

Transition of Steel Casting Technology through Codes, Standards, and Educational Tools

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Emergent Metal Casting Technologies (EMCS)

AMC Technology Review

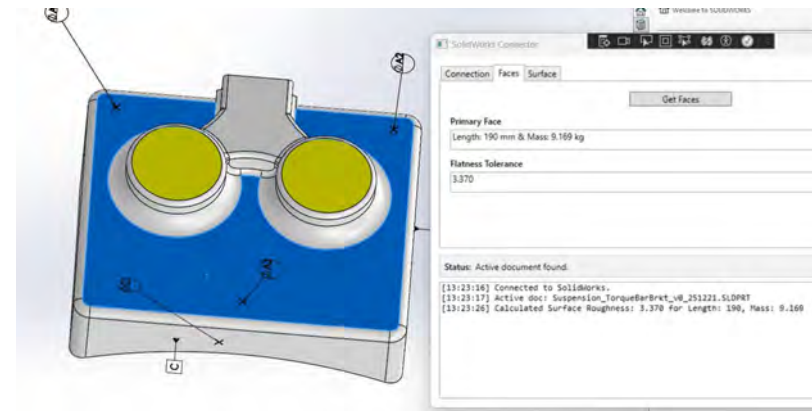
June 24-25, 2026



Overview

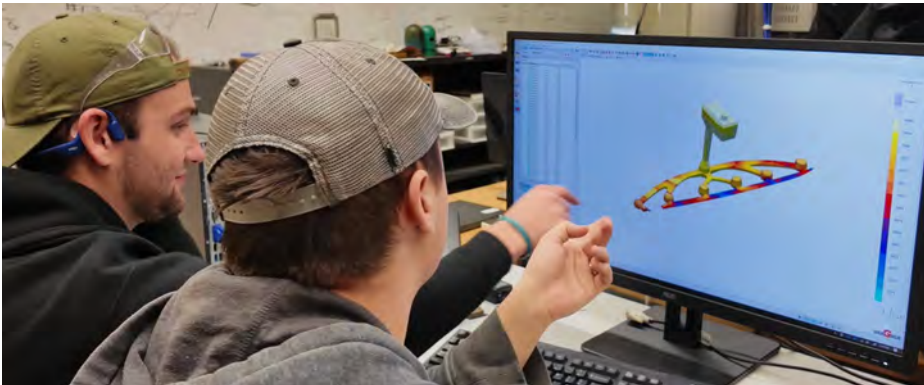


- Needs and Benefits
 - Developing needed capable artisans and engineers
 - Supporting engineering and procurement activities
- Progress
 - Developing key people with production problem-solving resources
 - Educating customers
- Transition
 - Web based tools
 - Webinars/videos
 - Spec database enhancements
 - Interactive casting design evaluation tool
- Codes and Standards
 - AWS D1.1 acceptance of steel castings
- Cost Share Provided: \$240,959



Needs

- **Problem**
 - Highly qualified people aging out at foundries and OEM designers
 - Knowledge lost makes it challenging to develop new capable people, risking the loss of critical capabilities and supply chains.
- **Objective**
 - Expand the inclusion of new technologies in areas of design, casting quality, and welding best practices in commercial specifications
 - State of the industry information resources for next-gen artisans, engineers, and buyers
- **Technology**
 - Online education resources for steel casting producers and customers
 - New and revised commercial standards to improve steel casting design
 - Interactive design and specification resources



Benefits

- DoW
 - Expand and sustain the steel casting supply chain for DoW and commercial markets
- Foundry / Casting Supplier / Industry
 - Online information resources to support qualified artisan development for steel casting producers and casting buyers and designers
 - Design and specification resources to enable improved casting quality and performance and design optimization to reduce costs



Wiki.sfsa.org



RESOURCES ▾ BUYERS & DESIGNERS ▾ CASTING SOURCES



<https://www.sfsa.org/subject-areas/education/steel-casting-design/>

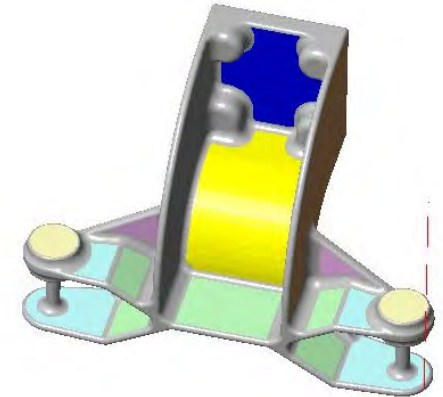
Milestones/Tasks

- **Completed**
 - 17 webinars – Heat Treatment and Specification
 - Steel casting design tool – Phase I completed
- **In Progress**
 - Specification webinars
 - Steel casting design tool – Phase II
- **Planned**
 - Welding training class – ASME Section IX
 - Specification database enhancements
 - Steel casting design tool – industry trials

