Dishwasher Durability of Eastman Tritan™ Copolyesters

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Brett Jones and Kaan Gunes

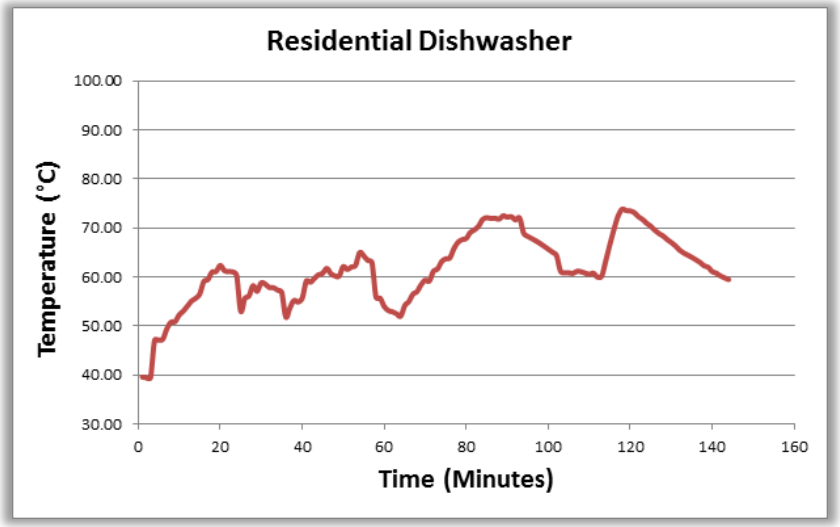
Dishwasher Durability

Many aspects to consider regarding dishwasher durability:

- Heat resistance
- Chemical resistance
- Hydrolysis resistance
- Scratch resistance

Factors combine to make the dishwasher a very challenging environment for many plastics

- Dishwashing could be the ultimate FFU testing for durable housewares



Critical that the housewares do not haze, scratch, chip, crack, deform or lose impact strength.

Residential Dishwashing & Beer Mug Testing

- Beer mugs were molded at Eastman from the following materials:
  - Eastman Tritan™ copolyester
  - Polycarbonate (PC)
  - Styrene-Acrylonitrile (SAN)
  - Methacrylate-Styrene (MS)
  - Acrylic (AC)
- Parts were dropped after 30, 50, 75, 100, and 125 residential dishwasher cycles
  - Filled with water to nearly full
  - Dropped from 4 feet / bottom impact
  - Maximum of 25 drops

Results of Beer Mug Drop Testing Before and After Dishwashing

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Material	*Initial*	*30 cycles*	*50 cycles*	*75 cycles*	*100 cycles*	*125 cycles*
Eastman Tritan™ copolyester	> 25	> 25	> 25	> 25	> 25	> 25
Polycarbonate (PC)	> 25	0 – crack	0 – crack	0 – crack	0 – crack	0 – crack
Acrylic (AC)	2 – crack	10 – chip	1 – shatter	3 – shatter	1 – split	1 – split
Methacrylate-Styrene (MS)	2 – chip	5 – chip	2 – crack	1 – crack	1 – chip	1 – chip
Styrene-Acrylonitrile (SAN)	1 – crack	2 – crack	7 – chip	1 – chip	1 – chip	1 - chip

- Tritan outlasts 125 dishwashing cycles followed by 25 drops after the set number of dishwasher cycles
- Acrylic (AC) and styrenic (MS & SAN) housewares fail after a single drop and have inferior toughness compared to Eastman Tritan™ copolyester.
- PC fails in the dishwasher due to cracking within 30 residential dishwashing cycles

Residential Dishwashing & Drop Testing

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Acrylic after 75 dishwasher cycles and drop test

