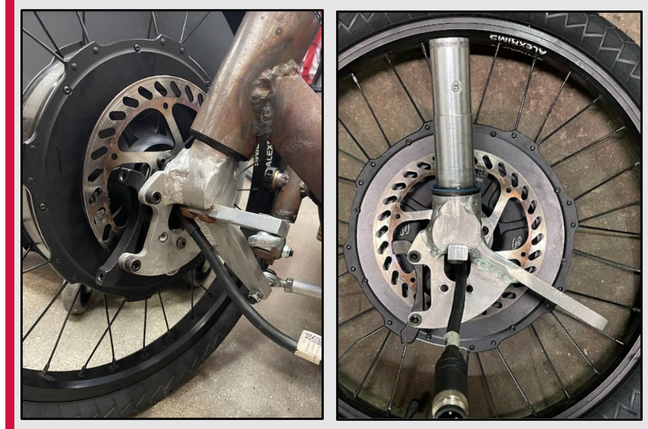
Human Powered Vehicle Steering Corner Aluminum Tilt-Pour Sand Casting

Human Powered Vehicle Club (HPVC) at the University of Wisconsin-Madison (UW), UW AFS Student Chapter

Objective

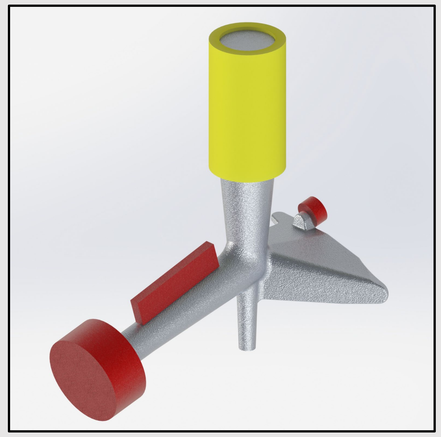


Welded steering corner on current HPVC bike

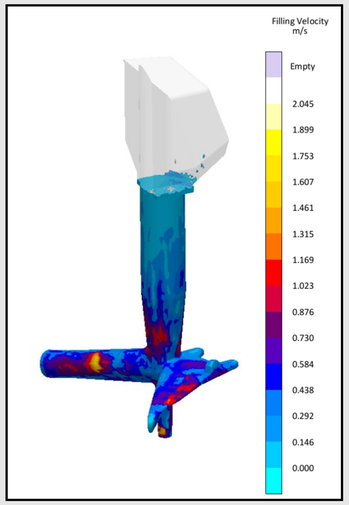
- Design new steering corner for 2023 vehicle to compete in upcoming ASME eHPVC competition
- Replace existing aluminum weldment design with a single-piece casting
  - Weldment contains 5 discrete pieces
  - Corner has two precision bearing surfaces
- Steering corner functions
  - Connects wheel to frame
  - Provides steering through linkage connection
  - Provides brake caliper mounting point

MAGMA Simulation and Design Optimization

Hot spot lifespan in casting center at 700°C (Top) and 750°C (bottom)



Casting with steel chills (in red) and riser insulator (in yellow)



Tilt-pour filling velocity

- MAGMA was used extensively to optimize casting design for adequate feeding and directional solidification in A206
- Steel chills added to headset cylinder to help solidification fronts converge at center to minimize porosity and prevent hot tears in regions of highest stress
- Riser insulator and exothermic hot topping simulated to ensure adequate feeding is completed during solidification
- Pouring temperatures varied to determine ideal pouring parameters based on duration of hot spots in casting center
- Tilt pour simulated to validate fill time parameters and melt velocity

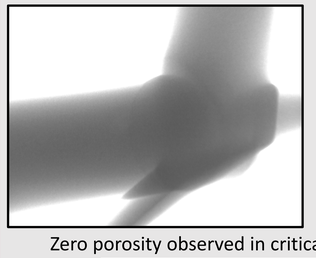
Casting Parameters

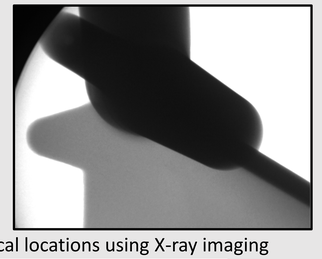
Process Parameters	
Pouring Temperature [°C]	750.0
Melt Volume [cm³]	655.5
Argon Degassing Time [min]	10.0
Argon Flow Rate [L/min]	14.0
Ideal Fill Time [s]	3.08
Grain Refining Content	
Sr	0.012%
Br	0.005%
Ti	0.025%