Project Plans

Interactive Casting Design Evaluation Tools

- Castability Geometry with Structural Geometry Overlay
 - User – Design Engineer
 - Input alloy choice with .STL file
 - Evaluation tool color-codes surfaces for classification of:
 - Dimensional Tolerances and surface finish
- 2026-2027 Plans
 - Downloadable Phase 2 tool that would enable a design engineer to improve dimensional tolerance and surface finish specifications for lower cost producibility.
 - Test and validate tool with designers and casting producers





Steel Casting Design Evaluation Tool

Project Overview

- A downloadable, interactive tool, available on the steel wiki
- For customer design engineers designing steel castings
- Aimed at more producible steel casting designs

Partners

- Metalcasting Design, LLC
- DR Consultants & Engineers
- Jake Richardson, CAD Development Engineer

Project Objective

Real-time steel casting design evaluation of a new solid model directly on the engineer's computer. Tool is not cloud-based for improved security.

Addressing the most significant 3 design attributes affecting a steel casting design's *producibility*:

1. Dimensional tolerances; GD&T-based; Feature-by-feature
2. Surface finish; As-cast if possible, Machined if necessary
3. Steel alloy "Castability Geometry" (Driven by casting interior cross-section thicknesses)

Application

Mold Cavity-Making Processes:

1. Air-Set Sand
2. Ceramic Shell Investment

Three Steel Casting Alloy Sub-Groups, with differing...

1. Solidification Shrinkage Types
2. Solidification Shrinkage Amounts

Unique Methodology

The Design Evaluation Tool Remains Inside the Solid Model Software's Mathematics

- Using SOLIDWORKS' accessible Application Protocol Interface (API)
- *NOT* having to export an .STL file for other software evaluation

The Graphical User Interface enables the designer to simply click on a model surface for:

- A recommended dimensional tolerance
- A recommended as-cast surface finish

Or form slices through interior thick sections for:

- Recommendation of a more castable, high integrity thickness

How the Application Protocol Interface Works

Behind what the designer sees of the model on the screen and all its menus:

- There is mathematics driving the model's size and shape that can be accessed through the Application Protocol Interface
- The Design Evaluation Tool resides there grabbing data from all the math and loading that data into our algorithms:
 - Recommending dimensional tolerances
 - Recommending as-cast surface finish grades
 - Evaluating interior section thicknesses for solidification integrity

How the Graphical User Interface Works

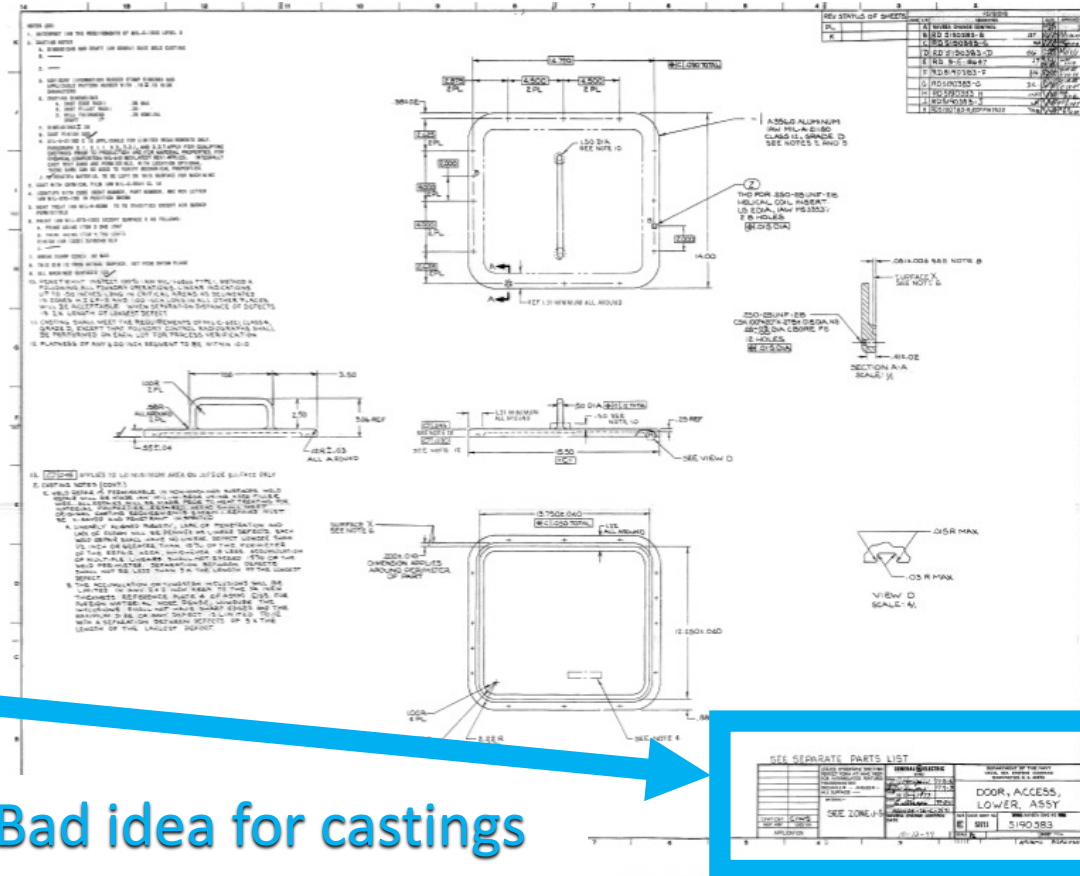
Graphical User Interface (GUI) add-in program, built into SFSA Design Evaluation Tool download, that enables engineers to:

