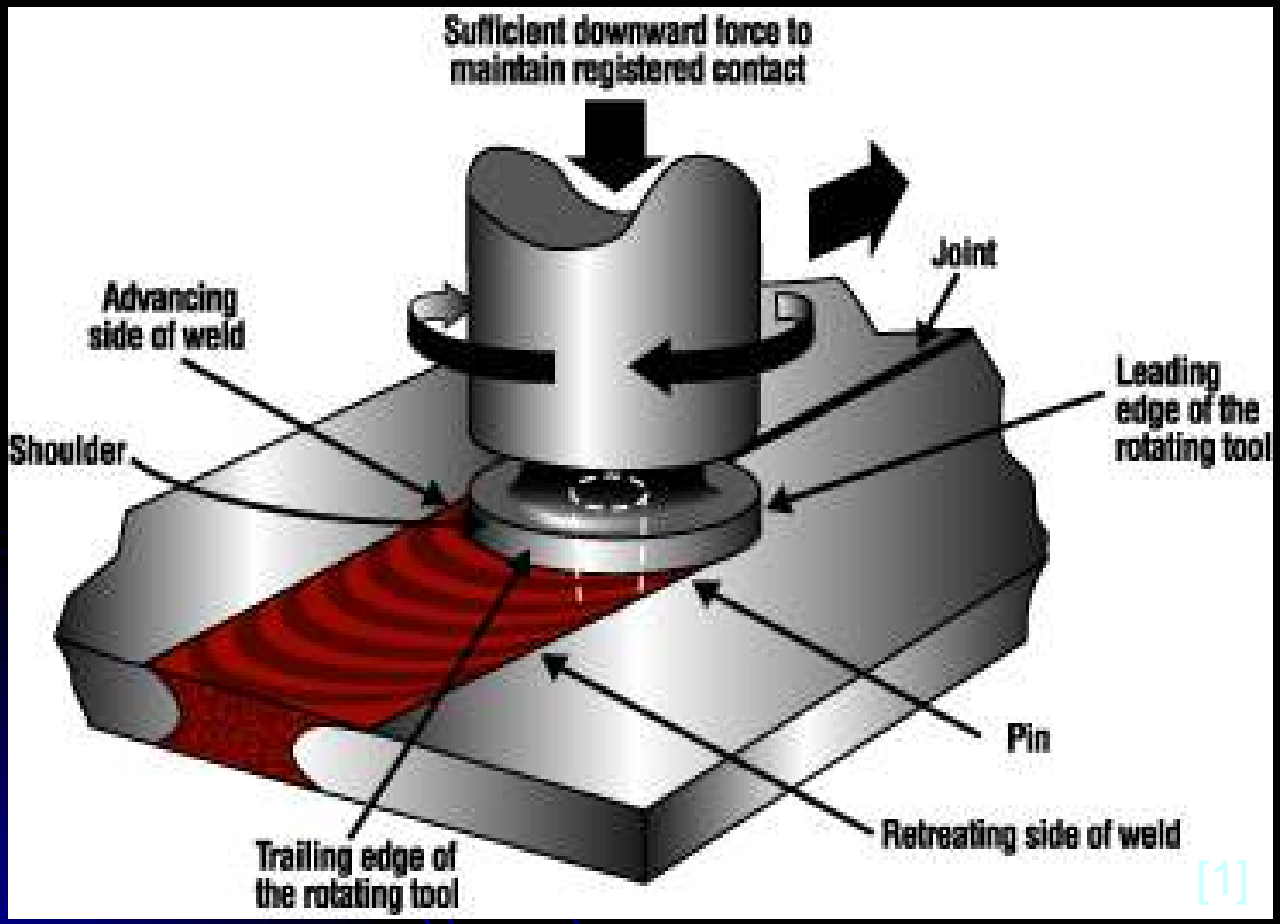
Initial Evaluation of a Spring-Opposed Shoulder Retractable Pin Tool for Friction Stir Welding

D.Lammlein, D.DeLapp, A.Strauss, G.Cook, Vanderbilt Univ., Nashville TN

T.Lienert, M.Bement, Los Alamos N.L., NM

Friction Stir Welding



- TWI, 1991
- Solid state process
- Rotating tool provides frictional heat
- Shoulder of tool retains stirred material

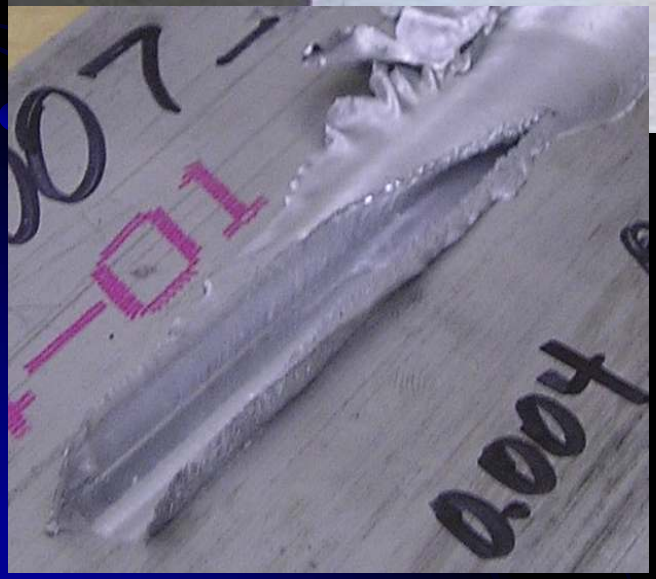
[1]frictionstirlink.com, Friction Stir Link Inc.

Why FSW?

- Maintain parent material strength (alloy dependent)
- No fumes, arcs, or spatter
- High repeatability
- No weld post-processing

Q: Why a Retractable Pin?
A: Exit Material Without Defects

- Closed Contours (e.g.cylinders,spheres)



Other Closed Contour Methods:

Figure: 'Start and park' method in the welding of cylinders without a RPT [2.]

[2.] Anderson, C.-G. (2002). Development of fabrication technology for copper canisters with cast inserts, Swedish Nuclear Fuel and Waste Management Co.

