

Effect and Measurement of PAV Pan Warpage and Pan Levelness and their Effects on Properties of Residue

ETG Task Force Status Report

David Anderson and Saman Barzegari
(Maria Knake and Karl Zipf)

May 9-10, 2018
Fall River, MA



Introduction

- ❑ Pan warpage and levelness are important variables that can affect the rheological properties of the PAV residue
 - ✓ The effect of pan levelness may be as important as pan warpage
- ❑ There is no well-accepted procedure for measuring either warpage or levelness
 - ✓ Need to be incorporated into PAV test method
- ❑ There are no established criteria for defining acceptable levels of warpage or levelness
- ❑ Both pan warpage and pan levelness must be addressed
 - ✓ Cannot separate the two
- ❑ Study that follows addresses measurement and criteria for levelness and warpage



Observations on Pan Warpage

- ❑ 30 pans from 8 laboratories were evaluated for warpage
 - ✓ Warpage may be in convex or concave direction
 - ✓ Outside periphery of pans may not be coplanar
 - ✓ Conclusion – pans warp in random and unpredictable pattern
- ❑ When supported at center or at periphery pans assume preferred position
 - ✓ Position can be repeated by placing pan on flat plate or ring at periphery
 - ✓ Referred to a preferred position – typically at center of pan
 - ✓ Preferred position is repeatable by simply pushing downward with index finger
- ❑ Tilt of pans in preferred position is different for edge support than for center support

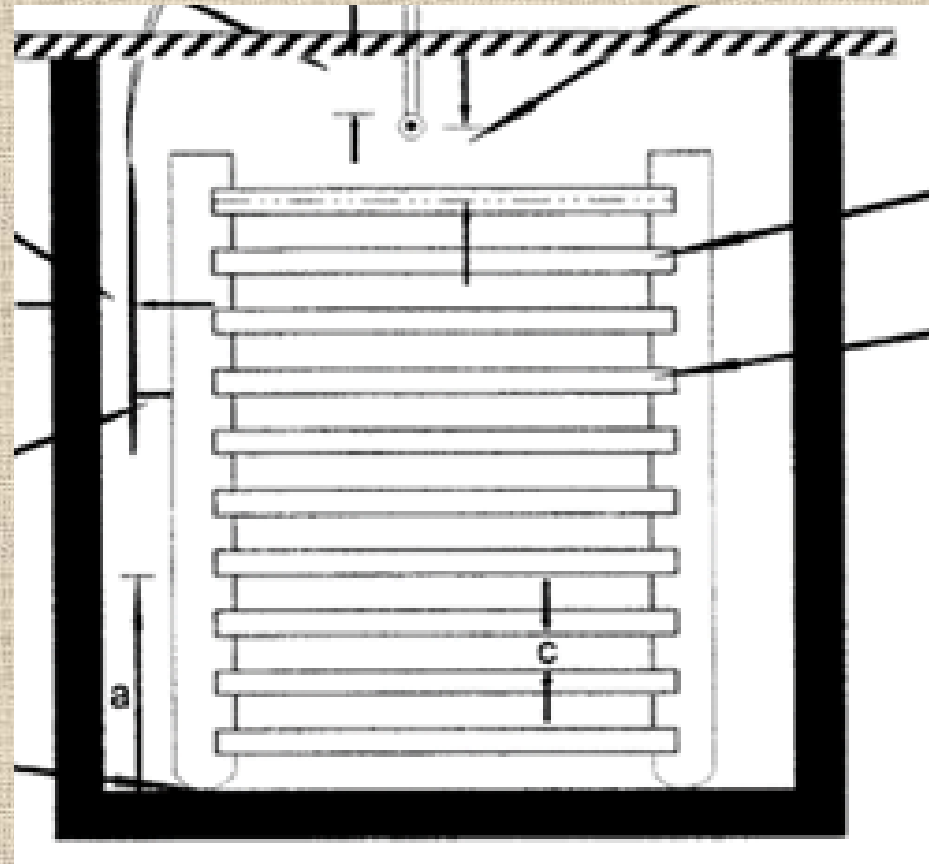


Pan Support Systems

- ❑ Three systems
 - ✓ Three-point Edge Support – SHRP
 - ✓ Center support – flat plate early use
 - ✓ Continuous Edge support – ring at periphery
- ❑ Have different effect on film thickness variation
 - ✓ Must be evaluated separately