- Click a model surface to identify adjacent geometry and receive recommendations for dimensional tolerances or surface finish based on localized thickness
- Analyze neighboring regions where section thickness increases and obtain guidance on geometry changes to improve cross-sections and solidification integrity

The Power of Dimensional Tolerance Guidance

In the “Old Days”

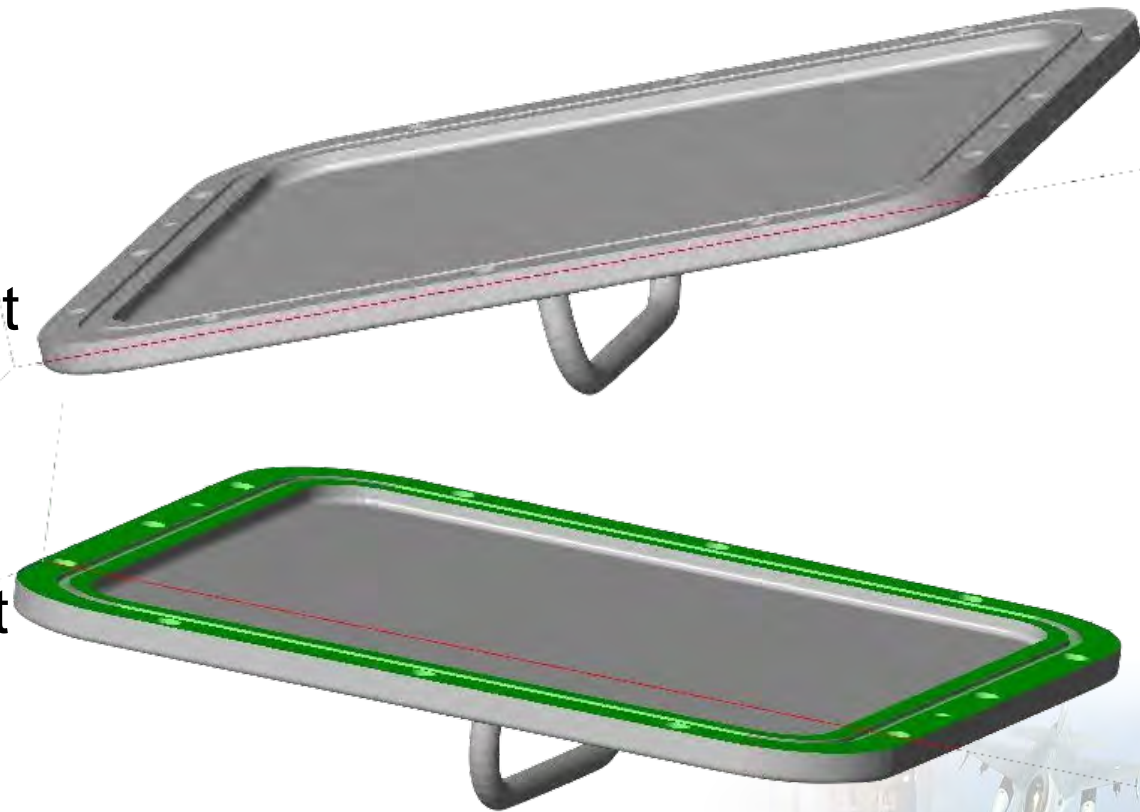
- Hand drawn
- Dimensioning & tolerancing as you went along, feature-by-feature
- For speed and convenience, many tolerances were referred to the drawing's Title Block, based on the number of decimals in the tolerance



Dimensional Tolerance Guidance

Now, with Solid Models...