Methacrylate styrene after 50 dishwasher cycles and drop test

SAN after 30 cycles and drop test

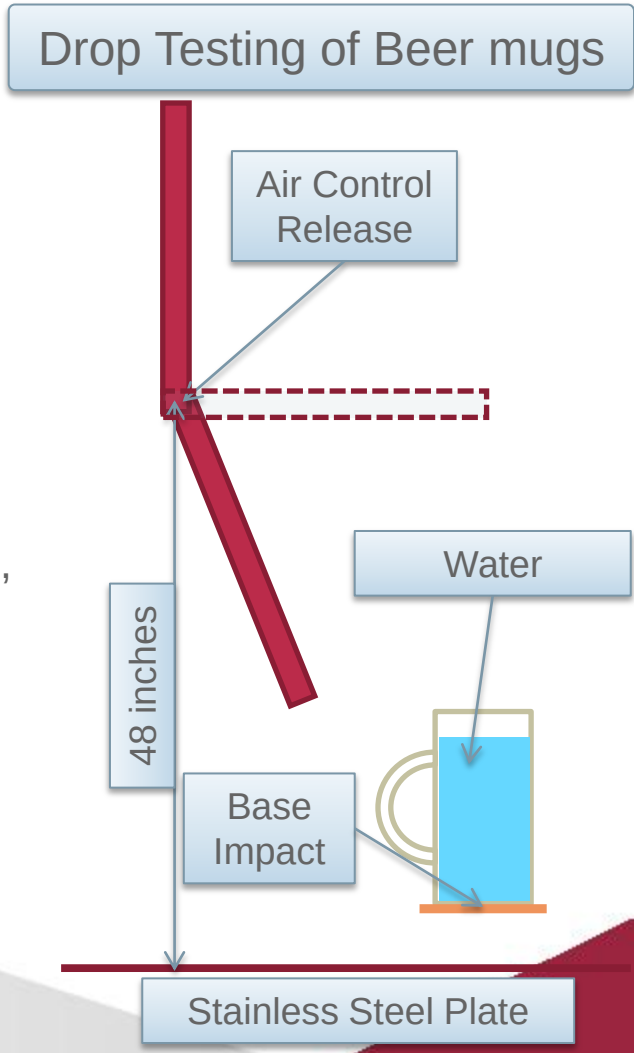
SAN after 125 cycles and **no drop test**

Polycarbonate after 125 dishwasher cycles and **no drop test**

Eastman Tritan™ copolyester after 125 cycles and drop test: **No effect**

Commercial Dishwashing and Drop Testing

- **Dishwasher Information:**
  - Ecolab Single Chamber, Model Performer E
  - Detergent: Solid Power XL
  - Rinse Additive: Solid Brilliance
- **Dishwasher Operation:**
  - Wash Cycle: 145-150°F for 48 seconds
  - Rinse Cycle: 185-190°F for 10 seconds
- **Reviewing dishwashed parts:**
  - Molded thin and thick walled parts reviewed for degradation (deformation, crazing, hazing, etc.) after 100, 250, 500, 750, and 1000 dishwasher cycles
- **Drop testing:**
  - Molded beer mugs dropped without dishwashing, and after 100, 250, 500, 750, and 1000 commercial dishwasher cycles
  - Maximum 5 drops per condition
  - Samples dropped on part base/bottom
  - Filled with water to approximately 1 inch from the top
  - Drop height of 48 inches (typical height of individual's hand while standing)
  - Stainless steel plate utilized for impact



Commercial Dishwashing and Drop Testing Results

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Materials	Initial	100 Cycles	250 Cycles	500 Cycles	750 Cycles	1000 Cycles
Tritan™	PASS	PASS	PASS	PASS	PASS	PASS
Polycarbonate	PASS	FAILED IN DISHWASHER	FAILED IN DISHWASHER	FAILED IN DISHWASHER	FAILED IN DISHWASHER	FAILED IN DISHWASHER
Polypropylene	PASS	PASS	PASS	PASS	PASS	FAILED IN DISHWASHER

Note: Tritan™ testing included all grades (TX1001, TX1501, and TX2001), which all passed drop testing to over 1000 commercial dishwashing cycles.

Polycarbonate after commercial dishwashing (cDW)