Keyhole Defect

Method: Stop traverse and remove tool

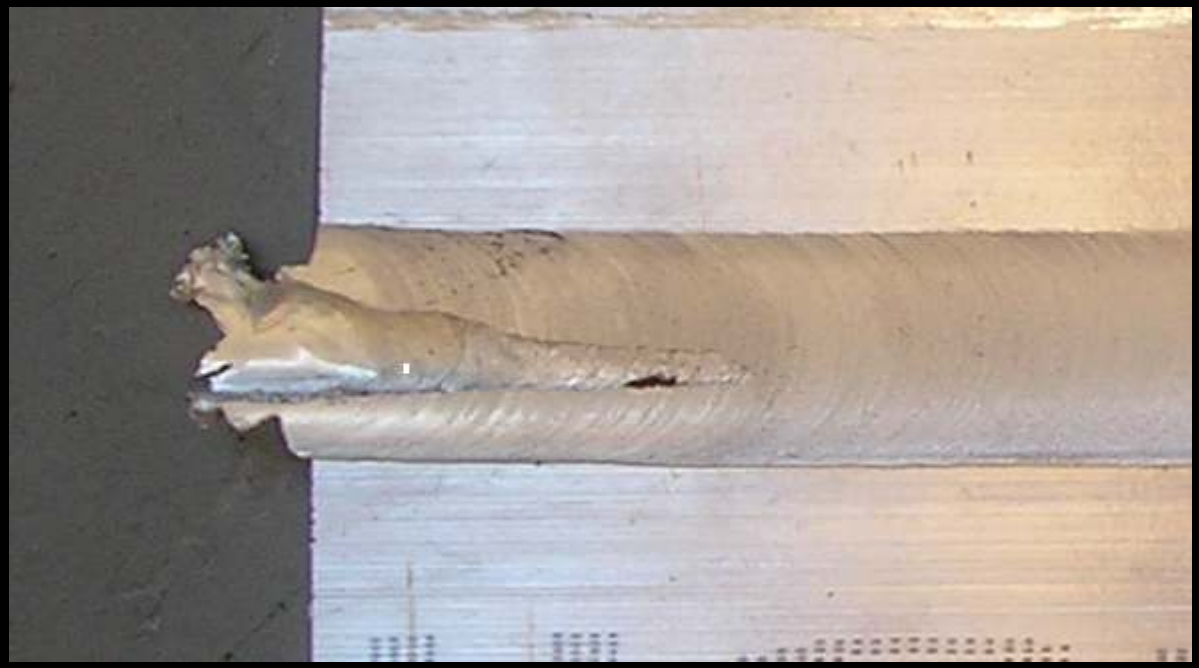
Result: Void left by pin

Run-out Defect

Method: Weld over material boundary

Result: Material fails

- Pin traverse forces
- Proximity of FSW influenced zone
- No edge material containment



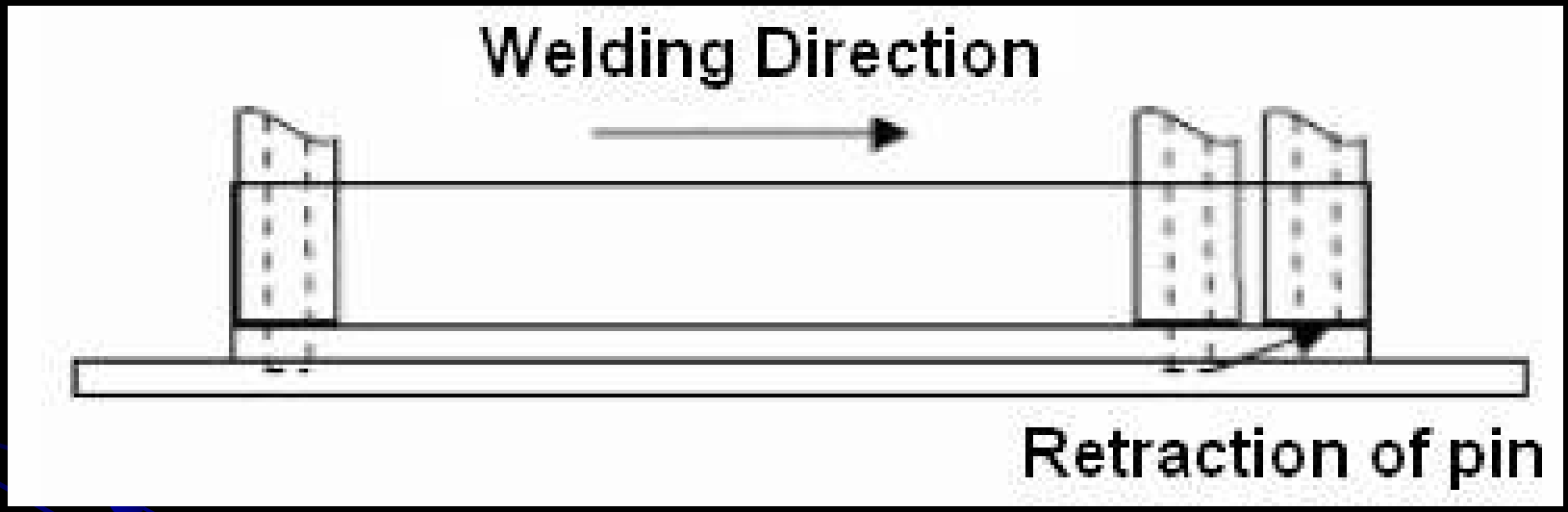
Tapered Retraction: Conventional FSW Tool

- Gradually remove pin during weld traverse

Tapered Retraction with a Conventional Tool

- Lack of shoulder pressure results in defect

Retractable Pin Tool: Tapered Retraction



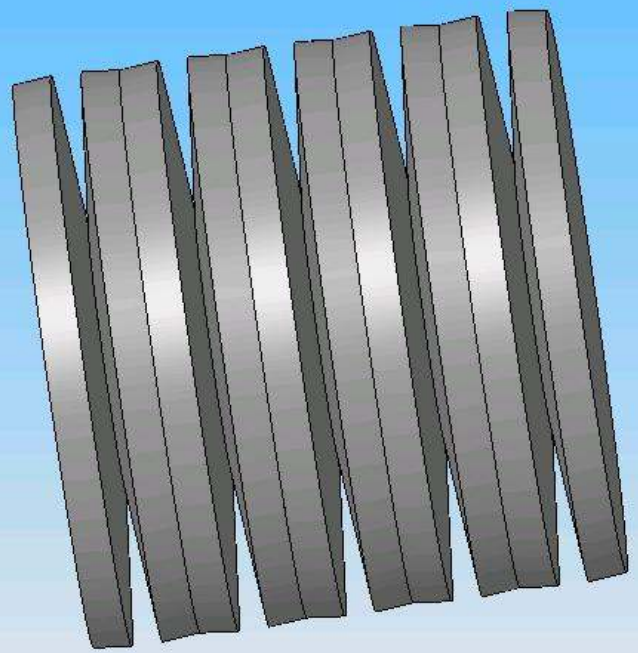
- Gradually remove pin during weld traverse while applying shoulder pressure

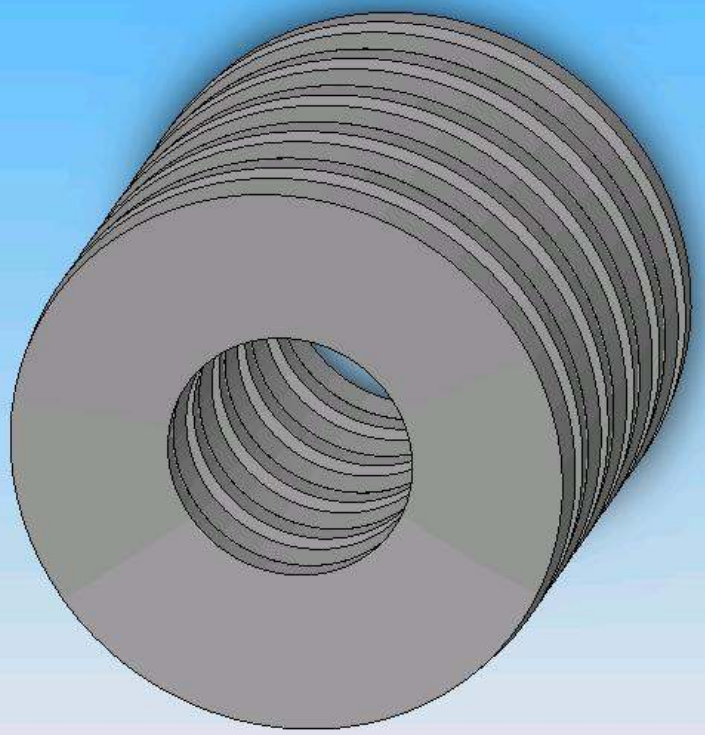
Spring-Opposed Shoulder Retractable Pin Tool (SSRPT)

Goals:

- Maintain shoulder/work contact while inserting & retracting pin.
- Maintain significant shoulder force on work during insertion & retraction to prevent flash.
- Leave no hole when welding cylinders or closed contours.

