AMC
AMERICAN METALCASTING CONSORTIUM

Identifying Casting Process Complexity and Applying Cost Minimization

University of Alabama
Charles Monroe

Innovative Casting Technologies (ICT)

AMC Technology Review

August 17-18, 2022

THE UNIVERSITY OF ALABAMA

SFSA

AMERICAN METALCASTING CONSORTIUM

Overview

Duration

1	2	3	4	5	6

- **Needs and Benefits**
  - Methodology to evaluate cost realism of bids
  - Reduced part costs and lead times through improved production design and process
- **Progress**
  - Developed software library for cost driving features of steel castings
  - Demonstration of new surface approach for capturing cost drivers not estimated by volume approach
- **Transition**
  - Software available now to industry and CAST-IT team, testing features

AMC
AMERICAN METALCASTING CONSORTIUM

Objective

- **Problem:** Unexpected process and manufacturing challenges delay production and delivery of quality castings
- **Objective:** Develop cost modeling software to predict process complexity and estimate variable costs
- **Technology:** Machine learning model of complexity classification, trained on process-related feature analysis of existing part libraries, and guided by expert knowledge

AMC
AMERICAN METALCASTING CONSORTIUM

Needs and Benefits

- **Benefits for DLA / DoD**
  - Methodology to evaluate cost realism of bids
  - Reduced part costs and lead times through improved production design and process
- **Benefits for Industry**
  - Identifying alternative manufacturing routes
  - Improving the speed, quality, and predictability of production
  - Minimizing operation and sustainment costs through better reliability of replacement parts

AMC
AMERICAN METALCASTING CONSORTIUM

Cost Scaling Analysis

- Example from Koller reproduced in Mueller 2011 for a gearbox
  – Lot of reuse in design from the small part to a large one
  – Technical/physical relationship between the small to large designs for example: "as design weight increases the cost increases with amount of material sold"

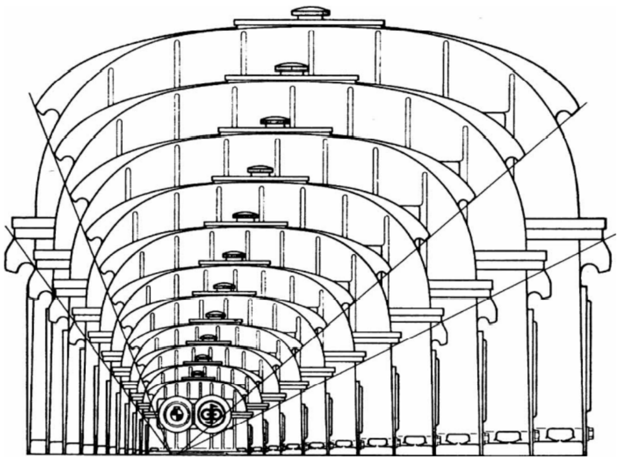


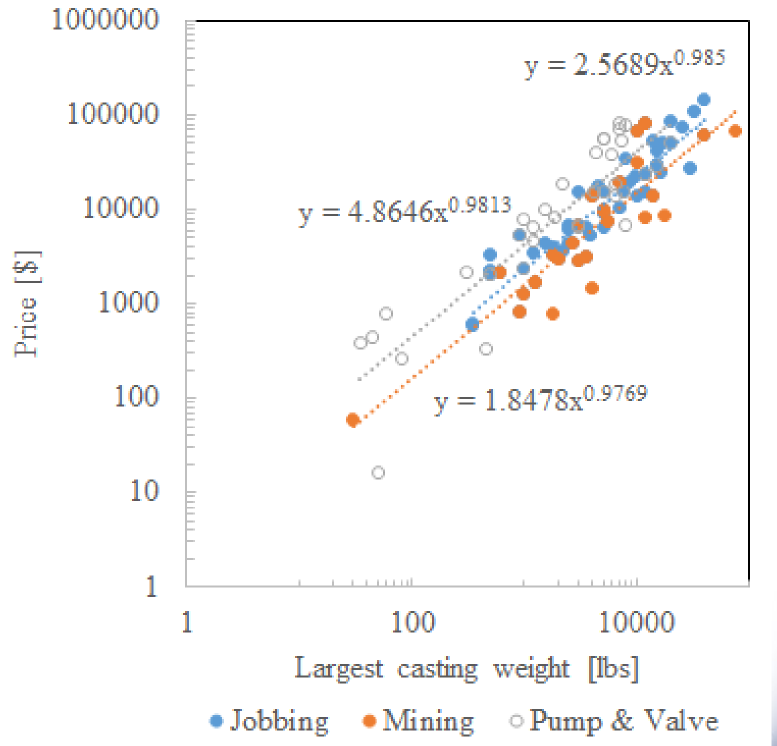
Figure 1. Display of a gearbox size range (Koller 1998, p. 328).

- Fundamental basis for current project
  – Identify the reused design elements in manufacturing of steel castings, such as risers, cores, machining, modulus, etc.
  – Predict casting design elements using geometric and process modeling and examine the scaling relationship for cost
  – One method is to identify the "family" for an analyzed part using a "complexity" factor and associated cost
  – Another method is to identify "activities" for associated cost
  – Third method is to identify "requirements" and corresponding "process steps" for associated cost
- Confounding elements in estimating cost with above method
  – Price fluctuations, supply changes, technology advances

DISTRIBUTION A. Approved for public release.

