BiTS 2011 Burn-in & Test Socket Workshop

Session 4

ARCHIVE 2011

OF MATERIAL IMPORTANCE

Electroformed Barrels for Fine Pitch Test Probes
Larre Nelson, John Winter—Rika Denshi America

Solder Migration DoE for Pin
Chen Yong Lai—Test Tooling Solutions Group

Challenges & Solutions For Characterization of Thin Connector Alloy Strip
John C. Harkness—Brush Wellman Inc.

Electroformed Barrels for Fine Pitch Test Probes

Larre Nelson
John Winter
Rika Denshi America

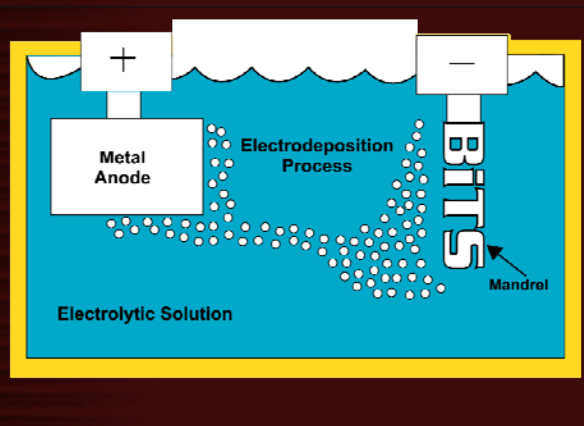
2011 BiTS Workshop
March 6 - 9, 2011

Content

- Electroforming Basics
- *e-barrel*™ Manufacturing
- *e-barrel*™ Characteristics
- Test Results

3/2011 Electroformed Barrels for Fine Pitch Test Probes 2

What is Electroforming ?



How to make an electroformed BiTS logo.

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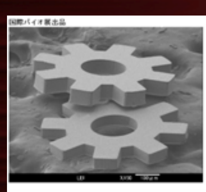
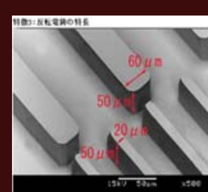
Miniature Electroformed Parts



Gears



Cantilevers

Barrels & Ferrules

Test Probes

3/2011 Electroformed Barrels for Fine Pitch Test Probes 4

Electroformed Test Probe Barrels

3/2011 Electroformed Barrels for Fine Pitch Test Probes 5

e-barrel™ Features

- **OD** — **0.085 mm (0.0033”)**
- **Wall Thickness** — **0.0075 mm (0.0003”)**
- **Gold on ID** — **1.5 µm (60 µ”) over entire length**
- **Temperature Rating** — **Gold on ID is non-oxidizing up to 175+°C**

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Machined Barrels

Machined from Tube

Machined from Solid Rod

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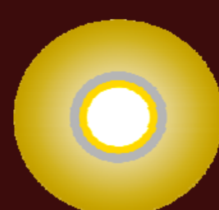
Clad Tubes

Welded Strip



Seamless Tube

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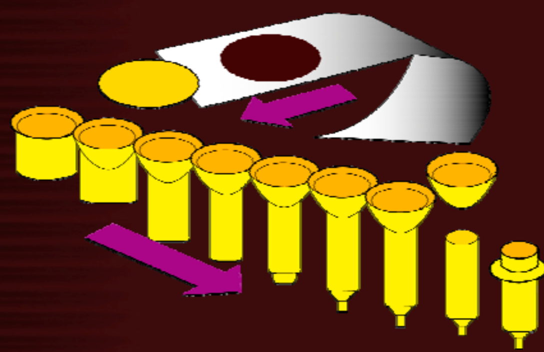
Deep Drawn Barrels



Strip material is fed into a sequence of dies.

e-barrel™ Manufacturing Process
(Rack Plating Method)

The process is similar to making candles.

e-barrel™ Manufacturing Process
(Continuous Plating Method)

A typical continuous wire plating line.

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e-barrel™ Manufacturing Process
(Cut to Specified Length)

Long tubes are cut to length like logs in a saw mill.

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e-barrel™ Manufacturing Process

Of course, it's always good to have a back-up plan.

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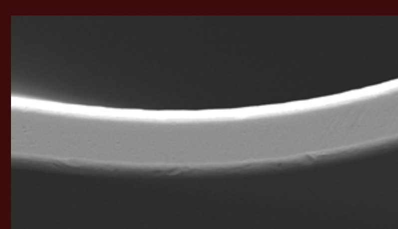
Wall Thickness



Thin walls with concentric ID and OD. (OD: 0.3 mm)

Gold plating on the ID. (Au: 1.5 µm, Ni: 13.5 µm)

