Finn Metalworking and Cutting Solutions

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Standard Test for the Machinability of Cast Iron

[Slide1] Standard Test for the Machinability of Cast Iron presented by Michael E Finn, President of Finn Metalworking and Cutting Solutions.

[Slide 2] The American Foundry Society is funding the project to develop a standardized test for evaluating the machinability of cast iron.

[Slide 3] The project is managed by a Steering Committee of the 5-J Quality Control Committee. Development of the machinability test is being conducted by the Industrial Partners, which includes Citation Innovative Metal Components, Wells Manufacturing Dura-Bar and ThyssenKrupp Waupaca, and the principle investigator, Finn Metalworking and Cutting Solutions.

[Slide 4] The Steering Committee includes representatives from Chrysler, Copeland, Finn Metalworking and Cutting Solutions, Metal Technologies, Slinger Manufacturing, Stork Climax Research Services, ThyssenKrupp Waupaca and Wells Manufacturing Dura-Bar.

[Slide 5] A complaint of poor machinability by foundry customers may be related to factors that:
1. Cannot be characterized by the foundry with current standard tests, or
2. Are not controlled by the foundry in the machining process.

[Slide 6] Investigation of a customer complaint of "bad machinability" revealed that the castings contained iron carbides from tramp elements. Iron carbides are hard and abrasive to the cutting tool.

[Slide 7] The iron casting was engineered for improved machinability by changing the process in the foundry, which included changes in the melting and charge materials.

[Slide 8] Investigation of another customer complaint of "bad machinability" revealed that the cutting tools contained different sized and shaped cemented tungsten carbides.

[Slide 9] The process in the customer's machining house was optimized by selecting an appropriate cutting tool and specifying the grade.

[Slide 10] After receiving a customer complaint for bad machinability, the foundry metallurgical staff usually checks compliance of material properties, which affect machinability.

[Slide 11] The foundry metallurgical staff currently analyzes one or more of the following material properties for grade and customer compliance:

- Chemical Composition
- Hardness
- Strength
- Ductility
- Toughness
- Microstructure

[Slide 12] A standard machinability test would provide cast iron producers with an additional measurement tool to detect material and processing concerns affecting machining! The test could be used as a quality control check for compliance of mechanical and metallurgical release parameters that affect machinability. The test could also be used to measure machinability quality of each heat. Obviously, the machinability test could be used to monitor engineered changes in foundry practices for improved machinability.

[Slide 13] In Phase 1, a method was established for machinability testing of cast iron. The International Standards Organization specification for machinability test in long turning steel bars was modified for face turning cast iron discs.

[Slide 14] The machinability test involves face turning a workpiece with an 8-inch diameter and 1-1/2 inch thick disc cast as a test sample. The disc has a 2 inch diameter by 2 inch long hub for chucking in the turning lathe. The specified cutting fluid is Master Chemical's Trim Sol at 5 volume percent. The specified cutting tool insert is an uncoated tungsten carbide insert (Kennametal's CNMG432) held in a holder providing a zero degree lead. The specified depth of cut is 0.075 inches with a feed rate of 0.008 inch per revolution. The end of test point is 0.015 inches of flank wear.

[Slide 15] In conventional metal removal processes, cutting tool wear occurs at a steady progressive rate along the clearance and rake faces. The flank wear is measured with a tool maker's or light optical microscope at 30 times magnification. Crater wear needs to be measured with a stereo microscope for depth of the crater. Crater wear is an important wear mechanism while machining steels with second phase particles such as found in leaded and inclusion engineered steels.

[Slide 16] For many machining processes, 0.010 to 0.015 inches of flank wear is an end of life criteria. During machinability testing, the cutting tool is frequently removed and measured for flank wear until it reaches the wear criteria.

[Slide 17] The flank wear in the AFS Machinability Test and ISO Test is measured as uniform wear between the nose wear and depth-of-notch wear.

[Slide 18] Several cutting tool wear points over a range of cutting speeds may be plotted as a cutting tool life curve.

[Slide 19] In Phase 1 of the project, the project team determined machinability values for two grades of ductile cast iron (ASTM A536 65-45-12 and 80-55-06) and two grades of gray cast iron (ASTM A159 G1800 and G3000). The V_{30} values, which is the maximum cutting speed for a thirty minute cutting tool life was validated in blind testing for each of the cast iron grades.

[Slide 20] Five wear tests at three different cutting speeds were plotted for the ASTM A536 65-45-12 ductile iron discs. A line of best fit, know as the Taylor Line, was drawn between the end-of-test wear points. The error bars for each observed point is a 95 percent confidence range. The V_{30} value was calculated as 566 sfpm from the formula for the Taylor Line at a time of 30 minutes. The machinability discs cast from the same heat were then machined at 566 sfpm until the flank wear on the cutting tool insert reached 0.015 inches. The time for the end-of-life is fairly close to the Taylor Line and within the error bands.