Cost Scaling Analysis (cont)

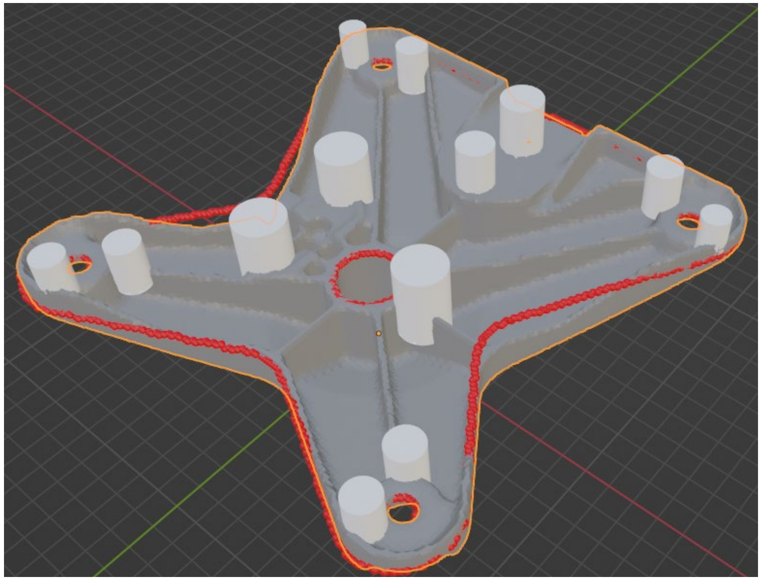
- Historically scaling variables for cost are weight/volume, area, and line. Example from 2017 SFSA T&O paper.
  - Most basic cost scaling is $/lb, there can be an order of magnitude difference in the price at a given weight
  - Variability is due to “complexity” but not simply more or less, the “family” is not just design elements but also requirements
- Part geometry drives process decisions for tooling, risers, cores, etc. Using process simulation these elements can be estimated, for example # risers, # cores, parting line
- Requirements are embedded in other information
  - Email, 2D drawing, or PPAP
  - Could be embedded into alternative 2D structure such as texture for automatic analysis

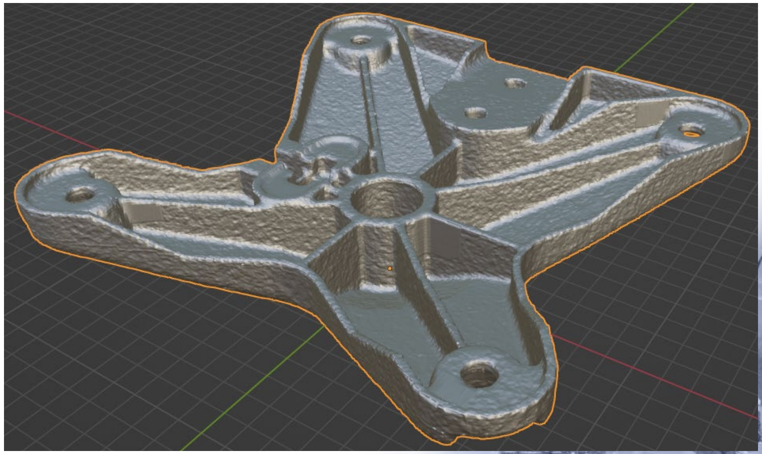


AMC
AMERICAN METALCASTING CONSORTIUM

A method for predicting and visualizing real metal casting part quality and cost

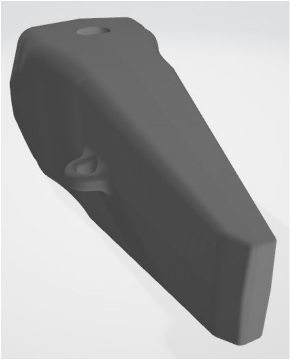
- From 3D part, geometric/process analysis to identify elements in steel casting
  - # Risers, cores, parting line
- On 2D texture comparing typical library of process output to match to requirements
  - Cost associated with additional steps
  - Visualization of final part with expected quality
- Predict and visualize the part with embedded cost scale and trouble areas
  - Aid for inspection
  - Technology for aggregating data on historic parts



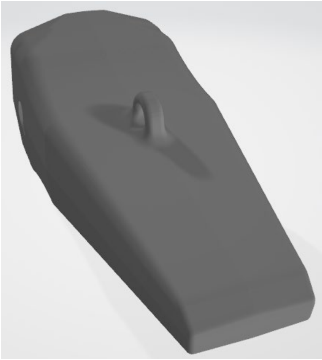


Example Cost Estimation of Ground Engaging Tool (GET)

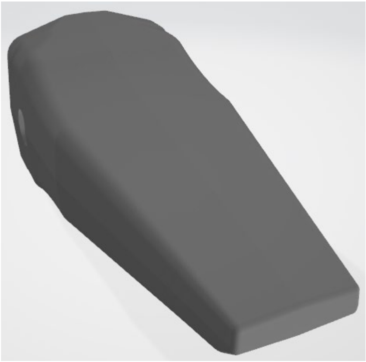
Through casting geometric tool suite, the data of riser and parting line would generate by STL and VTK file.