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Surface of the Barrel ID

e-barrel™

Standard barrel: 6X rougher than *e-barrel™*

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Barrel OD and Length

Top OD: 0.350 mm
Bottom OD: 0.085 mm

Top barrel: 5.6 mm long
Bottom barrel: 3.0 mm long

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Gold Plating on the ID

e-barrel™: open end

e-barrel™: middle section

Standard barrel: open end

Standard barrel: middle section

3/2011 Electroformed Barrels for Fine Pitch Test Probes 17

e-barrels™ for Fine Pitch Test Probes

Features	Benefits
• Small OD	Fine Pitch
• Thin Wall	Maximum Space for Spring
• Various ODs and Lengths	Custom Requirements
• Uniform Plating on ID	Low CRES, and High Durability
• Thick Plating on ID	High Temperature Rating

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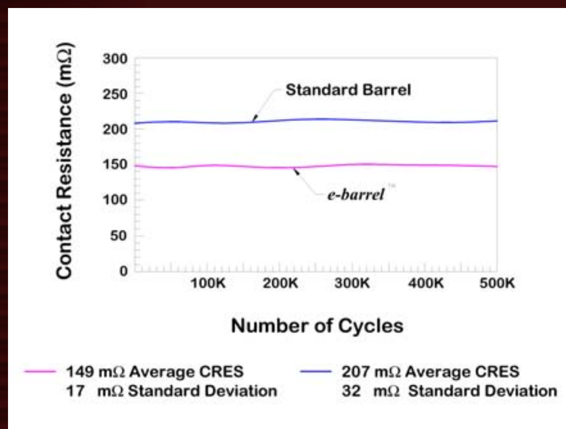
0.2 mm Pitch Test Probe



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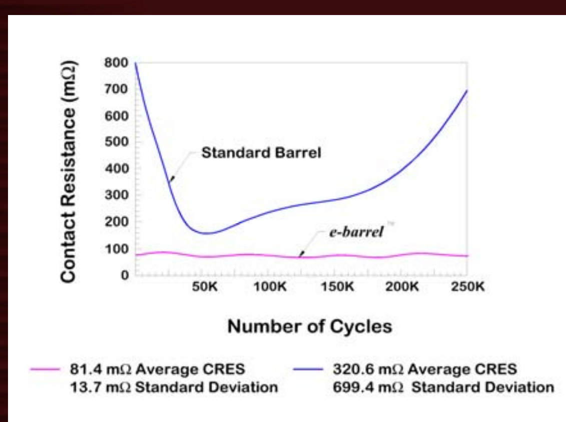
0.5 mm Pitch Test Probe
(Baked, then cycled at 175°C)



3/2011 Electroformed Barrels for Fine Pitch Test Probes 20

Prediction of Things to Come

- Smaller pitch
- Rigorous spring force and travel requirements
- Higher temperatures (→ 175°C)

3/2011 Electroformed Barrels for Fine Pitch Test Probes 21

Acknowledgements

T. Kohtaka
Kumamoto, Japan

W. Shiratani
Kumamoto, Japan

S. Amadio
Attleboro, Mass. USA

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Solder Migration DoE for Pin

Lai Chen Yong
Test Tooling Solutions Group

2011 BiTS Workshop
March 6 - 9, 2011

Content

- Objective
- DoE Set Up
- Lab Data (CRES data for particular cycle intervals)
- Conclusion

Objective

- DoE on different pin tip material and plating to address the solder migration issue

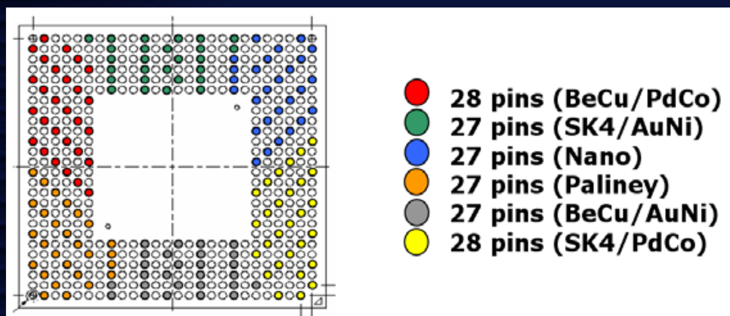
DoE Set Up

- BGA pin types details

Pin Type	Base material	Hardness	Plating
Type 1	BeCu	380HV	Au/PdCo/Ni
Type 2	SK4	650HV	Au Over Ni
Type 3	BeCu	380HV	Nano Coating On Au Over Ni
Type 4	Paliney 7	427HV	No plating
Type 5	BeCu	380HV	Au Over Ni
Type 6	SK4	650HV	Au/PdCo/Ni