- Model is usually completely built first
- The drawing is an output file from the solid model
- The software will put dimensions on the drawing output file... but no tolerances... no GD&T annotations



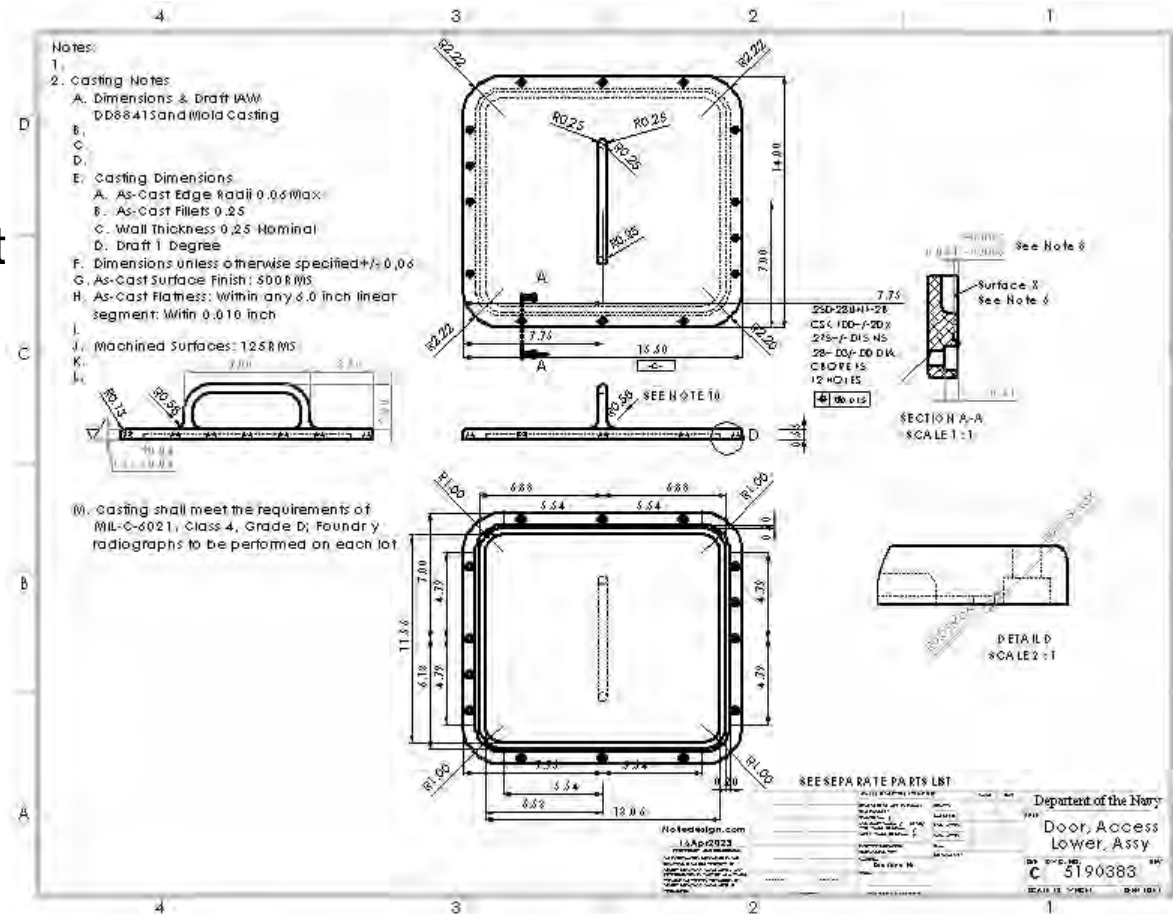
Machined Surfaces

Dimensional Tolerance Guidance

Tolerancing becomes an afterthought and tedious

- Get some underling to do it
- Common for new solid model to be given to a casting producer *with no dimensions at all!*