Three Point System

- ❑ Proposed by SHRP
- ❑ Not in common use
- ❑ If pan is warped at periphery film thickness will vary as rotate the pan
- ❑ System not in common use





Center Support – Early System

- ❑ Early Prentex System (?)
- ❑ Small tilt in support has little effect on pan orientation
 - ✓ Advantage
- ❑ Center is not open so cannot measure levelness of supports except by systematically disassembling from top down
 - ✓ Disadvantage



Ring Support System

- ❑ Most popular system
- ❑ Ledge around periphery of pan supports pan
- ❑ Levelness of supports contributes to effect of pan warpage
 - ✓ Disadvantage
- ❑ Center is open so levelness of each support can be verified while rack is on level surface
 - ✓ Advantage



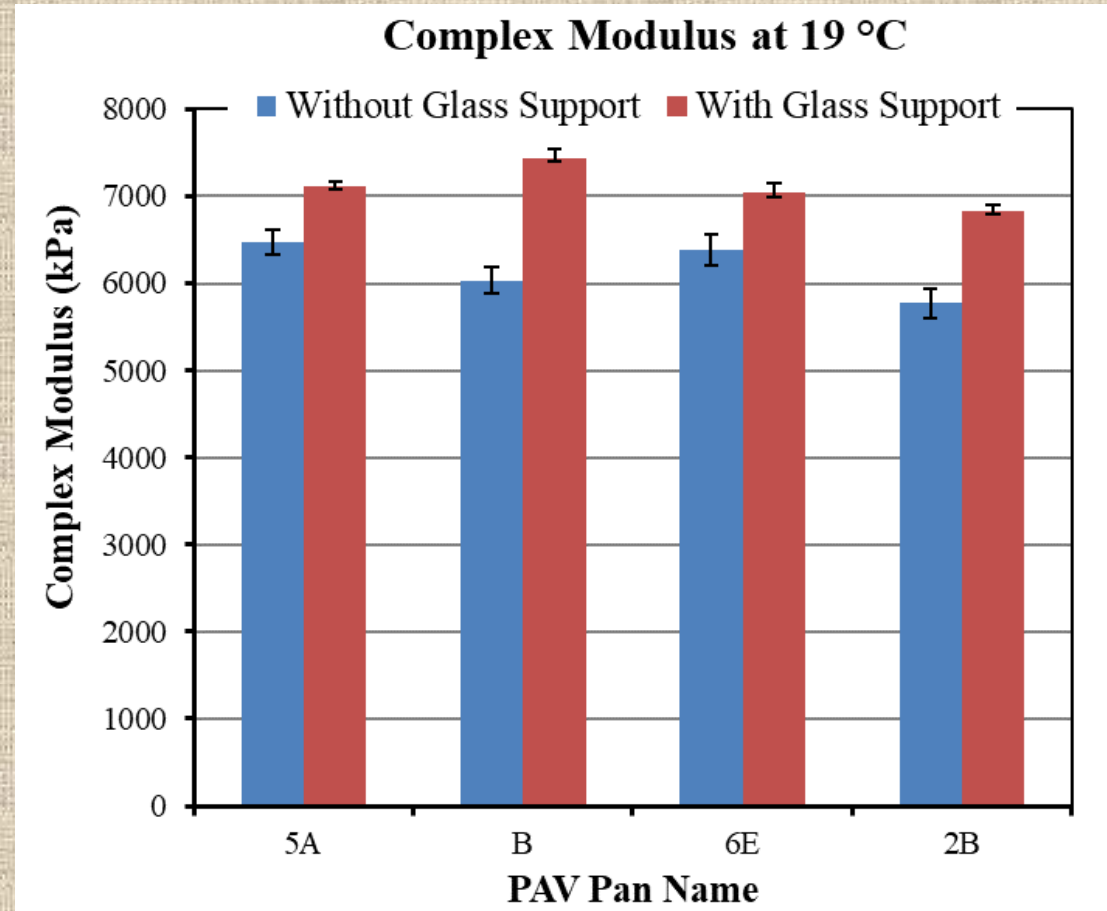


How Do We “Fix” Edge Support

- ❑ If support type is a problem we can simply add flat glass or metal plat under the pan
- ❑ This will be done with upcoming experiment
- ❑ Preliminary data shows difference in PAV residue for two support systems

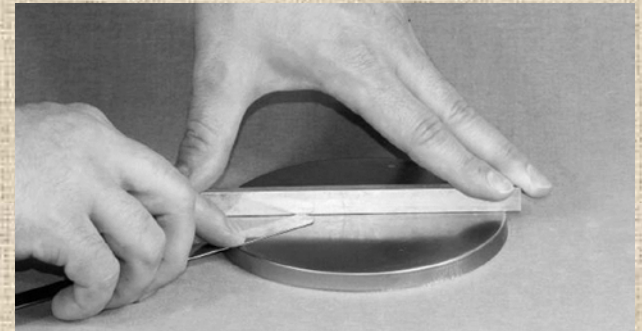
Is There a Difference?

- ❑ Preliminary data obtained at Penn State indicates "YES"
- ❑ Need to confirm this result with upcoming experiment