DoE Set Up

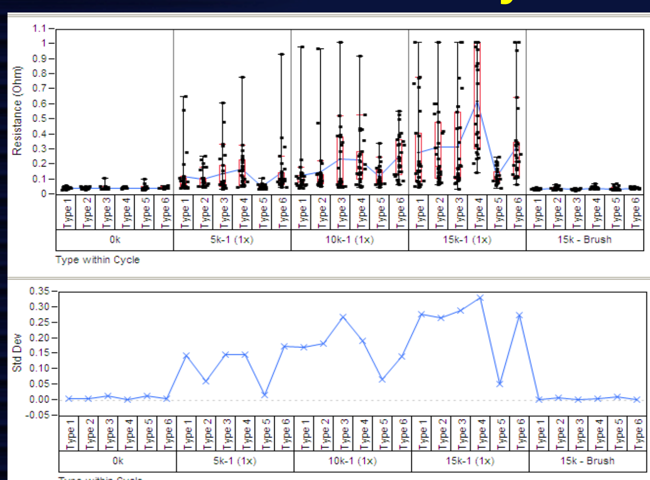
- 6 types of pins are populated in one test contactor



- Using BGA mechanical package for cycling test

3/2011 Solder Migration DoE for Pin 5

Lab Data: Variability Chart (0-15k)

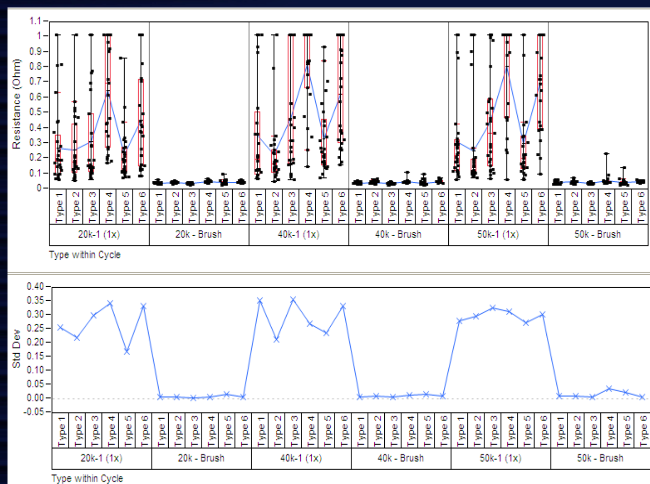


Type 1 :BeCu/PdCo
Type 2 :SK4/AuNi
Type 3 :BeCu/AuNi/Nano
Type 4 :Paliney7
Type 5 :BeCu/AuNi
Type 6 :SK4/PdCo

- Up to 15k, Type 5 pin lowest CRES mean & stdev.
- Type 4 pin shown the highest CRES mean & stdev after 15k
- Best to worst : T5 -> T1/T2/T3/T6 -> T4

3/2011 Solder Migration DoE for Pin 6

Lab Data: Variability Chart (20-50k)

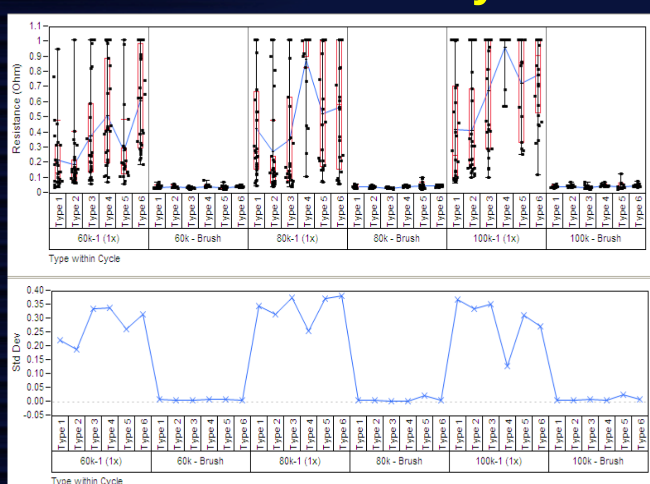


Type 1 :BeCu/PdCo
Type 2 :SK4/AuNi
Type 3 :BeCu/AuNi/Nano
Type 4 :Paliney7
Type 5 :BeCu/AuNi
Type 6 :SK4/PdCo

- From 20-50k, Type 1, 2 & 5 pin with lowest CRES mean & stdev.
- Type 4 & 6 pin shown the highest CRES mean & stdev.
- Best to worst : T1/T2/T5 -> T3 -> T4/T6

3/2011 Solder Migration DoE for Pin 7

Lab Data: Variability Chart (60-100k)

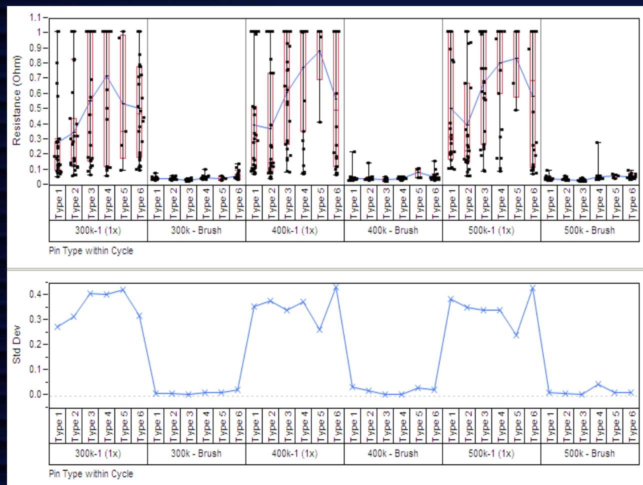


Type 1 :BeCu/PdCo
Type 2 :SK4/AuNi
Type 3 :BeCu/AuNi/Nano
Type 4 :Paliney7
Type 5 :BeCu/AuNi
Type 6 :SK4/PdCo