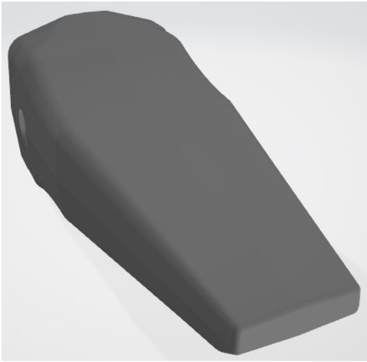
Option 1: hook direction(-X)



Option 2: hook direction(+Z)

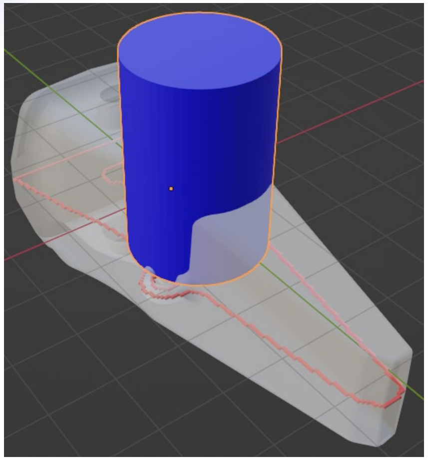


Option 3: hook direction(-Z)

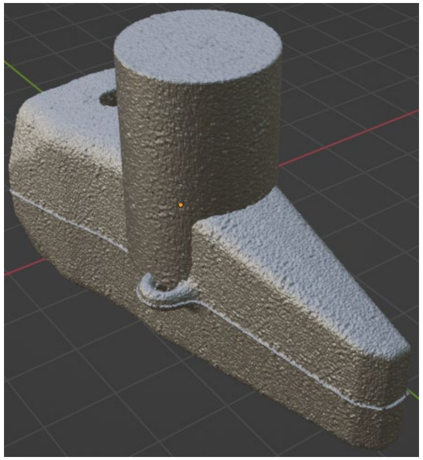


Option 4: hook direction(-Z) and no grinding

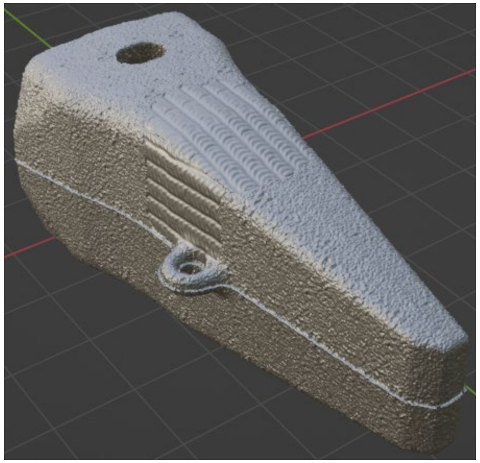
Option 1



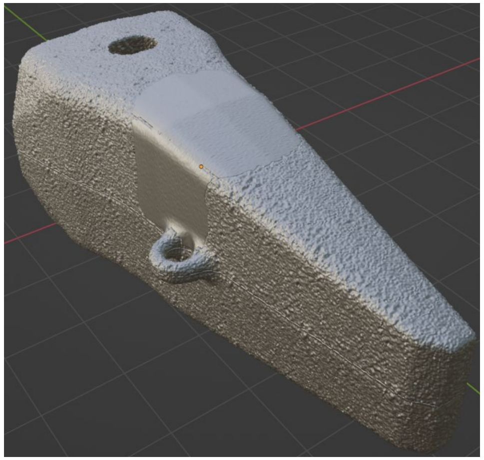
Simulation result



Shakeout

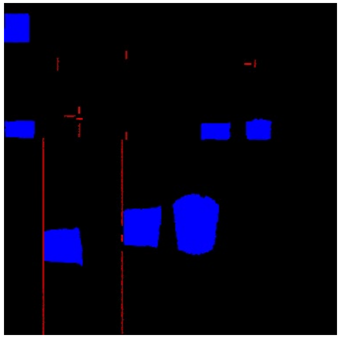


Riser removal

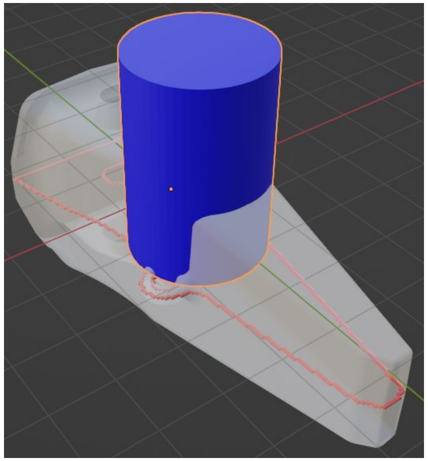


Final grind

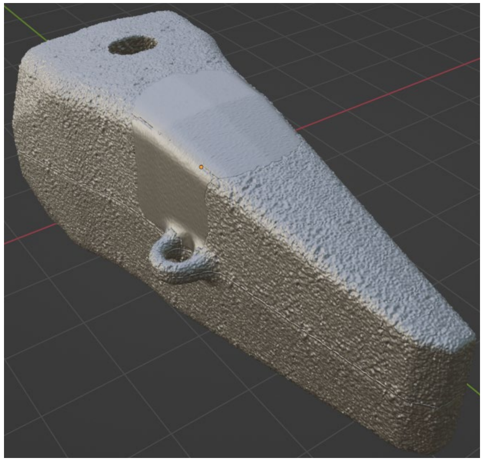
Option 1



Mark texture



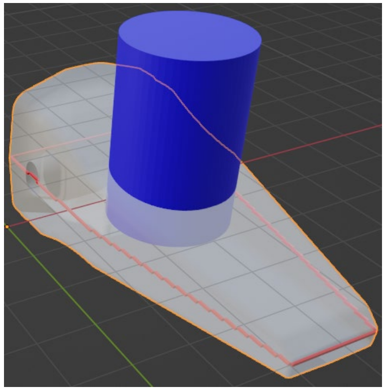
Simulation result



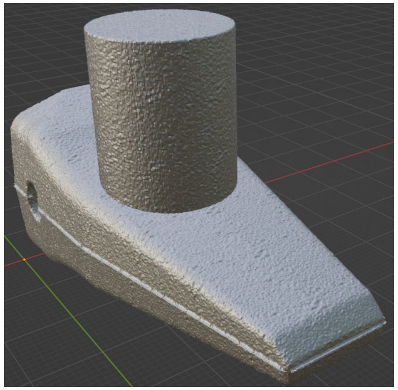
Machined Realistic geometry

- Number of parting line pixels = 1078
- Number of feeder pixels = 10895
- Area of each pixels = 12.9 mm^2
- Area of parting line = 13939 mm^2
- Area of feeder = 140861 mm^2
- Length of parting line = 3876.7 mm
- Length of feeder = 423.6 mm
- Cutting rate = 14 mm/min
- Grinding rate = 1 mm/s
- Labor cost = $15/hr
- Cost of riser removal = $7.6
- Cost of final grind = $17.9