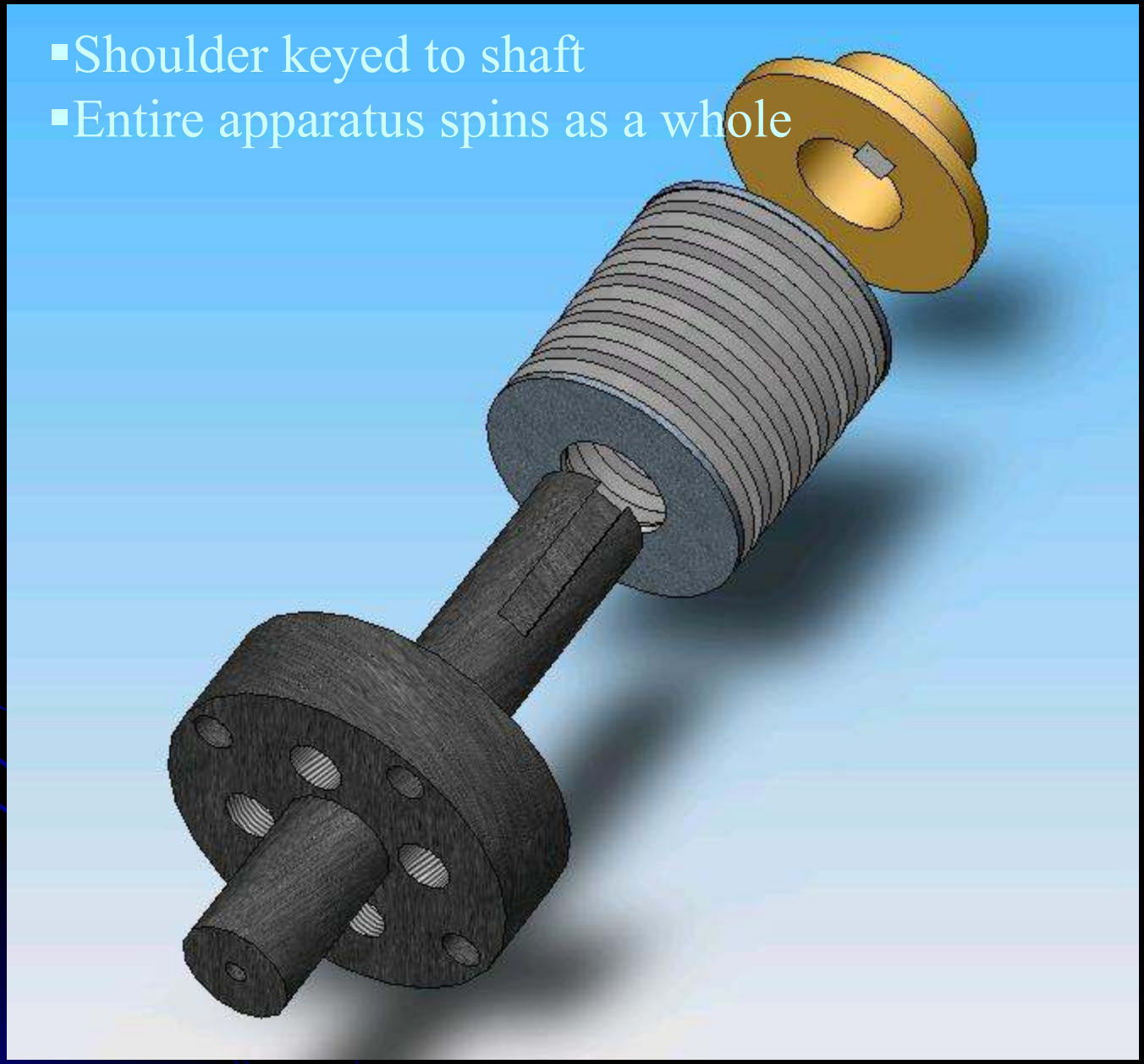
Stack of 10 Disc Springs Forces Shoulder into Contact