- From 60-100k, Type 1 & 2 pin with lowest CRES mean.
- Best to worst : T1/T2 -> T3/T5/T6 -> T4

3/2011 Solder Migration DoE for Pin 8

Lab Data: Variability Chart (300-500k)



Type 1 :BeCu/PdCo
Type 2 :SK4/AuNi
Type 3 :BeCu/AuNi/Nano
Type 4 :Paliney7
Type 5 :BeCu/AuNi
Type 6 :SK4/PdCo

- Type 1 & 2 still show the lowest mean & smaller spread among all.

3/2011 Solder Migration DoE for Pin 9

Conclusion

- Type 5 (BeCu/AuNi) pin tip didn't show major impact on the solder migration issue as it works normally after the brushing process.
- Type 1 (BeCu/PdCo) & type 2 (SK4/AuNi) pin showed lower mean CRES up to 500k cycles, and was consistent along all the test intervals from the DoE.
- Pin's CRES is able to reduced to acceptable region after the brushing process in all cycle intervals regardless of the pin type in different material and plating.

3/2011 Solder Migration DoE for Pin 10

CHALLENGES & SOLUTIONS FOR CHARACTERIZATION OF THIN CONNECTOR ALLOY STRIP

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Brush Wellman Inc.

2011 BiTS Workshop
March 6-9, 2011

Outline

- Thin strip – challenges for property testing
- New test methods for thin strip:
  - Issues with Near Elastic Properties
  - "Multiple Beam Width Test" for Bend Formability
  - Fatigue Tests:
    - "Creep Bending Fatigue Test" Machine (R = 0 unidirectional bending ONLY)
    - "Ductility Fatigue Flex Tester" (R = -1 fully reversed bending ONLY)
    - Ductility Measurement via "Flex Tester"
  - "Mandrel Test" for Stress Relaxation Resistance
- New vs Traditional Property Test Comparisons
- Conclusions & Acknowledgements

3/2011 Challenges & Solutions for Characterization of Thin Connector Alloy Strip 2

Challenges of Thin Strip (I)

- Miniaturization of contacts = driving force for very thin strip
  - Currently as thin as 0.0012 in. – 0.0008 in. (0.03 mm to 0.02 mm)
- Designers still expect traditional mechanical and physical property test results at thin delivered gauges

3/2011 Challenges & Solutions for Characterization of Thin Connector Alloy Strip 3

Challenges of Thin Strip (II)

- *Potential* "thickness effects" in strip
  - Microstructural features such as grain size and intermetallic particles may NOT "scale down" proportional to thickness reduction
  - Metallurgical processes may differ
    - More intermediate anneals to thin gauges
    - Compromises on proprietary process parameters due to equipment limitations at thin gauges

3/2011 Challenges & Solutions for Characterization of Thin Connector Alloy Strip 4

Challenges of Thin Strip (III)

- Traditional property testing equipment CANNOT handle very thin strip
  - "Near elastic" property tests are compromised or impossible
    - Spring Bend Limit – must use shorter span & lower permanent set criterion to define bending yield strength
    - Elastic Limit in Tension – test apparatus weight alone causes plastic deformation (or fracture!) before Elastic Limit can be determined
  - Traditional Tensile Elongation measurement is difficult
  - Stress Relaxation/Fatigue -- cannot achieve desired Initial Stress levels *in bending* with traditional tapered cantilever beam lengths/deflections

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"Near Elastic" Property Tests

Spring Bend Limit

(Bending Stress for 50 microns set)

•Stepwise load/unload 3-point bend

•**CAN test thin strip** by shortening span & dropping to 25 microns set

Elastic Limit in Tension

(0% offset YS)

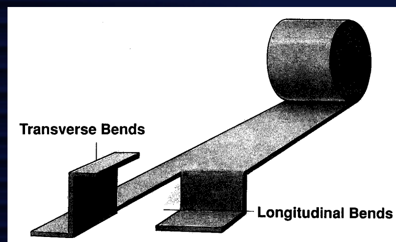
•Stepwise load/unload of strain-gauged tensile specimen

•Detect 1st microstrain of set

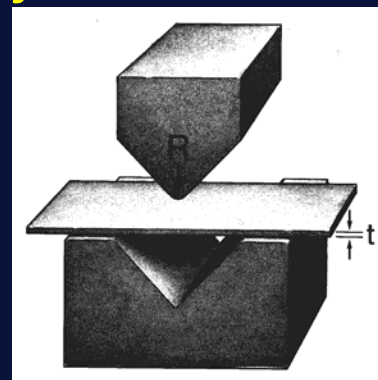
•**CANNOT test thin strip** – weight pan alone causes plastic yielding

