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Digital Standard for Surface Quality Inspection

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Innovative Casting Technologies (ICT)

AMC Technology Review

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IOWA STATE UNIVERSITY

SFSA

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Overview

Duration

1	2	3	4	5

- Needs and Benefits
  - ***Current surface finish determination methods are unreliable***
    - ***Excessive processing costs and delivery delays***
- Progress
  - ***Developed method that reliably and repeatably quantify surface roughness***
  - ***Applications optimized for simple geometries and scans of whole castings***
- Transition
  - ***Stand-alone hardware tool and software application***

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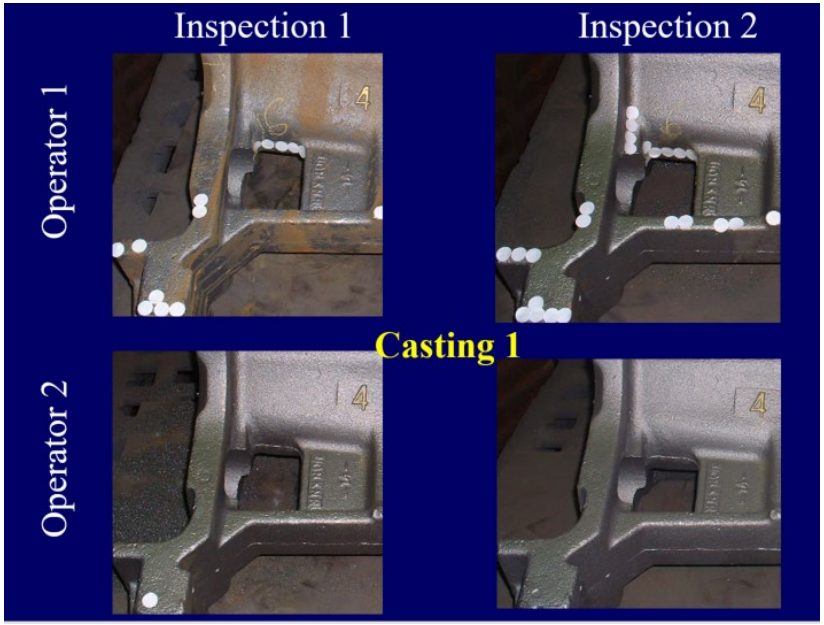
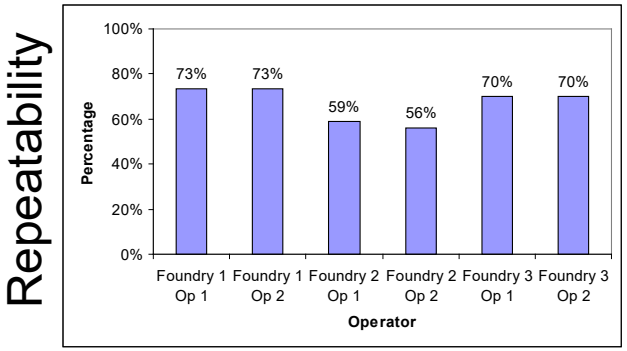
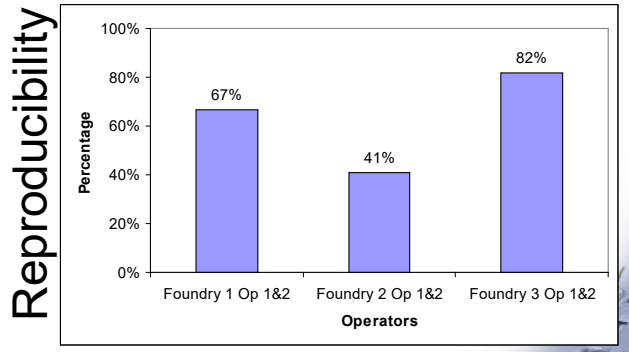
Objective

- **Problem Description:** Current methods of quantifying casting surface finish are unreliable and hence the standards are ambiguous. This leads to excessive processing costs and delivery delays.