Mechanical Properties

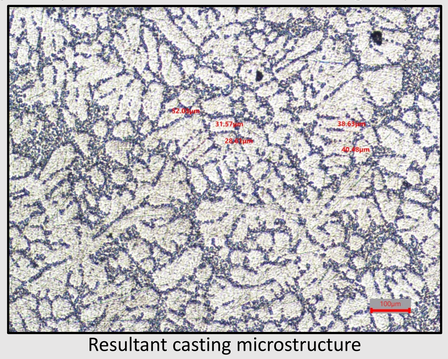
Property	Experimental A356	Theoretical A356[1]	Theoretical A206[2]
Yield Strength [MPa]	174.2	165.0	205.0
Tensile Strength [MPa]	261.7	234.0	345.0
Elongation [%]	7.46	3.5	10
Density [g/cm³]	2.642	2.67	2.80

Analysis



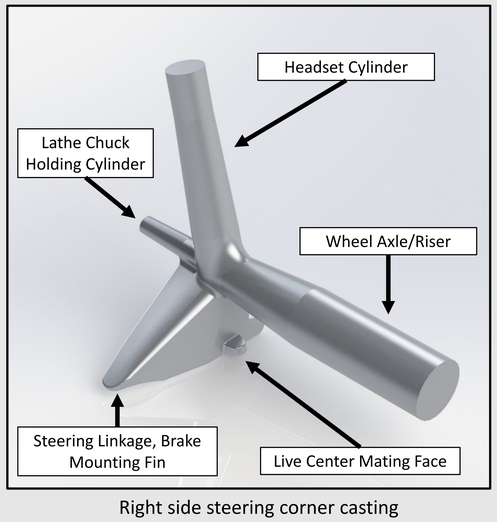


Zero porosity observed in critical locations using X-ray imaging



Resultant casting microstructure

Corner Design (As Cast)

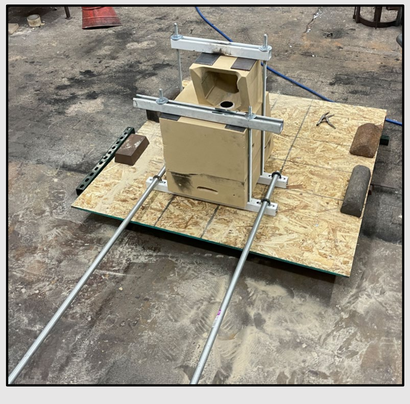


Right side steering corner casting

- Riser incorporated into wheel axle profile
- Features added for machining workholding
  - Wheel axle and headset cylinders extended to allow holding in lathe chuck
  - Flat added inline with headset cylinder axis to accommodate live center
- Steering linkage and brake mount merged into single fin profile

Mold Making and Pouring Setup

- Patterns were 3D printed, smoothened with body filler, and coated in mold release agent
- Polystyrene foam and oil clay were used on matchplate to create parting line
- Cope was formed from pattern secured in matchplate
- Drag was formed using a pre-made sodium silicate sand cope to match parting line
- Pouring basin was molded separately and glued to cope top



- Cope, drag, and pouring basin secured using steel channels and threaded rods
- Mold was elevated from ground to provide clearance for crucible
- Mold was rotated using steel pipes as handles
- Mold rotated around the front most edge of drag

References

[1] "Aluminum A356.0-T6, Sand Cast." MatWeb. [Online]. Available: https://www.matweb.com/search/DataSheet.aspx?MatGUID=d524d6bf305c4ce99414cabd1c7ed070

[2] "A206 Aluminum." Eck Industries, Inc. [Online]. Available: https://eckindustries.com/capabilities/a206-aluminum

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