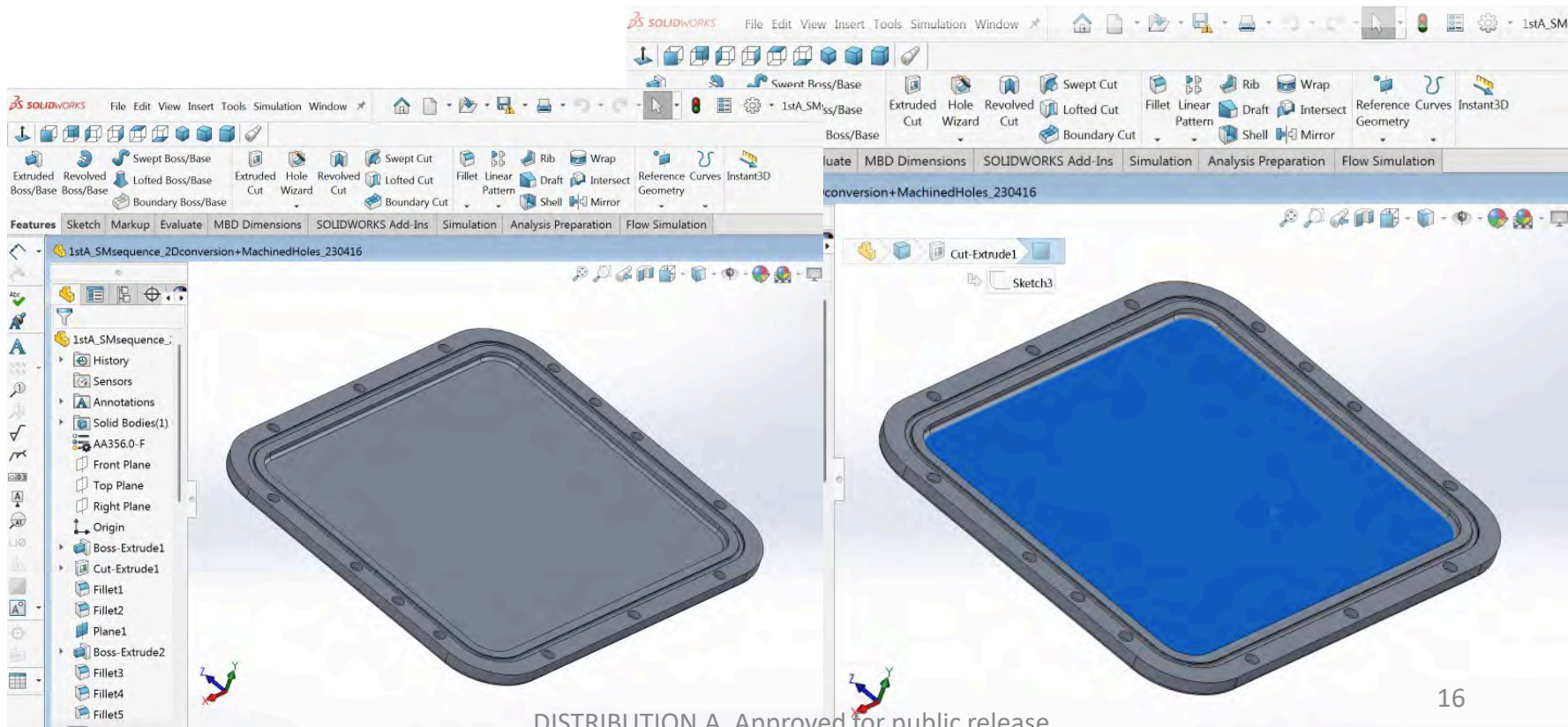
“Just cast a prototype for us”



Dimensional Tolerance Guidance

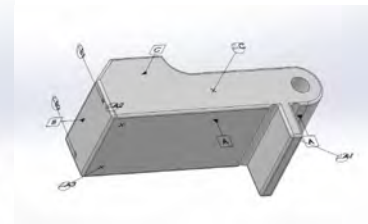
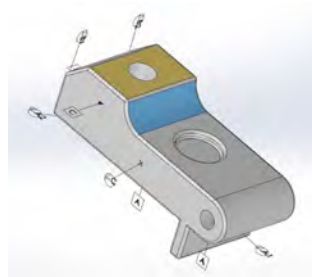
Now with the SFSA Design Evaluation Tool:

- A simple click on one of the model's surfaces results in a dimensional ***tolerance*** recommendation



6 Month “Proof of Concept” Completed

- **The 6-month proof of concept demonstrated the ability to interrogate SOLIDCast outputs to:**
- Qualitatively and quantitatively characterize casting surfaces
- Identify and quantify GD&T features, including datums and datum targets
- Extract surface-level data to support casting design evaluation and tolerance analysis



Fits Well Where Designers Are Going

Worldwide, CAD platforms are advancing toward more complete and precise tolerancing, unlocking major benefits for casting design and production.