Visual inspection was identified as the most important factor causing production delays within the foundry finishing operations

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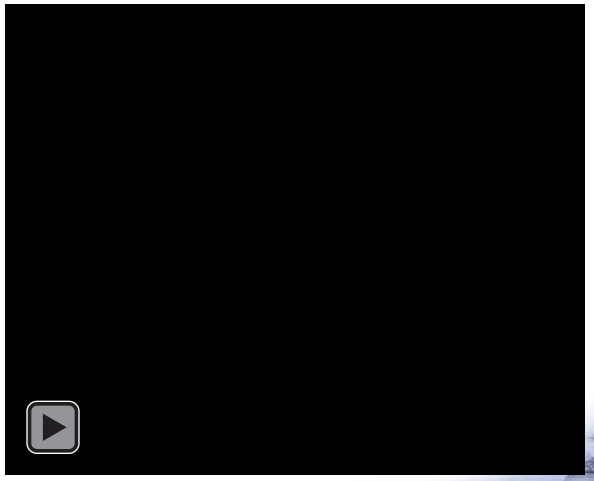
Objective Cont.

- **Objective:** Create a new standard that allows a designer to reliably specify the required surface conditions. Specifically, this will be based on non-contact digital inspection process that will also be refined in this work.

- **Technology:** Data processing algorithms will be developed that will process a set of data points collected from a casting surface to output key parameters of the scanned surface. Develop a hardware solution

Left: Prototype handheld 'patch' scanner
Right: Software output.



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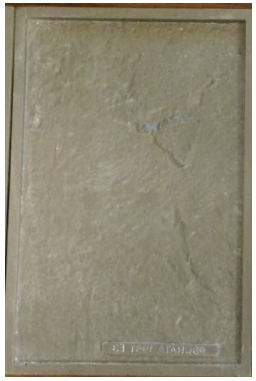
Needs and Benefits

- Reliable, quantifiable method of specifying casting surface finish to replace subjective comparisons with comparator plates and/or pictures
  - Improve Designer-Producer communication
  - Improve Within-Producer communication
    - Reduce costly rework time → improve delivery time
    - Reduce costly rework cost → reduced part costs



"The Caterpillar Ground Engaging Tools product group has started using the SCRATA surface comparator plates for acceptance criteria. Compared to a prior methodology of measuring the indication, the comparator plates pose a challenge because they are strictly subjective."

--Mike Thompson, Caterpillar

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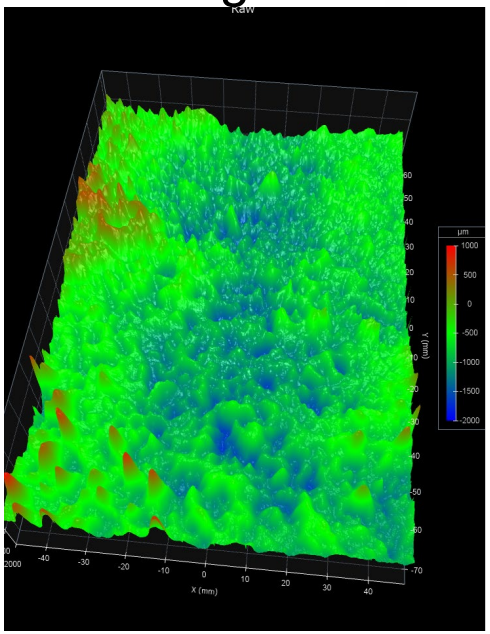
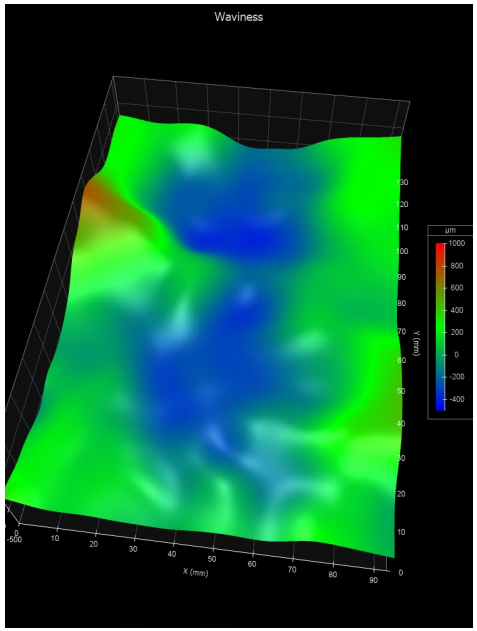
Technical Progress