- Compact
- Concentric
- High Capacity

- Shoulder keyed to shaft
- Entire apparatus spins as a whole



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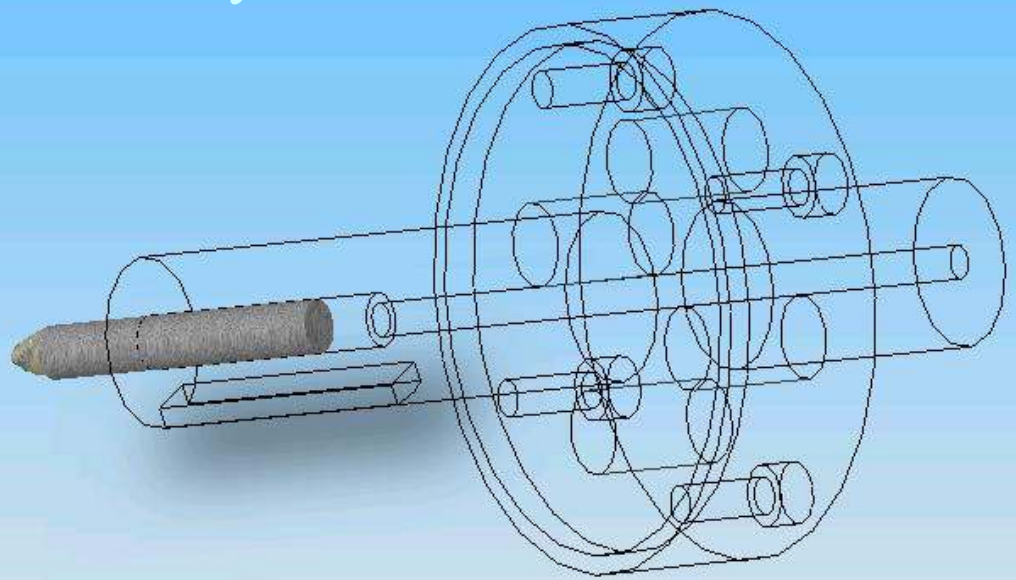
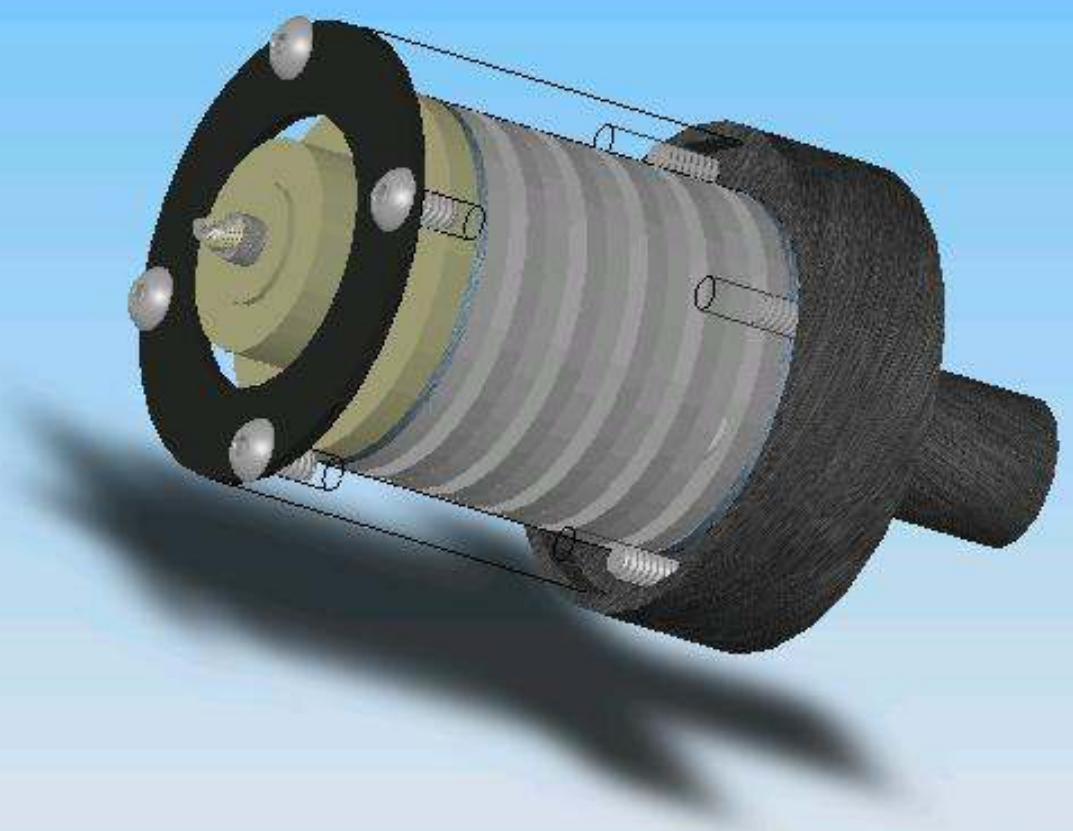
- Replaceable pin tool
- Press fit
- Backed by a channel to aid in removal.



- Outer boss further constrains discs
- Retaining washer allows application of preload condition in discs



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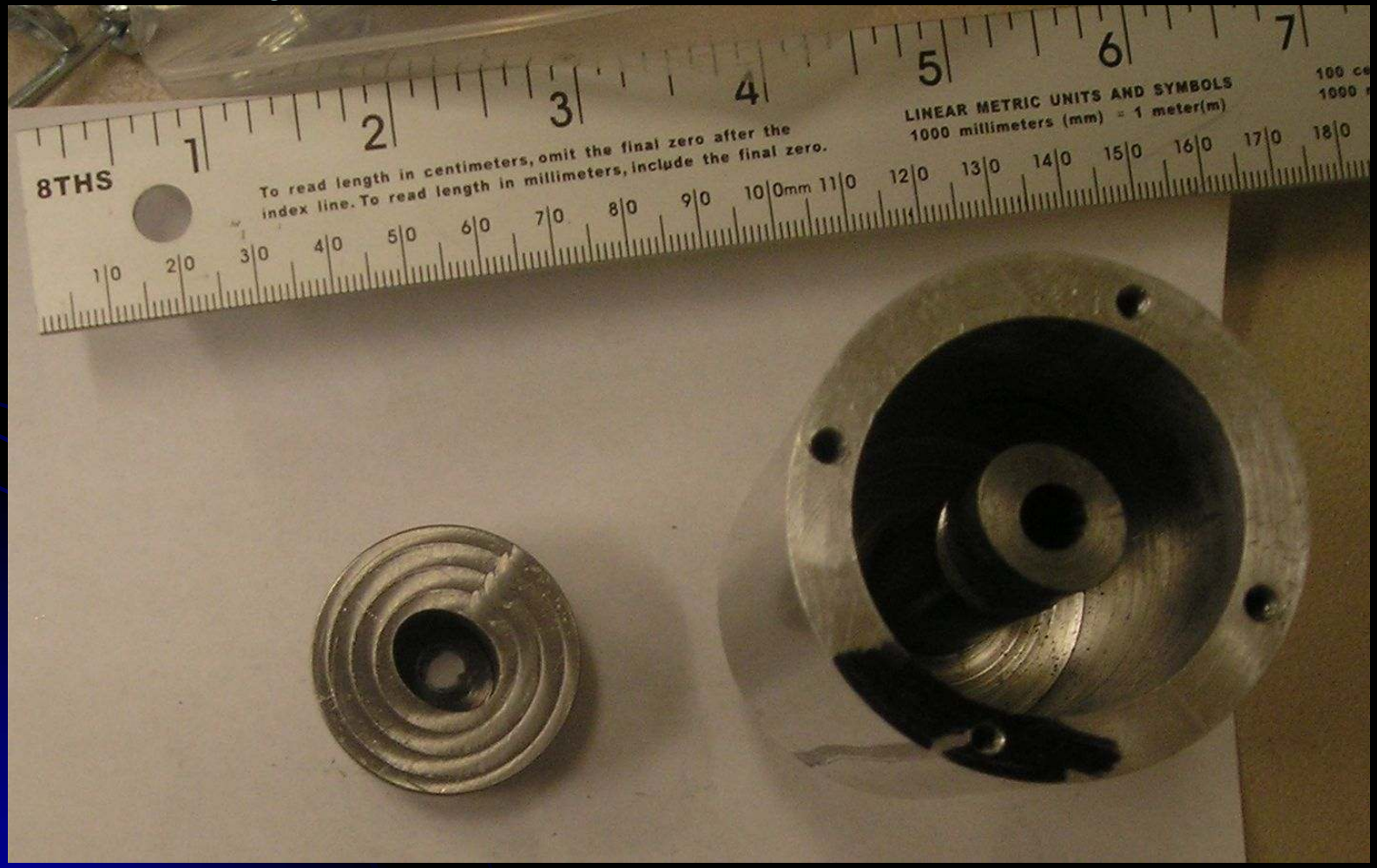
Elliptical mating for smooth actuation.