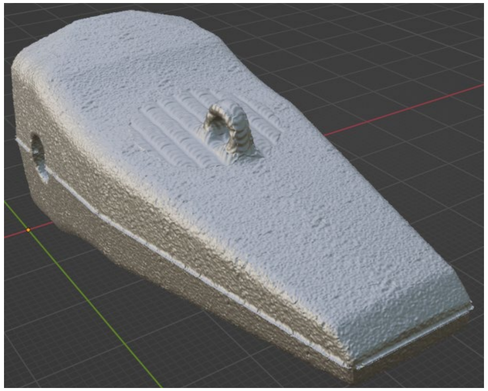
Option 2



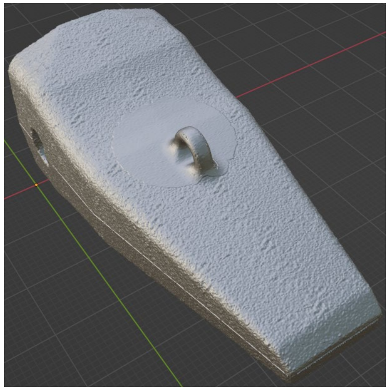
Simulation result



Shakeout

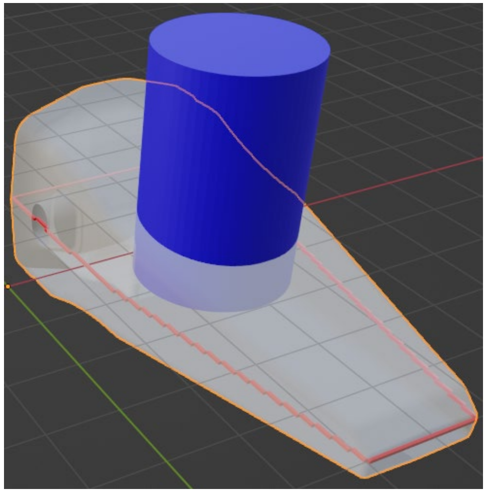


Riser removal

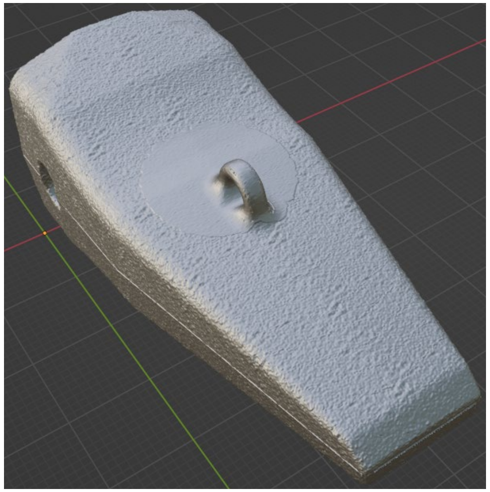


Final grind

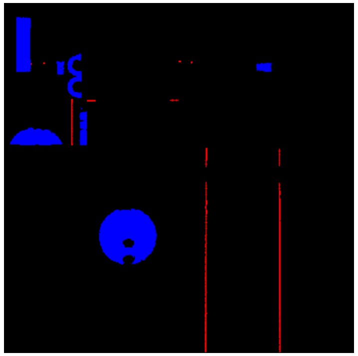
Option 2



Simulation result



Machined Realistic geometry

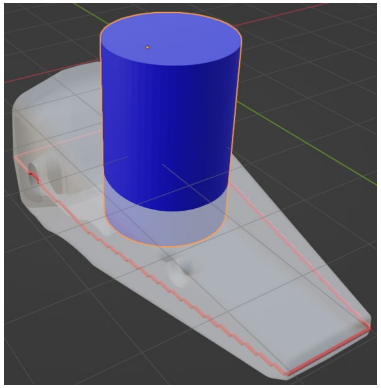


Mark texture

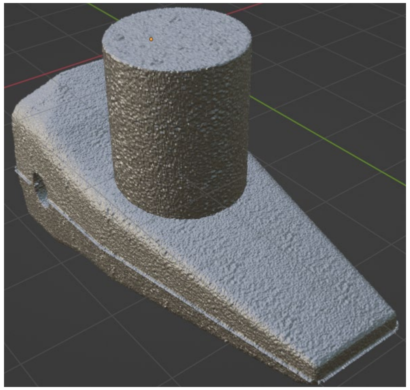
Number of parting line pixels = 967.5
Number of feeder pixels = 6311
Area of each pixels = 12.9 mm^2
Area of parting line = 12508 mm^2
Area of feeder = 81600 mm^2
Length of parting line = 3478 mm
Length of feeder = 322 mm
Cutting rate = 14 mm/min
Grinding rate = 1 mm/s
Labor cost = 15 $/hr
Cost of riser removal = 5.8 $