Shown here is one of the technologies; But the tolerancing is done **after** the model is built.

Our tool enables tolerancing **while** building the model.



“Proof of Concept” Completed

The 6 Month Proof of Concept demonstrated the ability to present designers, through a graphical user interface, with recommended tolerance values derived from algorithms based on SFSA Supplement 3 principles and refined using real-world steel casting producer experience.

<p>90% Capability $6\sigma = 2.990 + 0.018 * L^{0.9} + 0.009 * W^{0.8} + 1.020 * PL$</p> <p>50% Capability $6\sigma = 1.300 + 0.010 * L^{0.9} + 0.010 * W^{0.8} + 1.020 * PL$</p> <p>10% Capability $6\sigma = -0.383 + 0.008 * L^{0.9} + 0.012 * W^{0.8} + 1.030 * PL$</p>
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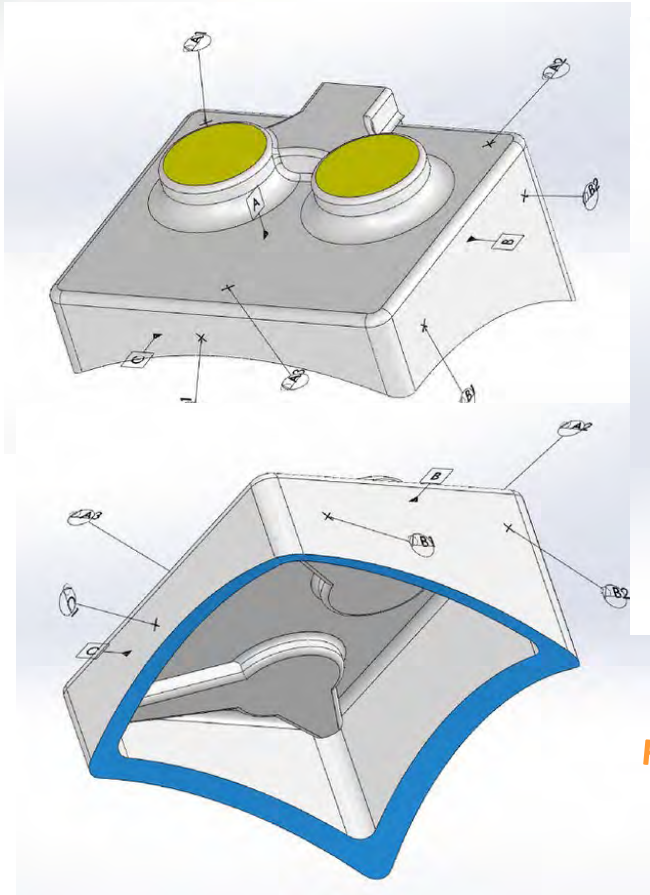
Tolerance equations from SFSA Steel Castings Handbook; Supplement 3

Table 3.8 Dimensional capability models for steel castings (mm)