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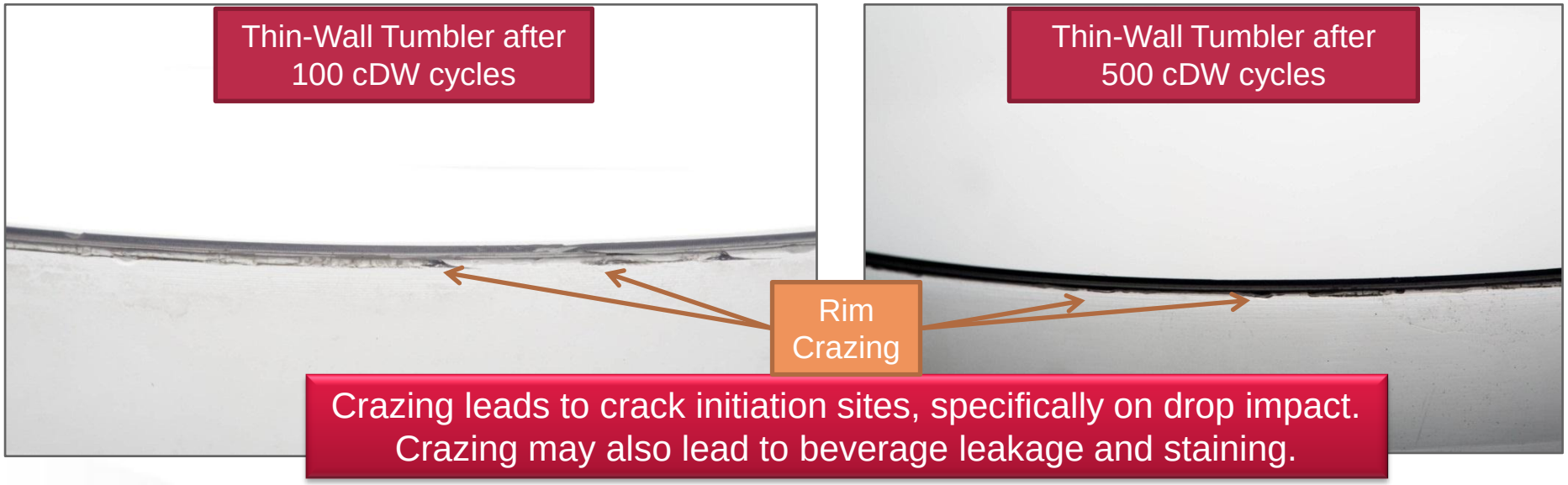
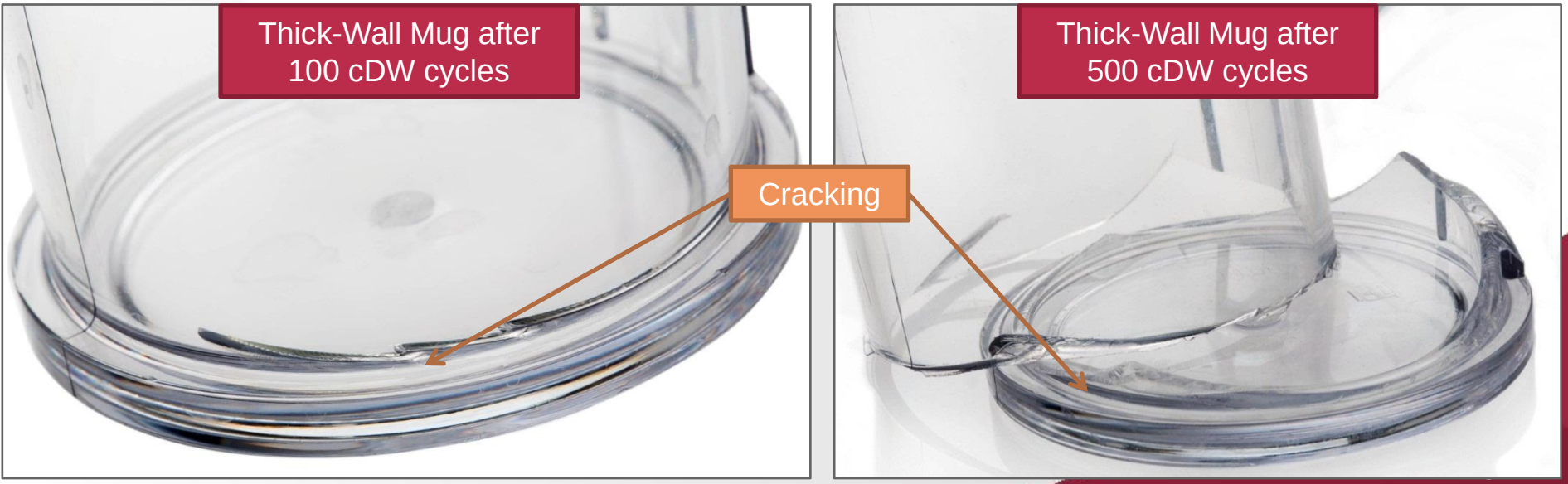


Crazing leads to crack initiation sites, specifically on drop impact. Crazing may also lead to beverage leakage and staining.