Cost of final grind = 15.8 $

AMC
AMERICAN METALCASTING CONSORTIUM

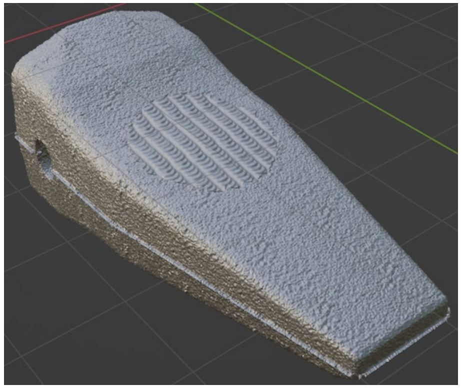
Option 3



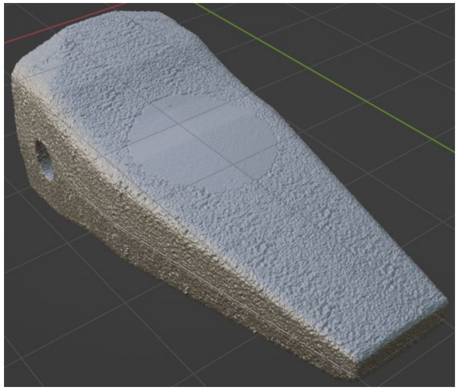
Simulation result



Shakeout

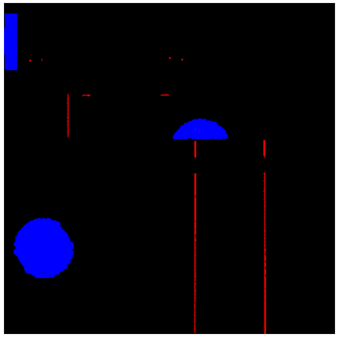


Riser removal



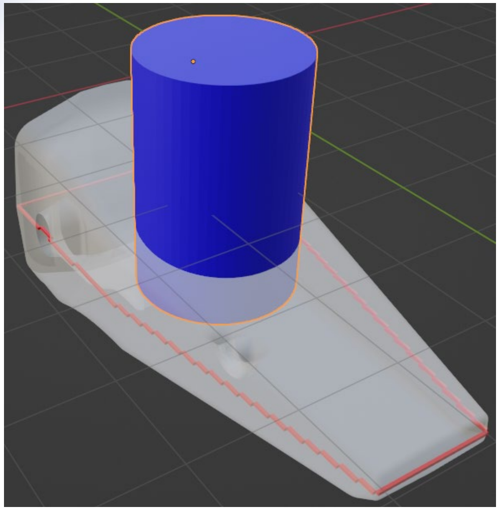
Final grind

Option 3

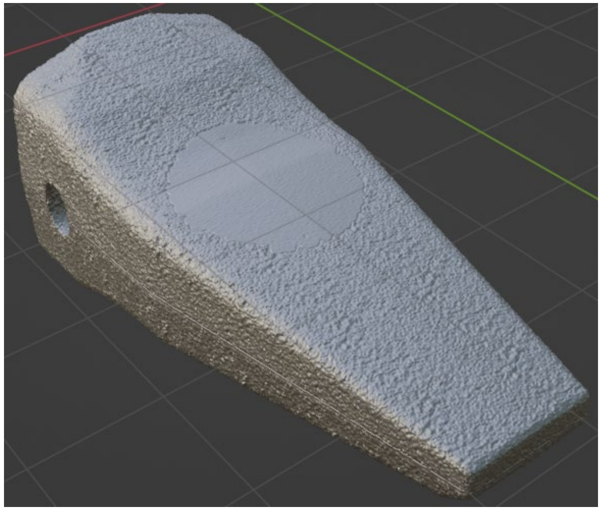


Mark texture

- Number of parting line pixels = 965
- Number of feeder pixels = 5527
- Area of each pixels = 12.9 mm^2
- Area of parting line = 12476 mm^2
- Area of feeder = 140861 mm^2
- Length of parting line = 3469.6 mm
- Length of feeder = 301.7 mm
- Cutting rate = 14 mm/min
- Grinding rate = 1 mm/s
- Labor cost = $15/hr
- Cost of riser removal = $5.4
- Cost of final grind = $15.7

