. Minimum load to pass - 19 Lbs. Actual load reached - 34 Lbs. Type of failure - wire breakage (not crimp failure).
**Test of Concept:**

Typical Oscilloscope Waveforms of Bad Crimp

Transmitters - 10 Mhz
Pitch - Catch Mode

Destructive Pull-Test Confirmation
Wire gage - 20 AWG.
Minimum load to pass - 19 Lbs. Actual load reached - 10.4 Lbs. Type of failure - wire pullout (*crimp failure*).
Data: Experimental Results

- Based on using 7.5 Mhz transducers
- 16-20 gauge wires used for connections
**Experimental Setup: Crimp-tool and Tester**

- The “Jaw”
  - *This study uses incomplete jaw closure to make the “bad” crimps*
- Handle closure is performed in 5 mm increments through standard jaw closure
- Wires and connectors are crimped together
- Crimp tester (Alphatron MPT200A) is used to measure force needed to pull wire-connector crimp apart
Experimental Set-up: Electronics and Ultrasonics

**Jaw of Crimp Tool**
(Raychem AD1377)

**7.5 MHz Transducers**
(Panametrics A121S)

**Connector**
Tyco D436-83

**Wire**
16 Ga M22759/87
18 Ga M22759/34
20 Ga M22759/11

**Oscilloscope**
(Agilent 54832B)

**Ultrasonic Pulser-Receiver**
(GE Panametrics 5900PR)
Experimental Results: Path Analysis

Transducers - 7.5 Mhz
Pitch - Catch Mode
16 Gauge wire and connectors

Path Analysis within jaws
- multiple reflections
- Path length measures 35 mm
  (34.7 mm from ultrasonics)

Path Length Analysis within connector
- ~ 7 to 8 distinct paths
- Length variation among paths ultrasonically measures 0.7 mm (16 ga)
## Data from 16 Gauge Wire-Connector Crimp Measurements

<table>
<thead>
<tr>
<th>Wire Gauge/Compression Level</th>
<th>Pulse Height (arb units)</th>
<th>Pulse Width (arb units)</th>
<th>Failure Mode</th>
<th>Pull at Failure (lbs) (Spec=50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16/1</td>
<td>3.9</td>
<td>2</td>
<td>Pull-out</td>
<td>17.5</td>
</tr>
<tr>
<td>16/2</td>
<td>7</td>
<td>2.5</td>
<td>Pull-out</td>
<td>50.2</td>
</tr>
<tr>
<td>16/3</td>
<td>31</td>
<td>8</td>
<td>Break (at crimp)</td>
<td>65.1</td>
</tr>
<tr>
<td>16/4</td>
<td>73</td>
<td>5</td>
<td>Break (at crimp)</td>
<td>62.0</td>
</tr>
<tr>
<td>16/5 (full crimp)</td>
<td>100</td>
<td>6.7</td>
<td>Break (at crimp)</td>
<td>59.7</td>
</tr>
</tbody>
</table>
A Plot of Pull at Failure vs. Ultrasonic Pulse-Height through Crimp-Connector Junction (16 Gauge)

Data from 16 Gauge Wire-Connector Crimp Measurements

Pull at Failure (Lbs) vs. Pulse Height (arb. Units)
## Data from 18 Gauge Wire-Connector Crimp Measurements

<table>
<thead>
<tr>
<th>Wire Gauge/Compression Level</th>
<th>Pulse Height (arb units)</th>
<th>Pulse Width (arb units)</th>
<th>Failure Mode</th>
<th>Pull at Failure (lbs) (Spec=38)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18/1</td>
<td>4</td>
<td>1.7</td>
<td>Pull-out</td>
<td>7.8</td>
</tr>
<tr>
<td>18/2</td>
<td>7</td>
<td>2</td>
<td>Pull-out</td>
<td>24</td>
</tr>
<tr>
<td>18/3</td>
<td>12</td>
<td>5.5</td>
<td>Break (at crimp)</td>
<td>42.4</td>
</tr>
<tr>
<td>18/4</td>
<td>37</td>
<td>5.5</td>
<td>Break (at crimp)</td>
<td>43.5</td>
</tr>
<tr>
<td>18/5 (full crimp)</td>
<td>96</td>
<td>7</td>
<td>Break (at crimp)</td>
<td>43.7</td>
</tr>
</tbody>
</table>
A Plot of Pull at Failure vs. Ultrasonic Pulse-Height through Crimp-Connector Junction (18 Gauge)

Data from 18 Gauge Wire-Connector Crimp Measurements

Pull at Failure (Lbs) vs. Pulse Height (Arb. Units)
# Data from 20 Gauge Wire-Connector Crimp Measurements

<table>
<thead>
<tr>
<th>Wire Gauge/Compression Level</th>
<th>Pulse Height (arb units)</th>
<th>Pulse Width (arb units)</th>
<th>Failure Mode</th>
<th>Pull at Failure (lbs) (Spec=19)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20/1</td>
<td>3</td>
<td>2.5</td>
<td>Pull-out</td>
<td>1.1</td>
</tr>
<tr>
<td>20/2</td>
<td>8.9</td>
<td>2.5</td>
<td>Pull-out</td>
<td>11.5</td>
</tr>
<tr>
<td>20/3</td>
<td>12.1</td>
<td>2</td>
<td>Pull-out</td>
<td>27.7</td>
</tr>
<tr>
<td>20/4</td>
<td>42</td>
<td>7</td>
<td>Break (at crimp)</td>
<td>33.9</td>
</tr>
<tr>
<td>20/5 (full crimp)</td>
<td>82</td>
<td>5</td>
<td>Partial Break</td>
<td>33.8</td>
</tr>
</tbody>
</table>
A Plot of Pull at Failure vs. Ultrasonic Pulse-Height through Crimp-Connector Junction (20 Gauge)
Results and Conclusions from Data

• Data was presented that examines the use of ultrasonics to evaluate crimp quality for incomplete crimps.

• Ultrasonic interrogation of crimp predicts crimp quality
  – Ultrasonic Pulse Height correlates very well with pull-test results for 16, 18, and 20 AWG wire-crimp connections
  – Ultrasonic pulse width is also a possible predictor for pull-test results

• Ultrasonic Pulse Height indicating a quality crimp is relatively independent of wire gauge
Concept for a Possible Commercial Instrument
Artist Conception of Two Versions of a Commercial Instrument

Optional Data Collection and Archival

Self-contained Instrument
Simple Pass/Fail Indications
Waveform Analysis Embedded in Instrument
Summary and Future Directions

- No current instrument for crimp quality assessment
- Ultrasonic instrument can be used to assess and/or verify crimp mechanical integrity and hence crimp quality
- Technique allows for re-inspection / recertification
- A fully developed system will permit improved data and record keeping on critical crimp connections.
- Additional measurements are underway to substantiate these and investigate frequency-depency of ultrasonic signals used to evaluate crimp quality.
- Investigate wide range of crimp failure modes