3/2011 Challenges & Solutions for Characterization of Thin Connector Alloy Strip 6

Traditional "Plane Strain" Bend Formability Test



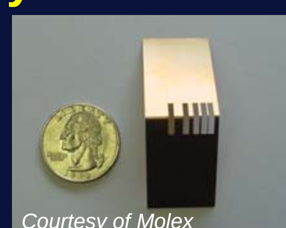
"Plane strain" (beam W/t >> 10-12) using 90 deg V-block & a series of punches of radius R
- Longitudinal & Transverse bends
  - Ultra conservative measure of R/t min for no cracking
  - Test data *appear* less "competitive"



- Hard to discriminate small differences in R/t min at very thin t (finite series of R's)

New "Multiple Beam Width" Bend Formability Test

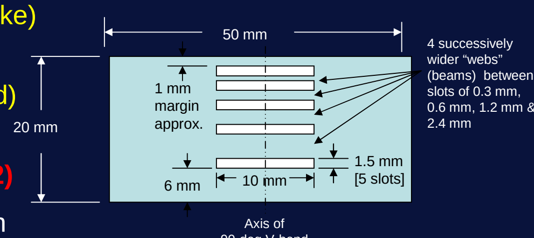
Brush Wellman pneumatic press & die (5 slots in single stroke)



Bent test coupon (run series of R's)

Test coupon (originally designed by Molex & Wieland)

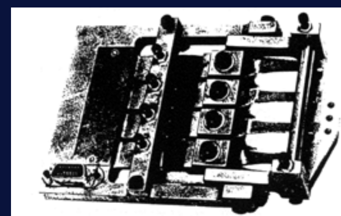
- "Plane strain" (W/t < 10-12) to "plane stress" (W/t>>10-12)
- More "competitive" R/t min in narrower beams



Traditional Tapered Cantilever Beam Fatigue Tester (Fatigue Dynamics)

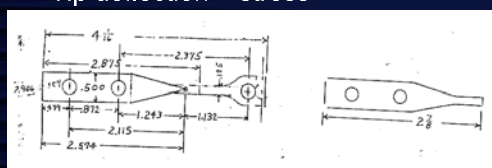
Fully Reversed (R = -1) & Unidirectional (R = 0) Bending

Shut-down controller & cam drive



Multiple specimen fixture -- individual counters shut-down at fracture

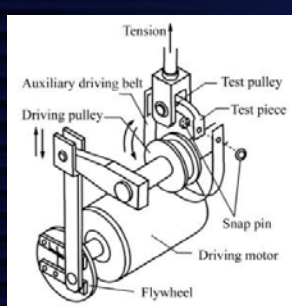
- Tip deflection = stress



Tapered beam specimen intended for **0.005-0.020”** strip

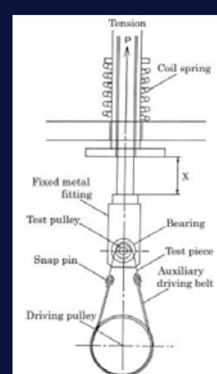
- In practice, **0.00787” min**
- Can’t detect failed thin strip
- Machine is out of production

New “Creep Fatigue Tester” (Nippon Bell Parts, Japan)



Unidirectional Bending ONLY (R ~ 0)

- For **0.02-0.2 mm** strip
- Tension, R slightly > 0
- Test pulley radius = stress
- Tests multiple specimens with individual counters stopping at break



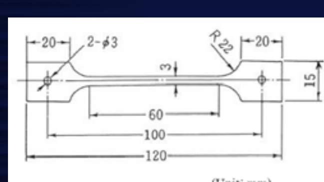


Photo etched “dog bone” test specimen

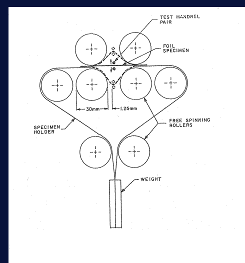
New "Ductility Fatigue Flex Tester"

(Jovil Mfg.)