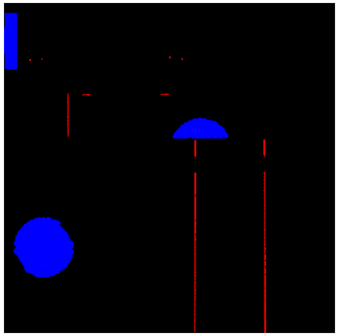


Simulation result

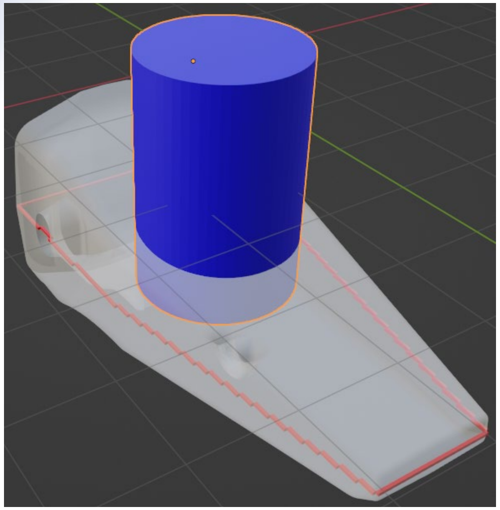


Machined Realistic geometry

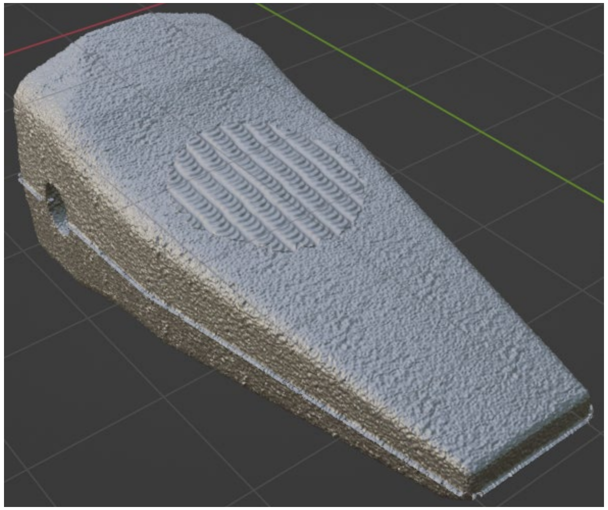
Option 4



Mark texture



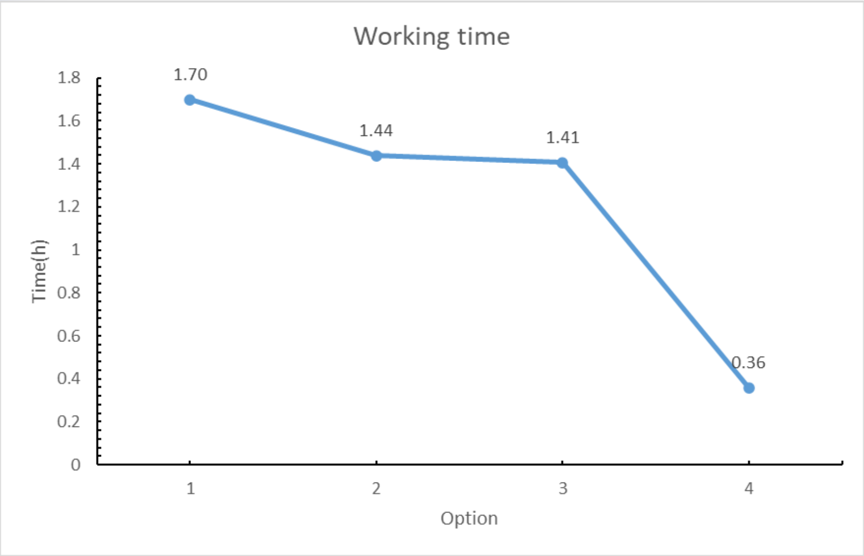
Simulation result

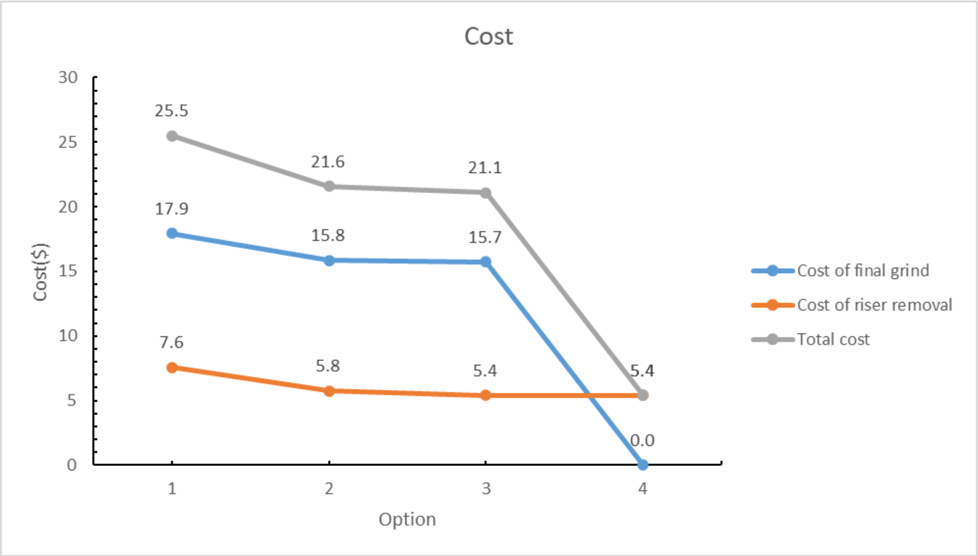


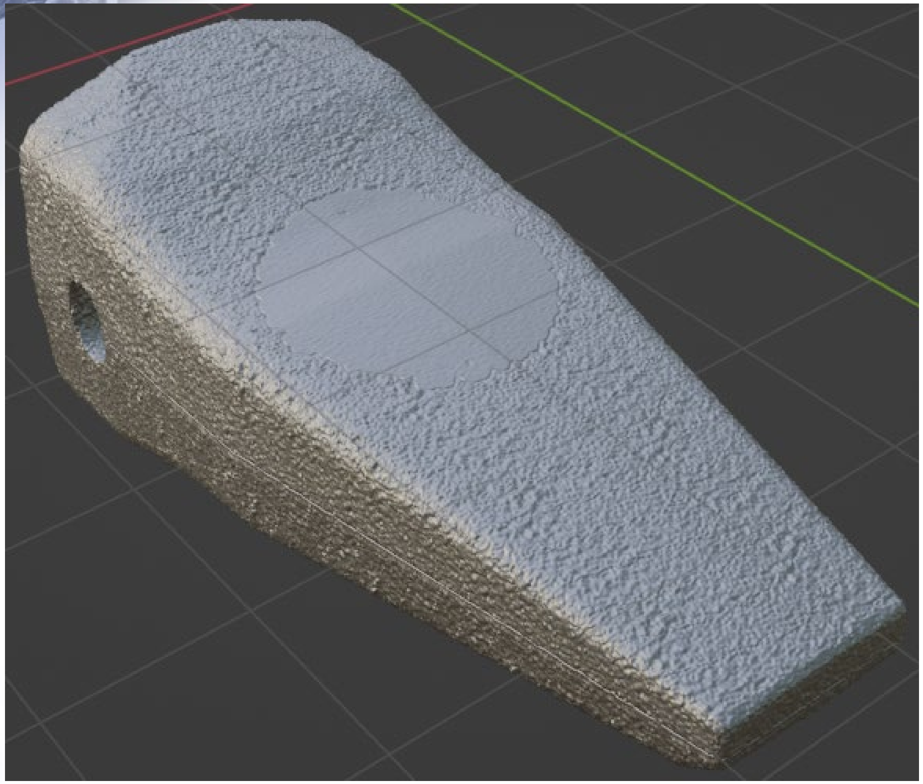
Machined Realistic geometry

- Number of parting line pixels = 965
- Number of feeder pixels = 5527