Polypropylene after 1000 commercial dishwashing cycles

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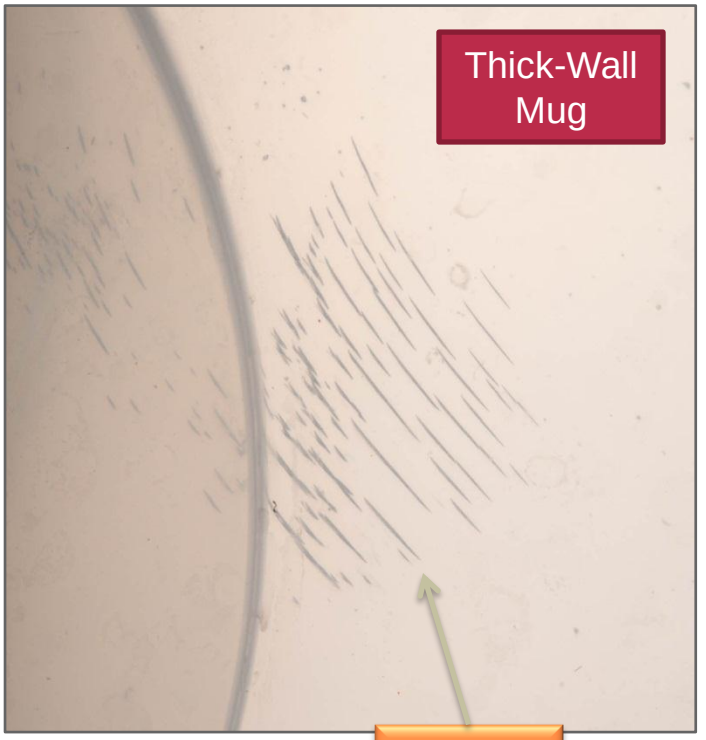