Fully Reversed (R = -1) Bending Only

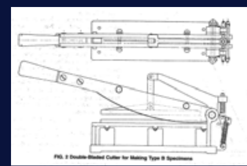
Tester w/cycle counter

- Tests flat flexible cable & foil gauge strip
- Single specimen only



Strip path -- guide rolls

- Mandrel dia. = stress
- **t << 0.00787"**
- Insufficient stress levels (mandrels) for t > 0.00787"



Precision specimen shear (Thwing-Albert)

- ¼" X 12" rectangles
- Duct tape leaders from specimen ends to suspended weight
- Conforms specimen to mandrel

3/2011 Challenges & Solutions for Characterization of Thin Connector Alloy Strip 11

"Flex Tester" DUCTILITY Measure (I)

(Per ASTM E 796-94, "Standard Test Method for Testing Ductility of Metallic Foil")

- Ductility measurement satisfactory for acceptance testing of commercial strip, manufacturing control & component design
- Alternative to tensile elongation methods of ASTM E 345-93, "Standard Test Methods of Tension Testing of Metallic Foil"
  - 2" gauge length = change in length between light scribe marks after pulling to fracture
  - 5" gauge length = taken from load-elongation graph to failure (on a positive head-speed type machine)

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"Flex Tester" DUCTILITY Measure (II)

- Run "Flex Tester" at a mandrel dia. small enough (stress high enough) to give 30-500 cycles to failure
- Iteratively solve empirical equation:

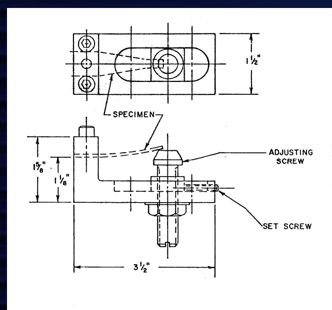
$$N_f^{-0.6} D_f^{0.75} + 0.9(S_u/E) * [(S_f/S_u)(\exp(D_f)/0.36)]^{0.1785\log(10^5/N_f)} - 2t_M/(2_p + t) = 0$$

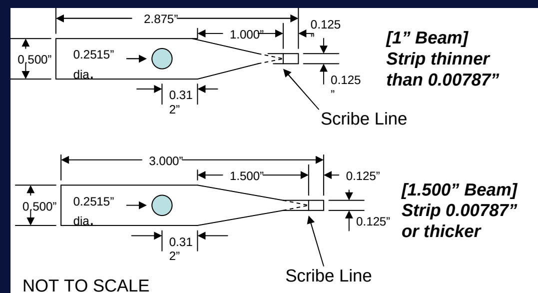
  - N_f = cycles to failure
  - D_f = fatigue ductility(X100%)
  - S_u, S_f & E = tensile strength, fracture strength & modulus in tension
  - t, t_M = thickness & min. core thickness (t – surface features)
  - 2p = mandrel dia.
  - Terms combine Manson-Coffin plastic strain/fatigue life relationship, elastic strain-fatigue life relationship & cyclically applied strain range
  - Programmable calculator/spreadsheet solution routines available
- Repeat for multiple specimens & report average D_f

"Flex Tester" DUCTILITY Measure (III)

- Formula for computing D_f in published ASTM specification was *incorrect*
  - Formula in previous slide (#13) has been corrected
- ASTM E 796-94 was actually WITHDRAWN in 2009
  - Failure to update within 8 years of last update
- Brush Wellman has had few problems testing elongation in thin strip per ASTM E 345-93 using low capacity horizontal tensile testers to pull CNC-milled "dog bone" specimens

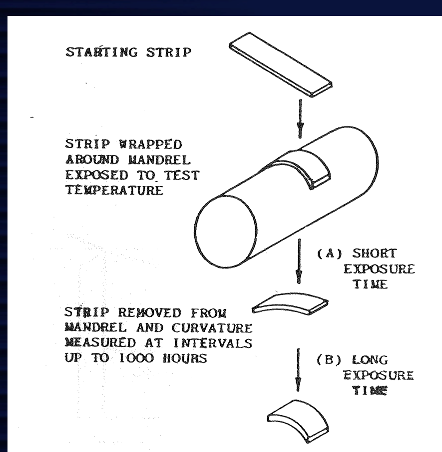
Traditional Stress Relaxation Test





- Tapered cantilever beam stressed in bending
- Difference between initial deflection & tip set after thermal exposure for various times = "% Remaining Stress"
- CANNOT deflect tip enough to apply 0.75% of 0.2%YS Initial Stress at very thin gauge, nor "scale down" fixture for shorter, thinner beams

New "Mandrel Test" for Stress Relaxation



- Sheared rectangle
- **Suitable for very thin strip**
- Wrap around mandrel with metal hose clamp
- Mandrel dia. = Initial Stress
- Difference between mandrel radius & specimen set radius of curvature after thermal exposure for various times = "%Remaining Stress"
- Downside = must custom machine mandrels for each material & strip thickness

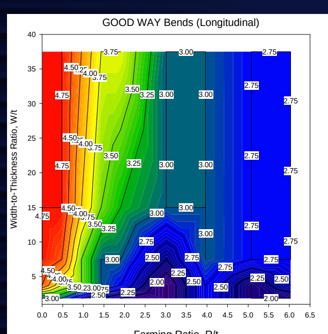
Test Method Comparisons

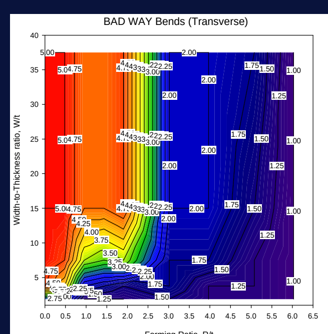
Bend Formability
Fatigue
Stress Relaxation