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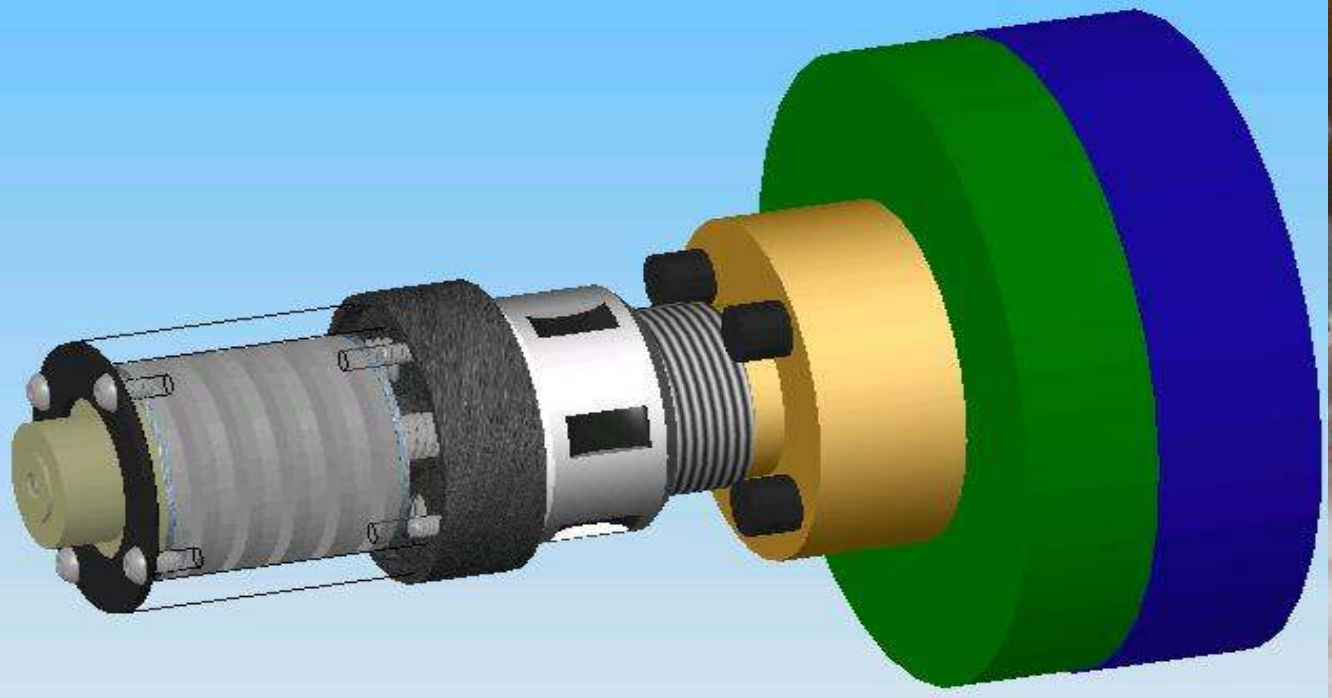
RPT placed in series with Dynamometer.



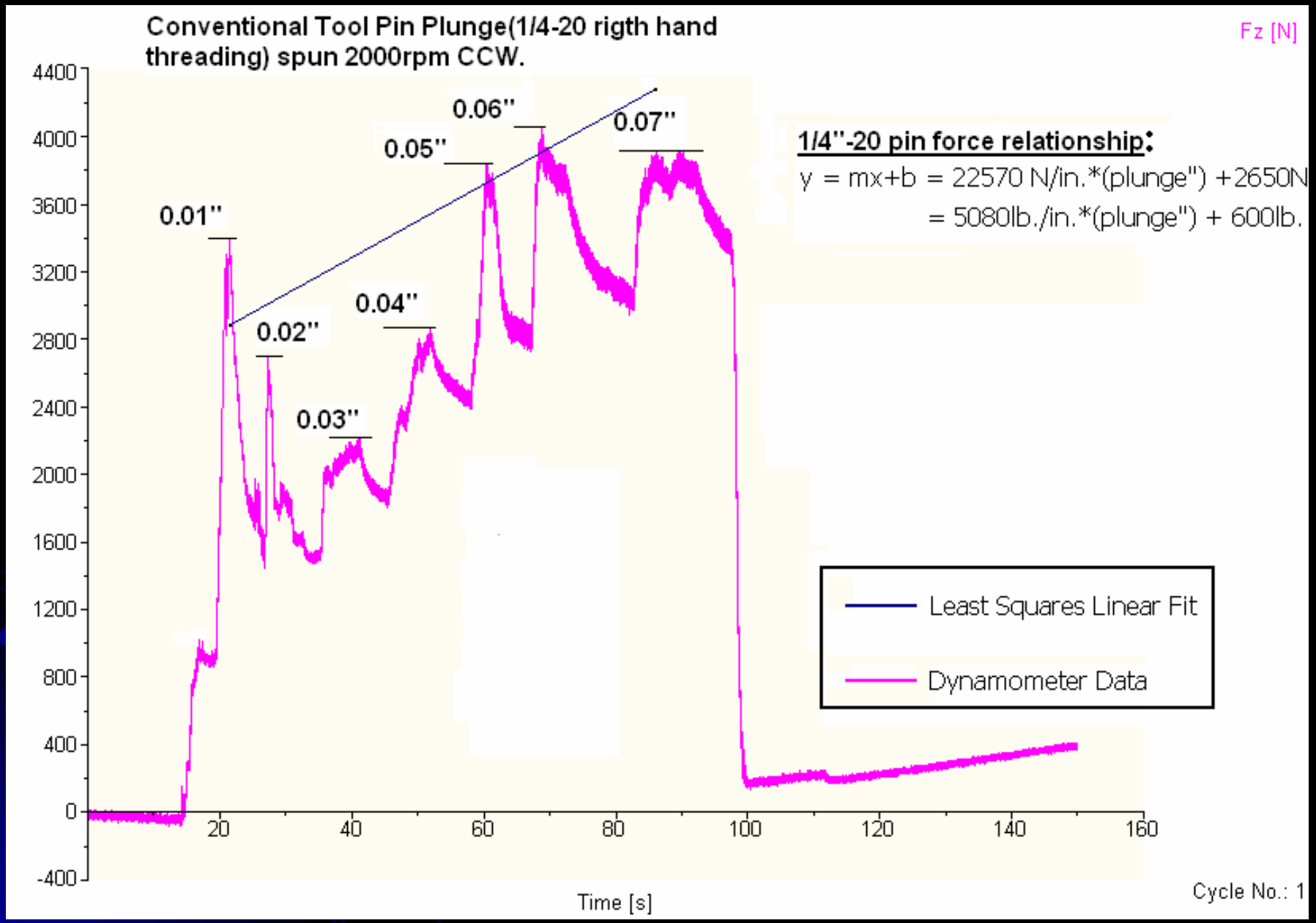
Static Welding Trials: Axial Force Calibration and SSRPT Validation