- Area of each pixels = 12.9 mm^2
- Area of parting line = 12476 mm^2
- Area of feeder = 140861 mm^2
- Length of parting line = 3469.6 mm
- Length of feeder = 301.7 mm
- Cutting rate = 14 mm/min
- Grinding rate = 1 mm/s
- Labor cost = $15/hr
- Cost of riser removal = $5.4
- Cost of final grind = $0

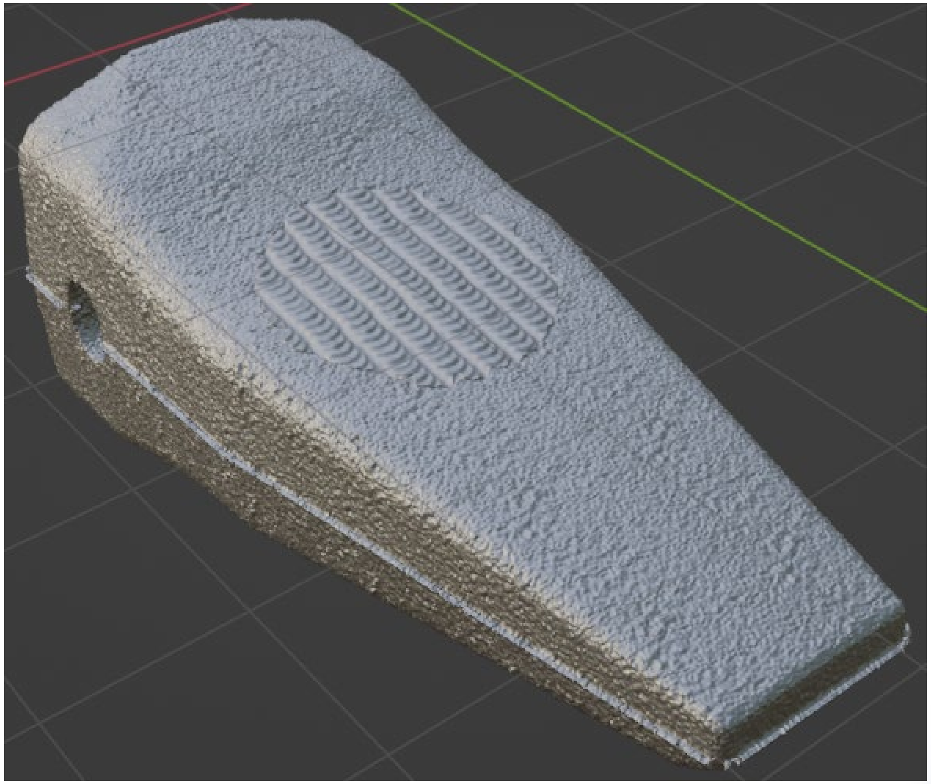
Cost estimation







Grinding GET with The least cost direction



Not grinding GET with The least cost direction

DEMO!