- *Graphs in examples reduced in size – fonts hard to read*
- *Key points of comparison highlighted by enlarged labels, trend direction arrows and/or figure captions*

3/2011 Challenges & Solutions for Characterization of Thin Connector Alloy Strip 17

Bend Formability Test Comparison (I)





0.0063"

Alloy 190 XHM

Multiple Beam Width (MBW) Bend Test – **Color contour plots of Bend Surface Appearance Rating vs. y = beam Width/t & x = punch R/t**

Red-yellow = rough/unacceptable Surface Appearance Ratings (> #4) on a scale of #1 = smooth to #5 = open crack

Green = typical acceptance limit for bend surface roughness (~#3 Rating)

Blues = smoothest, preferred Bend Surface Ratings (#2 - #1)

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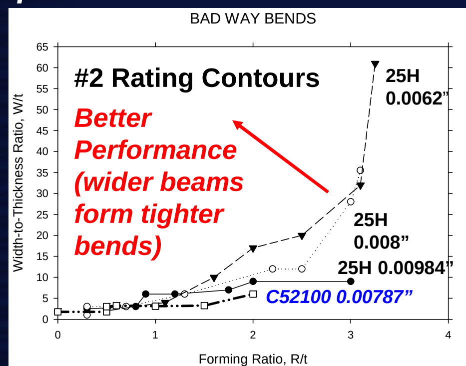
Bend Formability Test Comparison (II)

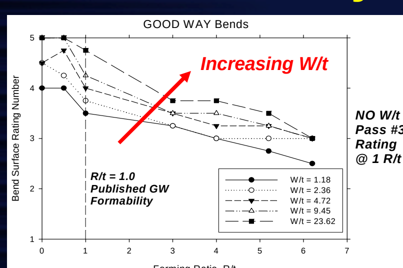
Unique Use of "MBW Bend Test" Data



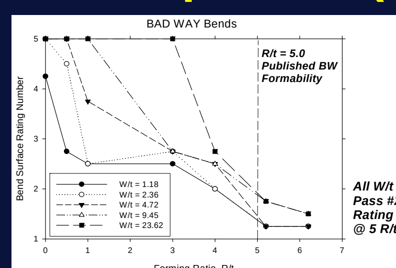
Superimpose Contours for Selected Surface Rating# on a Plot of W/t vs. R/t

- **Compare performance of same material vs. thickness**
- **Compare performance of different materials at ~ same thickness**

Bend Formability Test Comparison (III)



NO W/t Pass #3 Rating @ 1 R/t



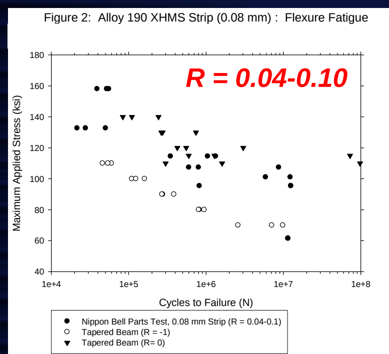
All W/t Pass #2 Rating @ 5 R/t

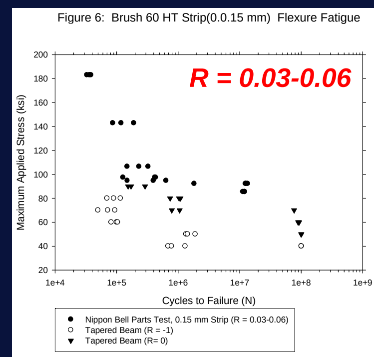
MBW Test Surface Rating vs R/t curves at several W/t's compared to Traditional Bend Test R/t min values (example = 0.010" Alloy 190 XHM)

- GW bends at test W/t's do NOT pass #3 Rating at published 1 R/t min
- BW bends at test W/t's all pass #3 Rating at published 5 R/t min

IN MOST CASES MBW Test #3 Rating correlates well with Traditional Test published R/t min for W/t >> 10-12 (Plane Strain)

Fatigue Test Comparison (I)



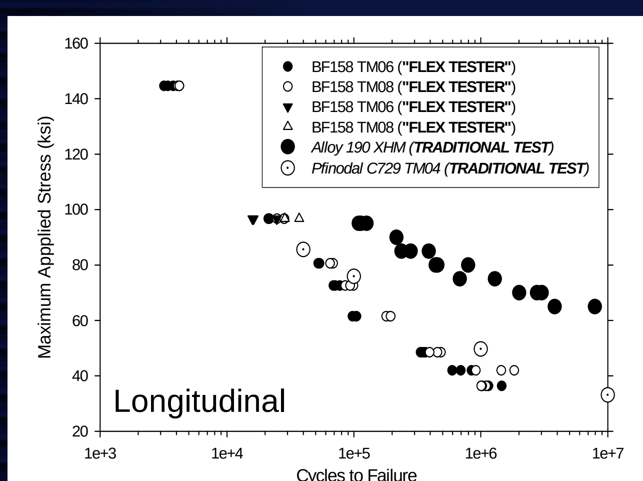


Nippon Bell Parts "Creep Fatigue Test" S-N data for thin Alloy 190 & Brush 60 at R ~ 0:

- Correlates well with **Traditional Test R = 0** for thick Alloy 190 & Brush 60
- Shows superior Fatigue Strength to Traditional Test R = -1 (as expected)

Fatigue Test Comparison (II)

Mill Hardened BrushForm158tm

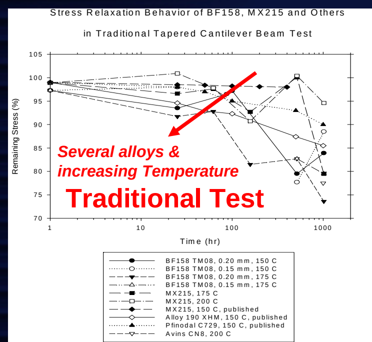


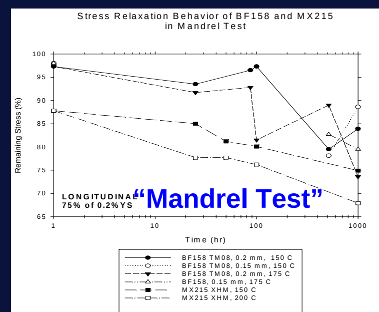
"Flex Tester" R = -1 S-N curves for thin BF158tm (C72900) correlate well with Traditional Test R = -1 curve for thicker Pfinodaltm C729

Alloy 190 R = -1 Traditional Test curve shown for comparison

Stress Relaxation Test Comparison

(%RS vs Time curves for C72900 CuNiSn Strip)





"Mandrel Test" vs Traditional Tapered Cantilever Beam Test:

- Thermal relaxation rates comparable (slopes of %RS vs Time curves)
- "Mandrel Test" = greater initial "mechanical relaxation" (set) at Room T
  - Compensate by "translating" curves up until 1 hr data point >95 %RS

Conclusions (I)

- Decreasing strip gauge introduces challenges in traditional property tests:
  - Premature plastic deformation in "Near Elastic" strength tests (Spring Bend Limit, Elastic Limit)
  - Inability to discriminate small differences in bend formability in "Plane Strain" V-block Test
  - Inability to achieve target stresses in bending via tapered beam specimen deflection (Fatigue, Stress Relaxation)

Conclusions (II)

- New test methods have been identified that overcome most testing challenges in thin strip
  - Simple adjustments to Spring Bend Limit Test parameters (but -- NO Elastic Limit Test alternative)
  - "Multiple Beam Width Bend Formability Test"
  - Novel Fatigue Tests
    - Nippon Bell Parts "Creep Fatigue Test" (R ~ 0)
    - "Ductility Fatigue Flex Tester" (R = -1)
  - "Mandrel Test" for Stress Relaxation

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Conclusions (III)

- New property tests generally correlate well with traditional test method results
  - **"Multiple Beam Width" Bend Test** typically gives acceptable #3 surface appearance rating in Plane Strain (W/t >>10-12) at R/t published for Plane Strain V-block Test
  - **"Creep Fatigue Test"** (R ~ 0) & **"Flex Test"** (R = -1) give S-N curves comparable to Tapered Cantilever Beam Tests
  - **"Mandrel Test"** gives Stress Relaxation curves comparable in thermal relaxation rate to Tapered Cantilever Beam Test
- Differences mainly attributable to mechanical effects
  - Tensile component in **"Creep Fatigue Test"** (R slightly > 0)
  - Increased Room Temp. set in **"Mandrel Test"**, shifting %RS vs. Time curves downward compared to Tapered Beam Test
- No *conclusive* evidence of metallurgical or processing "thickness effects" on new test outcomes

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Acknowledgements

- **John Wetzel** at Brush Wellman (Reading, PA) for acquiring pneumatic press and special die for "MBW Bend Test", and all thin strip for new test methods
- **Ted Skoraszewski** at Reading for running "MBW Bend Tests" of thin strip
- **Joshua Caris** at CWRU's Center for Mechanical Characterization of Materials for guidance in "Flex Tester" set-up & operation
- **John Fox** at Brush Wellman (Elmore, OH) for running "Flex Tester" fatigue & "Mandrel" stress relaxation tests (as well as traditional tests)
- **Tadashi Suzuki** at Brush Wellman (Japan) Ltd. for coordinating "Creep Fatigue Tests" of thin Brush Wellman strip at Nippon Bell Parts
- **Michael Gedeon** at Brush Wellman (Cleveland, OH) for helpful review, formula correction for "Flex Tester" Ductility Measurement & creation of solution spreadsheet