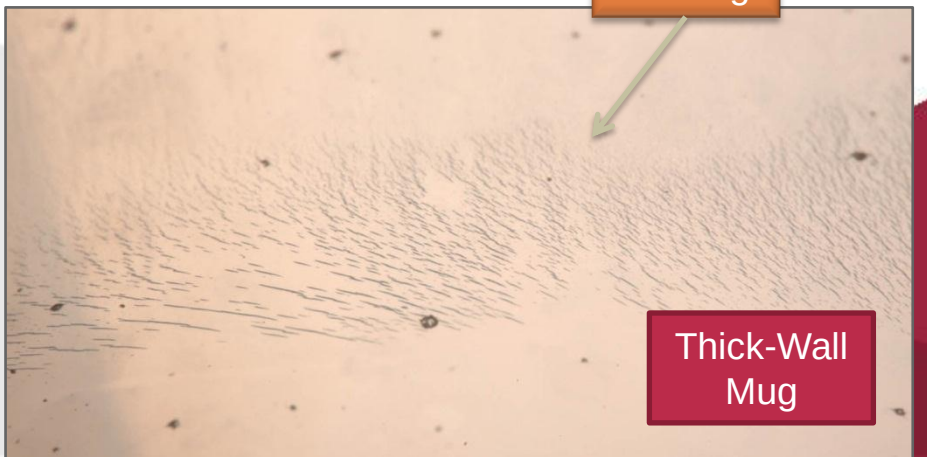

Tritan™ after 1000 commercial dishwashing cycles and drop testing

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No effect

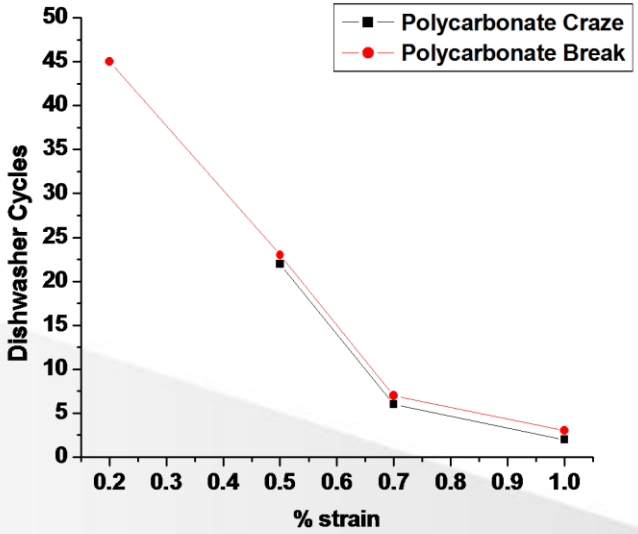
Hydrolytic Stability

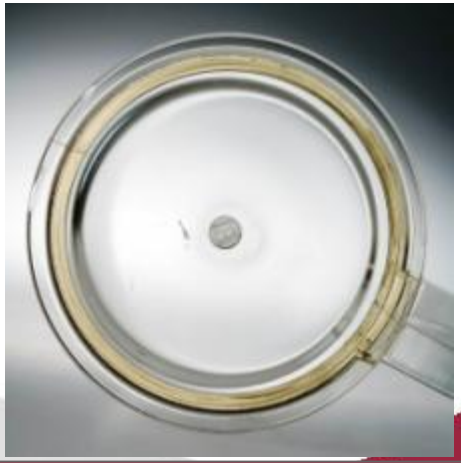
- Polycarbonate is well known for stress cracking due to hydrolysis

PC mug after 120 dishwasher cycles

PC starts to crack after only 10 residential dishwasher cycles

Residential dishwasher testing of stressed bars





Polycarbonate breaks at 1% strain after 2-3 cycles in a residential dishwasher using Cascade detergent.

No crazes or cracks in mugs molded from Tritan™ after more than 500 residential dishwasher cycles!

Dishwasher Durability – Conclusions

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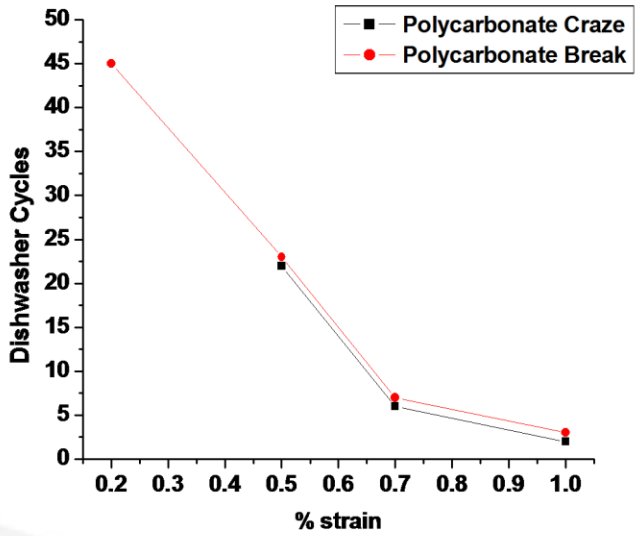
- Polycarbonate (PC) is known to craze and crack in a dishwasher due to hydrolysis and poor chemical resistance to common dishwasher detergent

Residential dishwasher testing of stressed bars



PC starts to crack after only 10 rDW cycles

No crazes/cracks in Tritan™ after >500 rDW cycles!

Polycarbonate breaks at 1% strain after 2-3 cycles in a residential dishwasher (rDW) using Cascade detergent.

- Hydrolysis is defined as the ester bond cleavage by the addition of water, and is accelerated by heat and chemical agents (detergents with high pH may act as catalyst)
- PC has reduced chemical resistance due to high molded in stress as a result of fast freezing of polymer chains. Annealing can partly reduce stresses, but is costly
- Tritan™ has significantly lower molded-in stresses and improved chemical resistance over PC due to a slightly lower glass transition temperature (T_g)
  - Tritan™'s functional T_g delays the onset of polymer chain freezing, allowing greater chain relaxation during cooling of molded parts

Dishwasher durability: validation

A number of tests have been performed to establish the dishwasher durability of parts made from Eastman Tritan™ copolyester TX1001 and TX2001

Testing	Testing location	Temperature and time	Chemical	# of cycles	Tritan™ performance
Residential dishwashers	Eastman	70 - 75°C peak / 2 hr cycle	Powder Cascade	125	No visual effects
Residential dishwashers: 1% applied strain	Eastman	70 - 75°C peak / 2 hr cycle	Powder Cascade	50	No visual effect
Labware dishwasher	Customer	65°C peak / 1 hr cycle	Powder Detergent	125	No visual effect
Commercial dishwasher	Eastman	91°C peak / 1 min cycle	Powder Detergent	500	No visual effect
Commercial dishwasher	Eastman	91°C peak / 1 min cycle	Powder Detergent	1500	No visual effect
Commercial dishwasher	Customer	unknown	unknown	4000	No visual effect

13

Tritan™ Dishwasher Success Stories

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