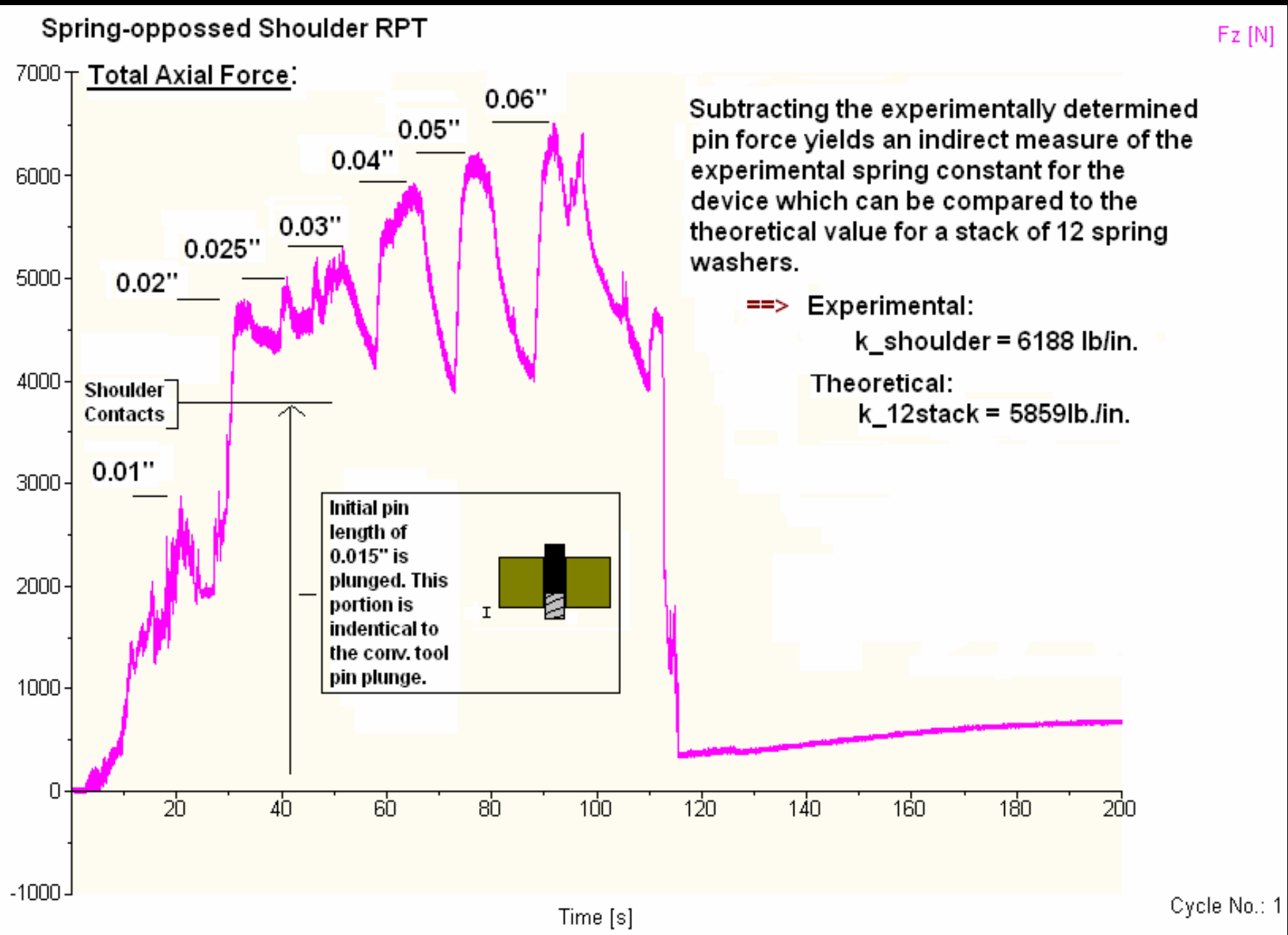
Goals:

- Discern axial force component in pin and in shoulder.
- Verify theoretical axial shoulder force as pin depth varies.

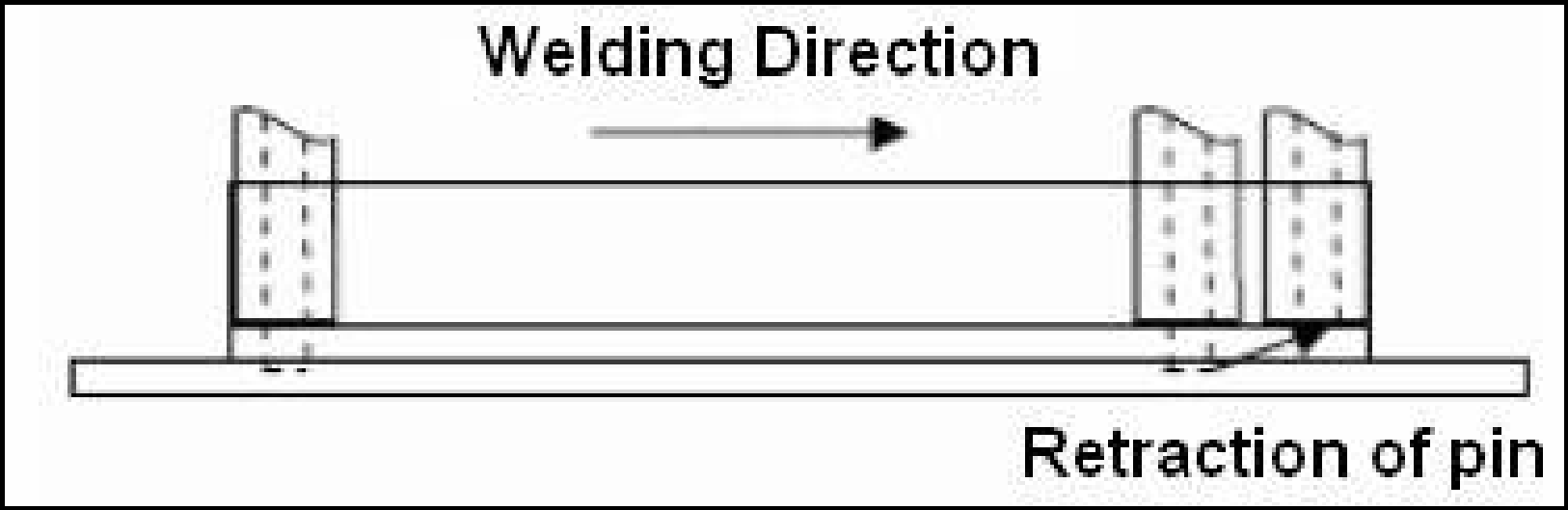
Methods:

- Incrementally plunge RPT without traverse.
- Incrementally plunge a dimensionally equivalent conventional tool without traverse.


Conventional Tool Pin Plunge(1/4-20 rigth hand threading) spun 2000rpm CCW.
Fz [N]
0.01"
0.02"
0.03"
0.04"
0.05"
0.06"
0.07"
1/4"-20 pin force relationship:
y = mx+b = 22570 N/in.*(plunge") +2650N
= 5080lb./in.*(plunge") + 600lb.
Least Squares Linear Fit
Dynamometer Data
4400
4000
3600
3200
2800
2400
2000
1600
1200
800
400
0
-400
20
40
60
80
100
120
140
160
Time [s]
Cycle No.: 1


Spring-oppossed Shoulder RPT
Fz [N]
Total Axial Force:
7000
6000
5000
4000
3000
2000
1000
0
-1000
0.06"
0.05"
0.04"
0.03"
0.025"
0.02"
0.01"
Shoulder Contacts
Initial pin length of 0.015" is plunged. This portion is indentical to the conv. tool pin plunge.
Subtracting the experimentally determined pin force yields an indirect measure of the experimental spring constant for the device which can be compared to the theoretical value for a stack of 12 spring washers.
==> Experimental:
k_shoulder = 6188 lb/in.
Theoretical:
k_12stack = 5859lb./in.
20
40
60
80
100
120
140
160
180
200
Time [s]
Cycle No.: 1