- Underlying geometry determination has been changed to gaussian high and low pass filtering
- Enables comparison of results from scanners with different accuracies

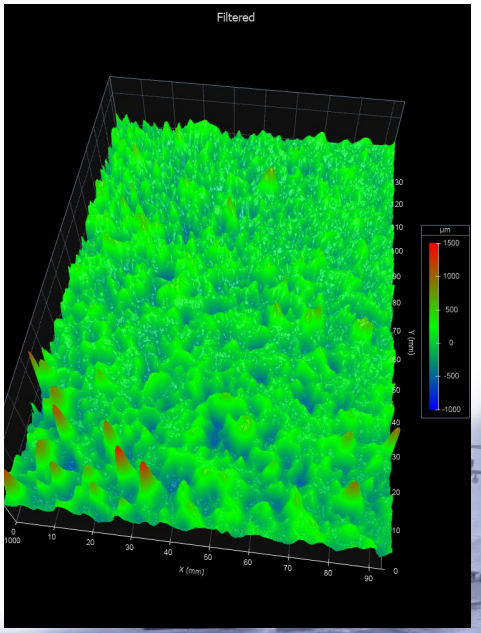
Original



Waviness



Filtered



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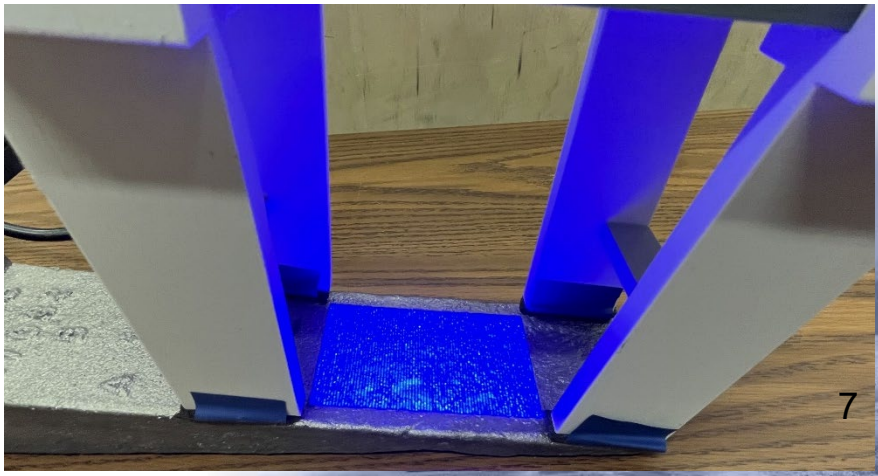
Technical Progress

- Developed variogram roughness metric (S_{VR})
- Portable scanner with integrated roughness analysis
  - Results were displayed on device
  - 3D scanner was able to handle reflective/shiny casting surfaces well