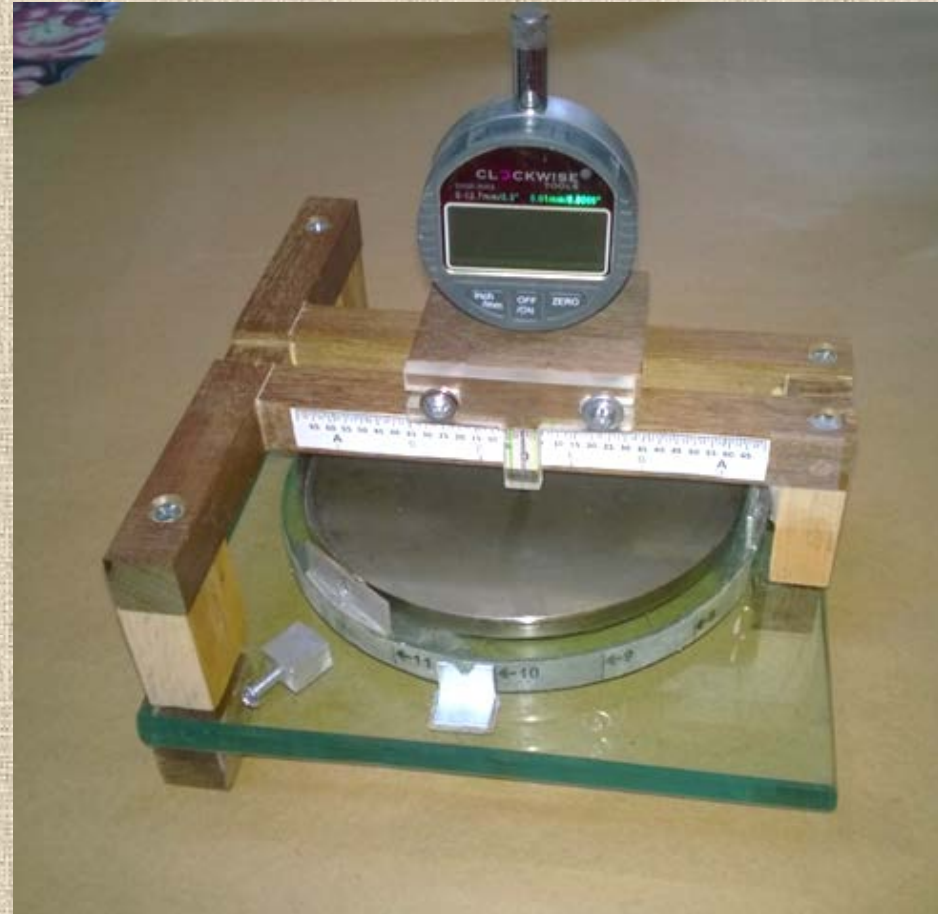
Methods for Measuring Warpage

- ❑ Many go-no-go methods
 - ✓ Pressing on edge
 - ✓ Straight edge
 - ✓ Spinning
 - ✓ Etc.
 - ✓ Do not give true picture of warpage
- ❑ Profiling
 - ✓ By directly profiling pan surface
 - ✓ By profiling or measuring cast of pan



Profile Gage (Prototype)

- ❑ Moving gage laterally and rotating upper glass plate allows profile at any point on pan
- ❑ May make casting of pan and profile casting by turning casting upside down
- ❑ Mat simulate each of three support systems
 - ✓ Center, ring, and 3-point





But the Pan Moves When the Measurement is Attempted!

- ❑ Problem with support systems 1 and 2
- ❑ Problem solved recognizing that pans are supported at unique point
- ❑ Procedure for ring support or center support
 - ✓ Place small dot of fast curing gel-type epoxy at periphery of glass plate or ring