Tapered Retraction Welding Trials



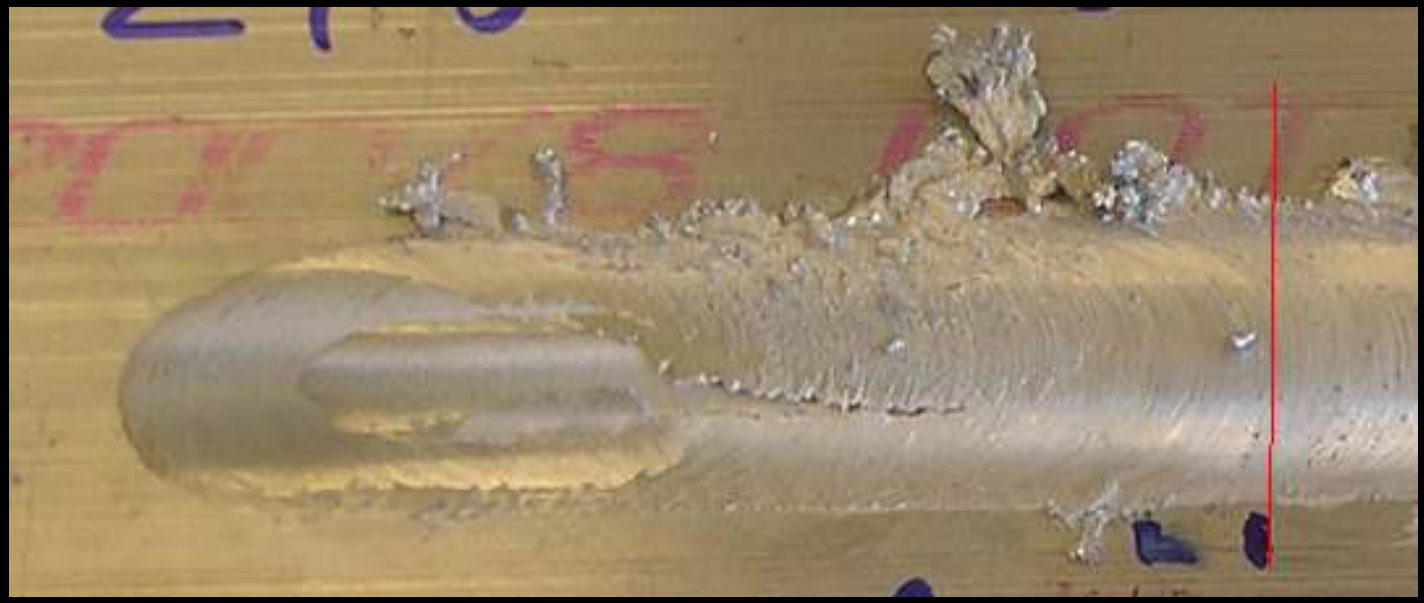
Initial Results:

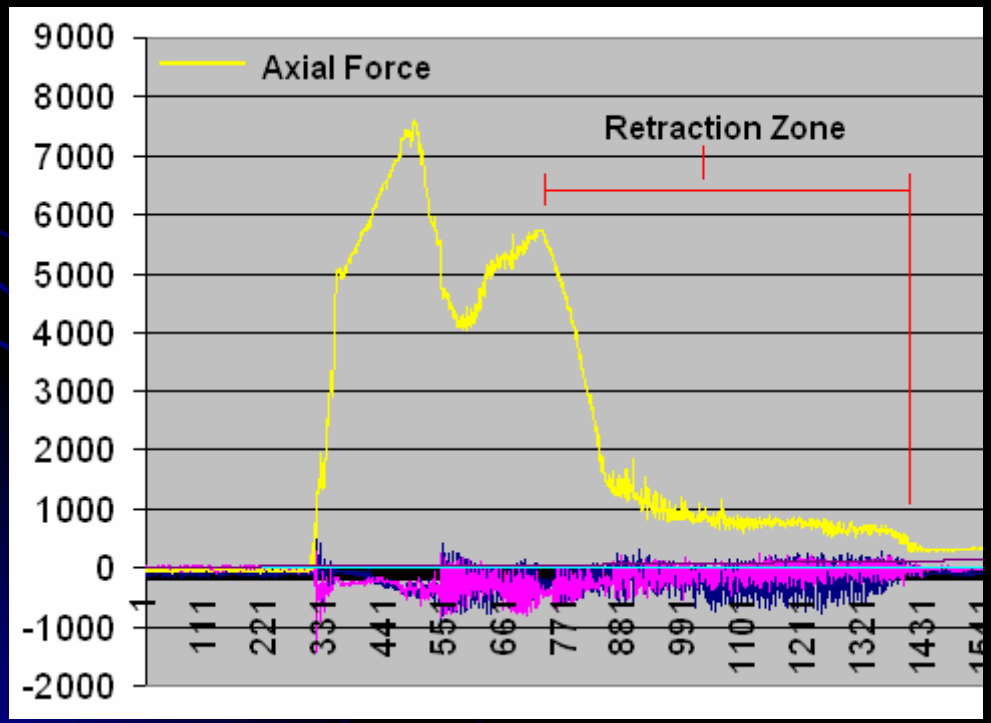
Retraction Zone

- Retract pin at 0.12 in/min
- Weld quality maintained through 40% of retraction

How can quality be improved?

- Adjust traverse rate and/or spindle speed during retraction
- Vary retraction rate over length of retraction
- Adjust force relationship of shoulder

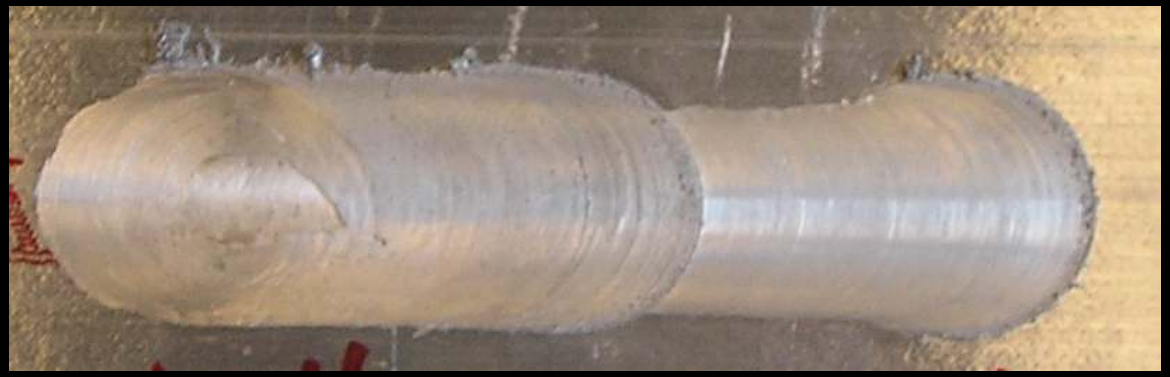




Tool: ¼” diameter pin, 0.7”diameter shoulder
Parameters: 2200rpm, 10ipm, 0.06” pin depth
Retraction Parameters: 2200rpm, 5ipm, 0.12”/min retraction rate