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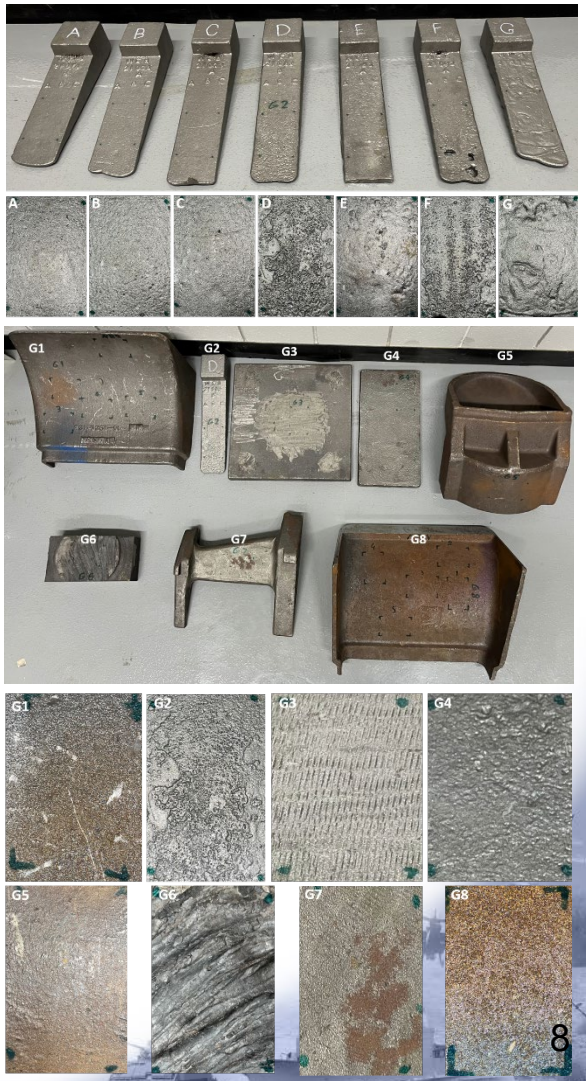
Technical Progress

- Gage R&R study on 14 castings
  - Seven castings with the same design
  - 8 different castings
  - Five sections on two castings each
  - Gage R&R: 0.9 % - 8.7 %
  - Repeatability: 1.7 µm – 3.6 µm (S_{VR})
  - Reproducibility: 0.4 µm – 2.1 µm



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Technical Progress

- Draft of ASTM standard has been created
  - Shared with member foundries for comments
  - Presented to ASTM committee
  - Includes tables for conversion from comparator plates (ACI, GAR-C9, SCRATA A) to S_{VR} roughness parameter

SCRATA Comparator	Mean: S_{VR} Equivalent (mm)	Min: S_{VR} Equivalent (mm)	Max: S_{VR} Equivalent (mm)	Standard Deviation: S_{VR} Equivalent (mm)
A1	0.0264	0.0214	0.0291	0.0020
A2	0.0448	0.0400	0.0472	0.0026
A3	0.0630	0.0564	0.0664	0.0034
A4	0.1315	0.1293	0.1393	0.0033

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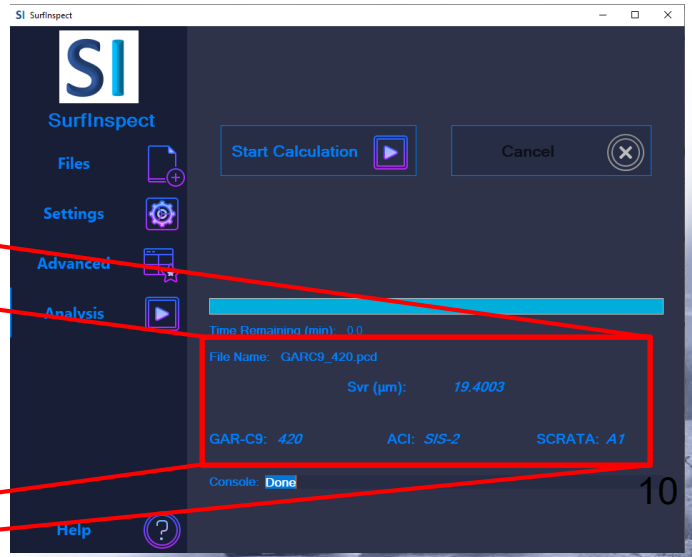
Technical Progress

- Developed standalone, easily deployable software for software analysis
- Has been shared with foundries for feedback



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Completion Plans

- Make adjustments to ASTM Standard draft based on industry and ASTM feedback
- Create final report

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Transition Plan

- Utilize Steel Founders' Society of America network to promote methodology
- Complete standard for consideration by ASTM International (Year 3 and 4)
- Work with hardware provider to deliver a stand-alone hardware tool (Year 4)

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Leveraging (Principal Investigator)