 - ✓ Remember to wax contact points before applying epoxy!!!
 - ✓ Place pan on supports and press down at unique point
 - ✓ Allow epoxy to harden (10 min at most)
- ❑ Perform profile as soon as epoxy is rigid
 - ✓ Epoxy supports will remove easily with proper waxing



Making a Casting

1. Level the support using a machinist's level or equivalent
2. Line the inside of the vertical lip with foam tape
 - Needed because some lips tilt to the inside
3. Wax the inside of the pan and the tape surface
4. Place the pan on the support
5. Pour the desired amount of self-leveling casting resin onto the pan and allow to harden – typically 24 hr.
6. Remove the cast from the pan
7. Profile with jig or measure with micrometer

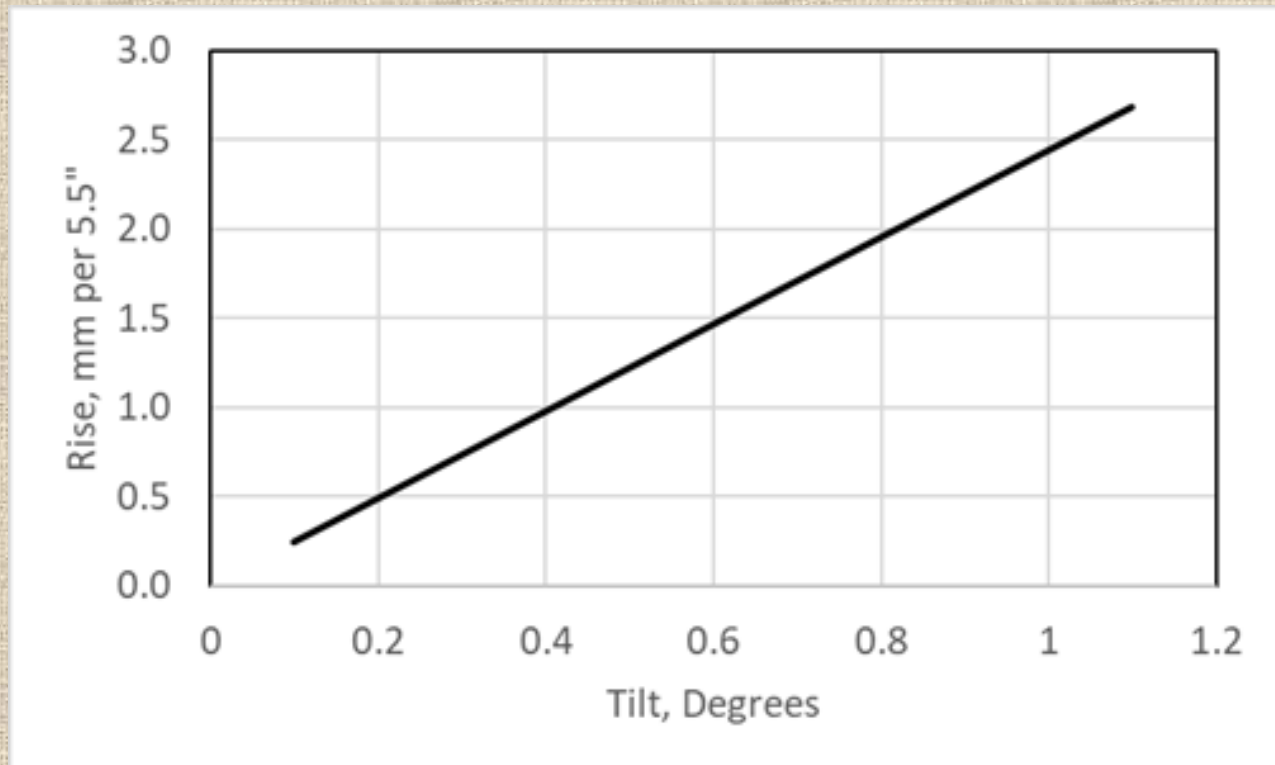
Measuring Profile of Casting without Jig