	Short Production Series	Long Production Series
Green sand (castings less than 230 kg)	<p>90% Capability $6\sigma = 5.200 + 0.0007 * L^{1.3} + 0.340 * W^{0.4}$</p> <p>50% Capability $6\sigma = 2.140 + 0.0007 * L^{1.3} + 0.340 * W^{0.4}$</p> <p>10% Capability $6\sigma = -0.922 + 0.0007 * L^{1.3} + 0.340 * W^{0.4}$</p>	<p>90% Capability $6\sigma = 4.330 + 0.0006 * L^{1.3} + 0.284 * W^{0.4}$</p> <p>50% Capability $6\sigma = 1.780 + 0.0006 * L^{1.3} + 0.284 * W^{0.4}$</p> <p>10% Capability $6\sigma = -0.768 + 0.0006 * L^{1.3} + 0.284 * W^{0.4}$</p>
No-Bake (castings up to 900 kg)	<p>90% Capability $6\sigma = 3.590 + 0.014 * L^{0.9} + 0.010 * W^{0.8} + 1.230 * PL$</p> <p>50% Capability $6\sigma = 1.560 + 0.012 * L^{0.9} + 0.012 * W^{0.8} + 1.230 * PL$</p> <p>10% Capability $6\sigma = 0.460 + 0.010 * L^{0.9} + 0.014 * W^{0.8} + 1.230 * PL$</p>	<p>90% Capability $6\sigma = 2.990 + 0.018 * L^{0.9} + 0.009 * W^{0.8} + 1.020 * PL$</p> <p>50% Capability $6\sigma = 1.300 + 0.010 * L^{0.9} + 0.010 * W^{0.8} + 1.020 * PL$</p> <p>10% Capability $6\sigma = -0.383 + 0.008 * L^{0.9} + 0.012 * W^{0.8} + 1.030 * PL$</p>
Shell (castings less than 50 kg)	<p>90% Capability $6\sigma = 2.040 + 0.001 * L^{1.4} + 0.494 * PL - 0.0005 * PL * L^{1.4}$</p> <p>50% Capability $6\sigma = 1.090 + 0.001 * L^{1.4} + 0.499 * PL - 0.0005 * PL * L^{1.4}$</p> <p>10% Capability $6\sigma = 0.138 + 0.001 * L^{1.4} + 0.504 * PL - 0.0005 * PL * L^{1.4}$</p>	<p>90% Capability $6\sigma = 1.700 + 0.0009 * L^{1.4} + 0.412 * PL - 0.0004 * PL * L^{1.4}$</p> <p>50% Capability $6\sigma = 0.909 + 0.0009 * L^{1.4} + 0.416 * PL - 0.0004 * PL * L^{1.4}$</p> <p>10% Capability $6\sigma = 0.115 + 0.0008 * L^{1.4} + 0.420 * PL - 0.0004 * PL * L^{1.4}$</p>

6σ = total tolerance capability, mm
 PL = 1 if feature across the parting line, otherwise 0
 L = feature length, mm
 W = casting weight, kg

6 Month "Proof of Concept" Early Demos



Feature Length L = 190mm

Casting Mass = 9.2kg

Recommended Tolerance +/- 1.6mm

Primary Face
Length: 190 mm & Mass: 9.169 kg
Flatness Tolerance
3.370

Status: Active document found.
[11:23:16] Connected to Solidworks.
[13:25:17] Active doc: Suspension_TorqueBarBrkt_v0_251221.SLDPRT
[13:25:26] Calculated Surface Roughness: 3.370 for Length: 190, Mass: 9.169

Tolerance Equation Development

Tolerance Algorithms (Feature Length)

Based on Metalcasting Design LLC/NoRedesign LLC, and Supplement 3 equations:

- Non-linear equations adjusted for casting weight/mass
- Reflect top 10% of SFSA member producer capability
- Incorporate long-run tooling design and construction refinement
- Account for longest surface length and casting mass dependencies.

Result is more practical, tighter tolerances... Pleasing the designer, yet coarse enough to be producible... Pleasing to steel casting producers

Tolerance Equation Development

Equations for **GD&T-based Flatness** based on Supplement 3 Flatness Table values, converted to non-linear equations:

- Long run tooling design and construction refinement
- Upper 10% of SFSA member producer tolerance capability
- Equations reflect dependencies on Longest length of the Flatness surface and Mass of the casting
- Tolerances are coarsened by GD&T consideration of distance of flatness surface from the Datum surface from which the Flatness feature is located, and possible angle of tilt of the surface compared the Datum, and
- Width of the Datum Targets that define that Datum surface.

These are real GD&T tolerance characterization principles applied automatically

Graphical User Interface Online Demo

Introducing now, Jake Richardson, our CAD software development engineer partner, who will demonstrate for us live, the Graphical User Interface. Demonstrations for:

- Simple Flat Feature Length
- GD&T Flatness of a Feature, unto itself, from a Primary Datum, or from a Primary Datum at an angle

Summary

- Built on the foundation of the Steel Casting Handbook Supplement 3, the Design Evaluation Tool uses non-linear regression equations and an intuitive Graphical User Interface (GUI) to provide steel casting designers with:
- Surface-by-surface dimensional tolerance recommendations for Simple Feature Length, based on the surface's longest dimension and overall casting mass
- Advanced GD&T-based Flatness tolerance recommendations, where the user selects the Flatness surface and the Tool calculates tolerance values using the associated Datum Plane and Datum Target spacing defining the surface
- **Phase 2 enhancements will expand capability to include:**
- Recommendations for the remaining two critical GD&T tolerances:
 - Profile across a range of surface geometries
 - Position tolerances for holes and bosses
- Equivalent tolerance recommendation capabilities for Investment Steel Castings, in addition to Air-Set Sand Steel Castings
- This progression advances the tool toward comprehensive, standards-based GD&T guidance informed by both SFSA Supplement 3 principles and practical steel casting production experience.