- Previous work from DOE Energy-SMARRT and SFSA has provided the groundwork for this current effort.
  - Visual inspection was identified as the most important factor causing production delays within the foundry finishing operations
  - Investigated how to improve human inspector through training and ‘calibrations’
  - Initial work on a digital method and standard
- Current work with SFSA on the Digital Innovative Design (DID) program
  - That project will test the impact of surface roughness on static and fatigue properties

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Project Metrics

Description	Baseline	Threshold	Goal	How Measured	Target Date	Progress	How Demonstrated
Repeatability of the digital inspection process to be within 30% of the actual roughness	Actual surface of representative castings samples	Within 30% of actual values	Actual values	Baseline comparisons measured with digital prolifometer	**8/1/2020**	95%	Measured roughness compared to proposed method
Digital surface inspection process that reduces error by 40% compared to visual inspection	Agreement on acceptability of a casting surface within and between operators of 65% and 54% respectively	Agreement within and between operators 91% and 76% respectively	92% agreement within and between operators	Gage repeatability and reproducibility test using the new method	**5/1/2022**	95%	Gage R&R using existing standards and proposed method
Digital surface inspection process validated on at least 25 different casting designs	Validation studies comparing current visual standards and proposed method with gage R& R	Validation studies completed on 25 different casting designs	Validation studies completed on 25 different casting designs at 5 producers	Results of industry trials	**1/15/2023**	90%	Conducting industry trials to refine approach and promote adoption

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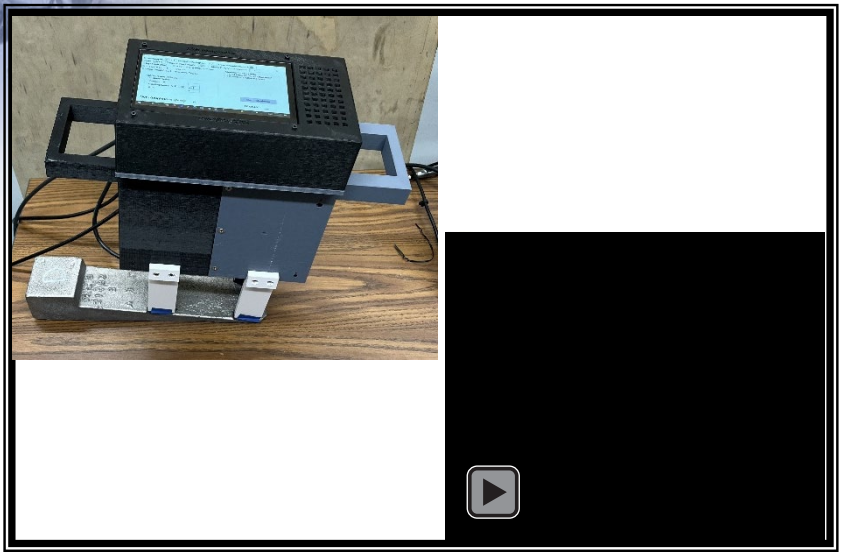

Problem

- Visual inspection of casting surface quality is a very subjective process and currently relies on comparator plates or photos of casting surfaces. A digital standard based on an objective method is needed to improve the inspection process.

Objectives

- Refine and implement a digital method for the inspection of casting surfaces.

Benefits to Warfighter

- An objective process will result in reduced production lead times and associated costs as the over processing to counteract measurement error is reduced. More importantly, this will enable correlation studies between casting surface and casting performance.

Description of Project:

This project will develop a digital standard for the inspection of casting surfaces based on an objective method so quality can be specified and verified to meet the intent of the component design.

Team:

Iowa State University, Steel Founders' Society of America, ATI

IOWA STATE UNIVERSITY

SFSA

ATI ADVANCED TECHNOLOGY INTERNATIONAL

Milestones / Deliverables

- Refine the current proposed ASTM Standard to aid its adoption.
- Implement algorithms to process data.
- Develop error checking methods for data processing.
- Collect industry data to validate system and validate digital standard.
- Develop hardware device