- Make casting of pan and measure thickness with screw micrometer
 - ✓ Casting can be made by supporting pan on plate
 - ✓ Measure thickness with deep throat screw-type precision micrometer (\$130)



Importance of Level and Level Gages

- ❑ Levelness of pan supports is important consideration
- ❑ Question current practice which is not well standardized



Levels – Choices

- ❑ Inadequate – bubble gages commonly found in lab

- ✓ <\$15



- ❑ Preferred – Machinist gage

- ✓ Starrett 98-4

- ✓ Has markings

- ✓ ≈ \$90



- ❑ Electronic Gage

- ✓ Wixly Model WR365

- ✓ Good experience with discontinues 320 Type 1

- ✓ Avoid 320 Type 2 and Imported knockoffs





Verifying Levelness of Supports

- ❑ Preheat the rack in in the PAV vessel with a 5.5" diameter glass plate on top support
 - ✓ Distortion in PAV vessel when heated is accounted for
- ❑ Check level in two directions perpendicular to sides of cabinet
- ❑ Level the glass plate by shimming the PAV cabinet
 - ✓ Easier than using screws on base
 - ✓ Marking on gage in tilt per division (mm/m) can be used as a guide to needed shim size
- ❑ After shimming glass plate should be level to + 0.1 degree
- ❑ If rack is open on interior parallelism of lower supports may be checked by placing rack on level surface and checking levelness at each support



Rack Position

□ Position of the rack

- ✓ Experience shows that moving the rack can affect the levelness significantly
- ✓ Slight movement of rack gave change of 0.3 degrees
- ✓ Equivalent to 1.3 mm at edge of pan