Content

- Validated the surface condition and visualized
  - Blender part -> using surface texture to represent the surface requirement
    - Texture of SCRA plates
    - Assessment of resolution and discretization voxel
    - Additional requirements on edges Voxel and surface detail
    - Unique surface location requirement: Limited angle and Unwrapping
    - Data output: UVSTL export
  - MATLAB part -> creating prediction of final surface for comparison to requirement
    - Function workflow
    - Algorithm: Connecting VTK file to Geometry
    - Algorithm: Connecting STL file to Geometry
  - Result -> visualized demo with unmachined and machined surface
- Cost estimation of GET compared to requirement
  - Extreme examples "unmachined casting" least cost or "fully machined casting" greatest cost

Completion Plan

- Final Months
  - Integrating the non-geometric surface data into software tool
  - Testing of tools with industry
- Key Accomplishments
  - Validation of feature predictions with industry
  - Alignment of “best casting” vs “worst casting” for both volume and surface predictions
  - New volumetric visualization method

AMC
AMERICAN METALCASTING CONSORTIUM

Transition Plan

- Continue to coordinate with CAST-IT Team on DLA Should Cost requests
- Guidelines on fundamental cost scaling variables over a variety of purchased casting geometries
- Software tool to be made available to members through SFSA
- SFSA Research Reviews with industry
- Presentations to industry at SFSA T&O Conference / AFS Casting Congress

AMERICAN METALCASTING CONSORTIUM

Leveraging

- Should cost model and part complexity libraries follow from previous work
  - CAST-IT Team / Gary Burrow (funded through DLA CSR)
  - ICT's On-Line Casting Cost Advisor (Gary Burrow)
- Feature analysis software tools follow from previous work
  - iFAB AVM (funded through DMDII, Penn State and Iowa State)
  - CastANA / ANADashboard Software (funded through DMDII, Iowa State)
- With support (expertise and data) from member SFSA companies

AMERICAN METALCASTING CONSORTIUM

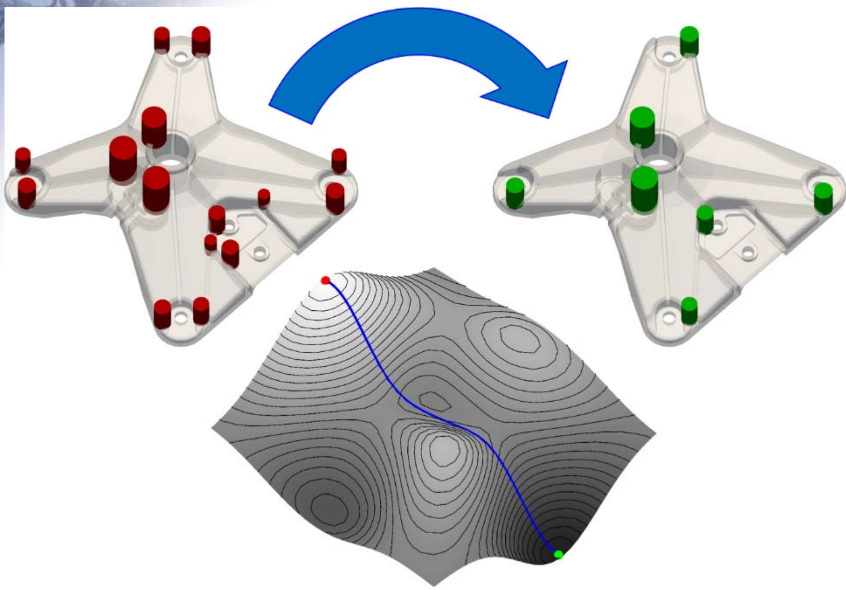
Project Metrics

Description	Baseline	Threshold	Goal	How Measured	Target Date	Progress	How Demonstrated
Software cost predictions	Existing purchase orders & cost data	Within 20% of actual on 80% of parts	Within 10% of actual on 80% of parts	Predicted vs actual cost	**Jun 2023**	90%	Software demonstration and measurement
Gating/rigging improvements	Present yield	5% improvement in yield	10% improvement in yield	Improved yield vs present	**Jun 2023**	70%	Laboratory experiment
Lead time reduction on complex parts	Historic lead times	Automated cost estimation and 50% reduced cost estimation time	50% lead time reduction	Past vs future procurement activity	**Jun 2023**	60%	Industry response

AMERICAN METALCASTING CONSORTIUM

Identifying Casting Process Complexity and Applying Cost Minimization

DLA - POC: DLAR.DPR@dla.mil



Problem

- The ability to produce and deliver cast parts on time and with the required quality is thwarted by unexpected process complexities and associated manufacturing difficulties

Objectives

- Develop software that will predict the manufacturing process complexity using a cost model which estimates variable costs

Benefits to Warfighter

- Will provide design and manufacturing technology by:
  - Identifying alternative manufacturing routes
  - Improving the speed, quality, and predictability of production
  - Minimizing operation and sustainment costs of the weapon system through better reliability of replacement parts

Description of Project:

This project will identify possible manufacturing routes, improve the speed, quality, and predictability of production, and minimize the operation and sustainment costs through better reliability of replacement parts

Team:

University of Alabama, Steel Founders' Society of America, ATI

THE UNIVERSITY OF ALABAMA

SFSA

ATI ADVANCED TECHNOLOGY INTERNATIONAL

Milestones / Deliverables

- Fundamental-cost scaling variables over a variety of casting geometries
- Software and interfaces for enhanced casting-cost simulation
- Case study on simulating the estimation of selected cast-component cost.
- Gating and rigging system recommendations