Transition Plan

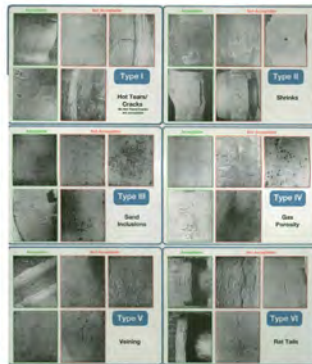
- Production Welding – seminars, Welding Procedure Specification (WPS)
- New and revised specifications
- Web based tools
- Webinars/videos
- Spec database enhancements
- Interactive casting design evaluation tool



AB82 – 95 (Reapproved 2015) Standard Practice for Steel Castings, Surface Acceptance Standards, Visual Examination



Figure 2-3 Various SCRATA comparators. First row left to right: A1, A2, A3, A4. Second row left to right: B4, C3, D5, E3



<https://msshq.org/page/SP55>

Heat Treating is about heating and cooling steel to get the performance we need.

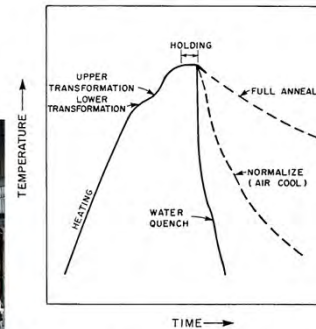


Fig. 24-1 A generalized sketch of the steps in the heat treating of steel castings

Leveraging

- Leverages AMC research work for wiki content
- Wiki includes:
 - SFSA Steel Castings Handbook
 - All research and conference papers, including DLA, DOE research results
 - Educational webinar videos available to steel foundries and military/government
- Workforce development for SFSA artisan program and industry's intern programs
- SFSA's Digital Innovative Design Program
- SFSA's SPI Steel Technology Advance Research (STAR) funding to support Artificial Intelligence (AI) Language Learning Model (LLM) for the Wiki.



Project Metrics

Description	Baseline	Threshold	Goal	How Measured	Target Date	Progress	How Demonstrated
Workforce and Customer Resources	70 webinars as of Dec 2023	6 webinars/yr.	12 webinars/yr.	Monthly Usage	Oct. 2028	45 total webinars completed Averaging 100 uses per month	Website analytical software
Production Welding Resources	Webinar and white paper	Additional training resources	2 industry seminars	Monthly Usage	Oct. 2027	1 Industry seminar complete	Industry feedback
Steel Casting Design Evaluation Tool	Doesn't Exist	Beta version by Fall 2026	Downloadable Evaluation Tool	User Feedback	Oct. 2027	Proof of concept complete. Phase II underway	Producer and designer feedback
Interactive specification Handbook Supplement	Search tool available online	Incorporate new and revised casting standards	Integrate lower bound properties for common steel grades	Monthly Usage	Oct. 2028	Searchable database publicly available Averaging 90 searches per month	Website analytical software



Acknowledgements

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Transition of Steel Casting Technology through Codes, Standards, and Educational Tools

DLA - POC: DLAR.DPR@dla.mil



Problem

- A knowledge gap exists that makes it challenging to educate a new generation workforce, risking the loss of a critical capability

Objectives

- Educate at least 200 employees per year through customer education and workforce development webinars, develop at least 1 Welding Procedure Specification (WPS) for common cast grades, and develop or revise at least 3 steel casting resources/references

Benefits to Warfighter

- Expanding and transitioning SFSA advanced methodologies and steel casting resources will bridge the knowledge gap that currently exists, allowing for a wider use of steel castings while reducing cost and time of acquisition and increasing performance and service reliability of cast parts

Description of Project

This project will expand and transition technologies in areas of design, casting quality, and welding best practices into commercial specifications, and to provide educational resources to ensure a future generation workforce of artisans, engineers, and buyers.

Team: Steel Founders' Society of America, ATI



Milestones / Deliverables

- Complete customer education and foundry workforce development webinars
- Participate in bi-annual committee meetings and in quarterly ASME BPVC meetings
- Expand search functions in web-based Supplement 2
- Steel casting interactive design tool
- Update Supplement 2 with any new/revised standards