□ Conclusion

- ✓ Need procedure for indexing rack position

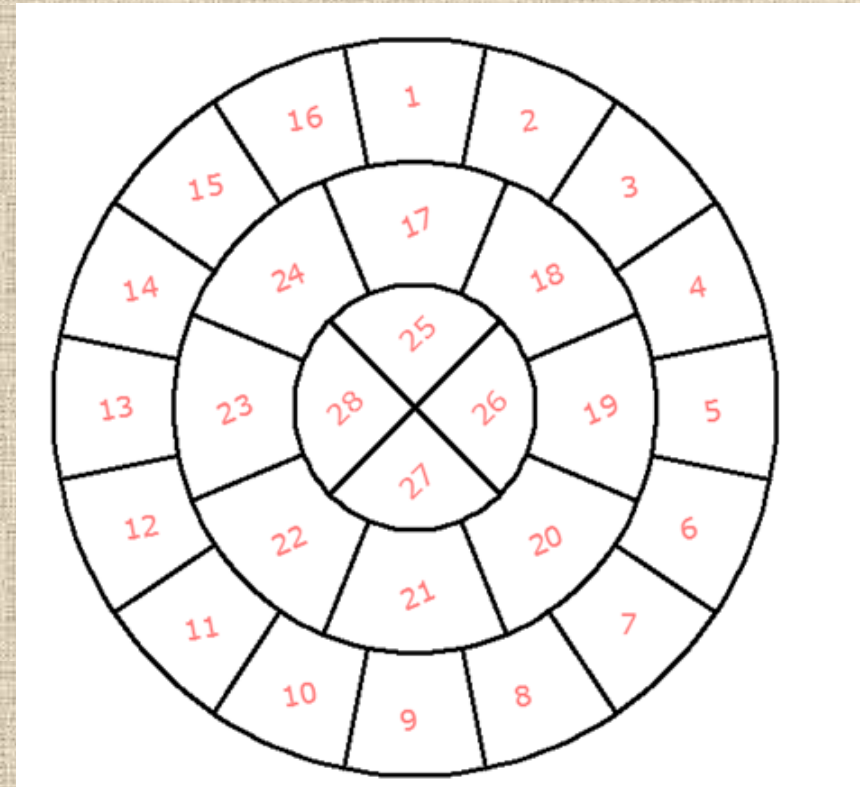


Calculating Effect of Film Thickness Variations Using Profile Measurements

- ❑ Divide the area of pan into segments of approximately equal size
- ❑ Calculate the x-y coordinates for the centroid of each segment
- ❑ Measure or calculate the profile at each centroid
- ❑ Weight the effect of the thickness for each segment according to the area of each segment as a percentage of total area of the pan
- ❑ Why is this needed?
 - ✓ Thick and thin sections do not average because effect of film thickness is not linear with thickness
 - ✓ Thinner area has more effect than thicker area

Calculation of Methodology

	Point ID	Angle (degrees)	Area (mm ²)	X _c (mm)	Y _c (mm)	Disance (mm)
Outer Annulus	1	0.00	532.22	0.00	58.61	58.61
	2	22.50	532.22	22.43	54.15	58.61
	3	45.00	532.22	41.44	41.44	58.61
	4	67.50	532.22	54.15	22.43	58.61
	5	90.00	532.22	58.61	0.00	58.61
	6	112.50	532.22	54.15	-22.43	58.61
	7	135.00	532.22	41.44	-41.44	58.61
	8	157.50	532.22	22.43	-54.15	58.61
	9	180.00	532.22	0.00	-58.61	58.61
	10	202.50	532.22	-22.43	-54.15	58.61
	11	225.00	532.22	-41.44	-41.44	58.61
	12	247.50	532.22	-54.15	-22.43	58.61
	13	270.00	532.22	-58.61	0.00	58.61
	14	292.50	532.22	-54.14	22.43	58.61
	15	315.00	532.22	-41.44	41.44	58.61
	16	337.50	532.22	-22.43	54.15	58.61
Middle Annulus	17	0.00	638.66	0.00	35.29	35.29
	18	45.00	638.66	24.96	24.96	35.29
	19	90.00	638.66	35.29	0.00	35.29
	20	135.00	638.66	24.96	-24.96	35.29
	21	135.00	638.66	0.00	-35.29	35.29
	22	225.00	638.66	-24.96	-24.96	35.29
	23	270.00	638.66	-35.29	0.00	35.29
	24	315.00	638.66	-24.96	24.96	35.29
Inner Circle	25	0.00	425.78	0.00	13.98	13.98
	26	90.00	425.78	13.98	0.00	13.98
	27	180.00	425.78	0.00	-13.98	13.98
	28	270.00	425.78	-13.98	0.00	13.98





Plan for Upcoming Experiment

- ❑ Profile series of pans using jig and measurement of castings
- ❑ Send to participating laboratories
 - ✓ RTFOT material
 - ✓ Level
 - ✓ Glass plates
 - ✓ Instructions for leveling PAV supports
 - ✓ Proposed go-no-go gages for qualifying pans
 - ✓ Proposed methods for prequalifying pan warpage
- ❑ Conduct PAV aging with two support types
 - ✓ Edge support
 - ✓ Flat plate
 - Simulate flat plate by inserting glass plate in rack to support pan