Weld Parameters: 2200rpm,10ipm, 0.03” pin depth, smooth pin
Retraction Parameters: All 2ipm, 0.12”/min retraction rate

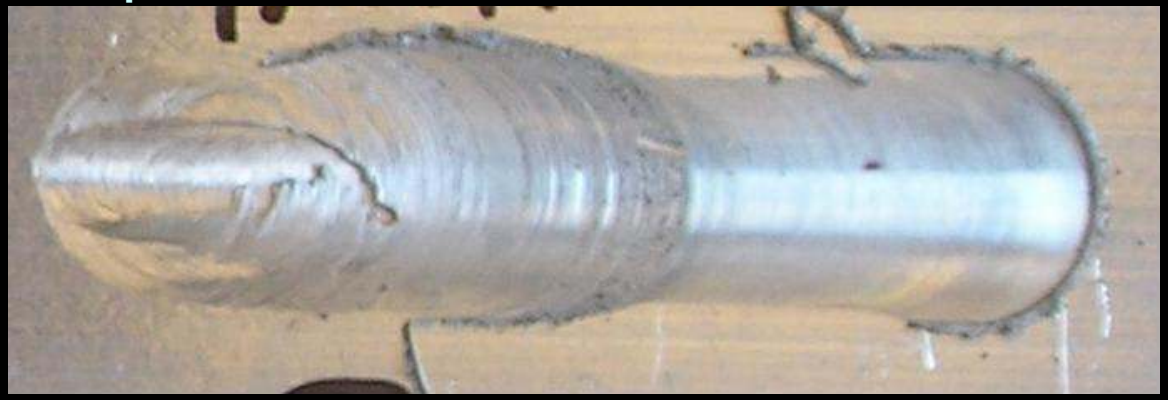
2200rpm retraction:



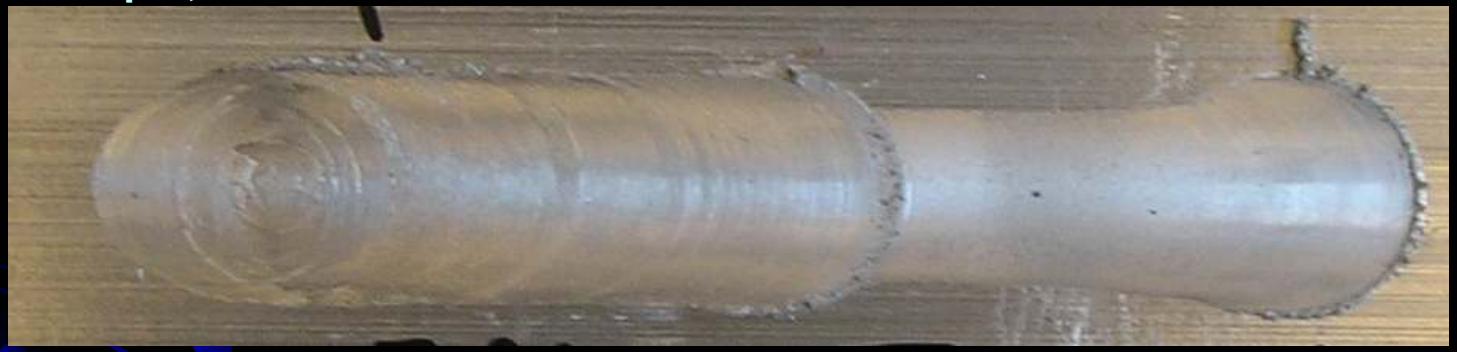
1900rpm retraction:

2500rpm retraction:

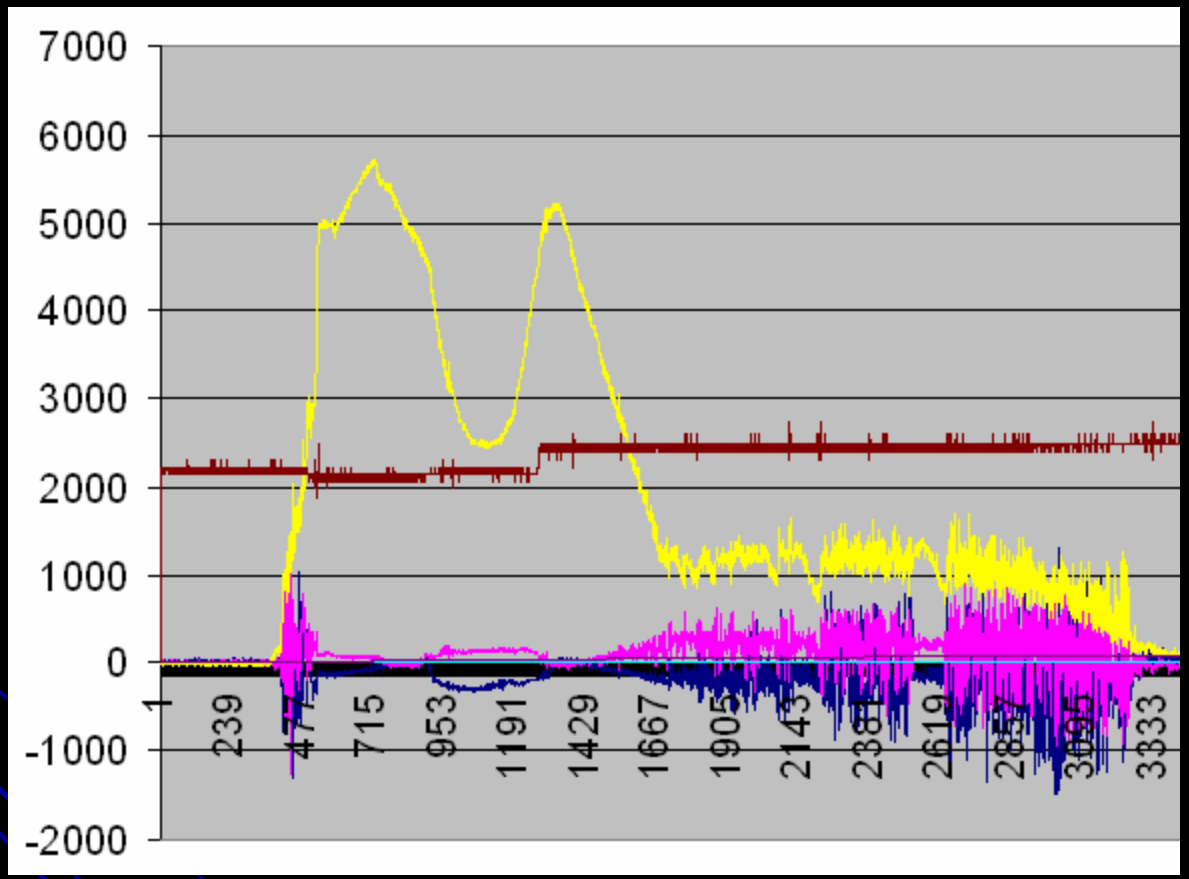
2800rpm retraction:



➔2500rpm is best, try slowing retraction rate to 0.06”/min:
2500rpm, 0.06”/min retraction rate:



Weld Parameters: 2200rpm,10ipm, 0.03” pin depth, smooth pin
Retraction Parameters: 2500rpm, 2ipm, 0.12”/min retraction rate



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