[Slide 21] Five wear tests at three different cutting speeds were plotted for the ASTM A536 80-55-06 ductile iron discs. The Taylor Line was drawn between the end-of-test wear points. The V_{30} value was calculated as 347 sfpm from the formula for the Taylor Line at a time of 30 minutes. The machinability discs cast from the same heat were then machined at 347 sfpm until the flank wear on the cutting tool insert reached 0.015 inches. The time for the end-of-life is fairly close to the Taylor Line and within the error bands.

[Slide 22] Five wear tests at three different cutting speeds were plotted for the ASTM A159 G1800 (Damp) gray iron discs. The Taylor Line was drawn between the end-of-test wear points. The V_{30} value was calculated as 387 sfpm from the formula for the Taylor Line at a time of 30 minutes. The machinability discs cast from the same heat were then machined at 387 sfpm until the flank wear on the cutting tool insert reached 0.015 inches. The time for the end-of-life is fairly close to the Taylor Line and within the error bands.

[Slide 23] Five wear tests at three different cutting speeds were plotted for the ASTM A159 G3000 gray iron discs. The Taylor Line was drawn between the end-of-test wear points. The V_{30} value was calculated as 352 sfpm from the formula for the Taylor Line at a time of 30 minutes. The machinability discs cast from the same heat were then machined at 352 sfpm until the flank wear on the cutting tool insert reached 0.015 inches. The time for the end-of-life is fairly close to the Taylor Line and within the error bands.

[Slide 24 and 25] The recommended procedure of removing at least 0.020 inches of metal off the face of the disc eliminates cooling effects of the microstructure, ie subsurface layers of pearlite and ferrite.

[Slide 26] Phase 2 work is focused on developing Taylor curves and V_{30} values for ASTM A48 Class 35B gray iron at three different machining laboratories and houses. The three machining facilities are determining the reproducibility and repeatability of the V_{30} values on additional lots of ASTM A48 class 35B gray iron.

[Slide 27] Team members at Wells Manufacturing Dura-Bar determined that the V_{30} value is 320 sfpm for machinability discs cast from the first heat of ASTM A48 Class 35B gray iron.

[Slide 28] Team members at Finn Metalworking and Cutting Solutions determined that the V_{30} value is 316 sfpm for machinability discs cast from the first heat of ASTM A48 Class 35B gray iron.

[Slide 29] Validation of the V_{30} value, 316 sfpm is excellent. The cutting tool insert had a 29.9 minute life when facing the discs from the first heat of gray cast iron. The validation was done three times with the same life of 29.9 minutes.

[Slide 30] Wells Manufacturing Dura-Bar is about to validate the V_{30} value of 320 sfpm. Citation Innovative Manufacturing Components started developing the Taylor Line a few weeks ago.

[Slide 31 and 32] The chemical composition, tensile strength and hardness values are within grade and customer compliance.

[Slide 33] Current quarter plans include:

- Wells Manufacturing Dura-Bar will validate the V30 value.
- Citation Innovative Manufactured Components will determine the V30 value and validate it.
- Finn Metalworking and Cutting Solutions will validate the V30 value on a second lot of Machinability Discs cast from another heat of ASTM A 48 Class 35B Gray Cast Iron.

[Slide 35] A few years ago the security check lines at Pearson Airport in Toronto were extremely long due to an Orange Alert, which caused flight delays for a few hours. So I took my client to the safest place to be during an Orange Alert.

[Slide 36] Thanks for listening. I would be happy to answer your questions and hear your comments. Here is my contact information:

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Standard Test for the Machinability of Cast Iron

Michael E. Finn

Finn Metalworking and Cutting Solutions

AFS Machinability Test

Project is funded by the *American Foundry Society (AFS)*

Purpose of the project is to develop a standardized test for evaluating the machinabilty of cast iron!

AFS Machinability Test

Managed by a Steering Committee of the 5-J Quality Control Committee

Industrial Partners are Citation Innovative Metal Components, Wells Manufacturing Dura-Bar and ThyssenKrupp Waupaca

Principle Investigator is Finn Metalworking and Cutting Solutions

Steering Committee

Representatives from:

- Chrysler, Copeland, Finn Metalworking and Cutting Solutions, Metal Technologies, Slinger Manufacturing, Stork Climax Research Services, ThyssenKrupp Waupaca and Wells Manufacturing Dura-Bar

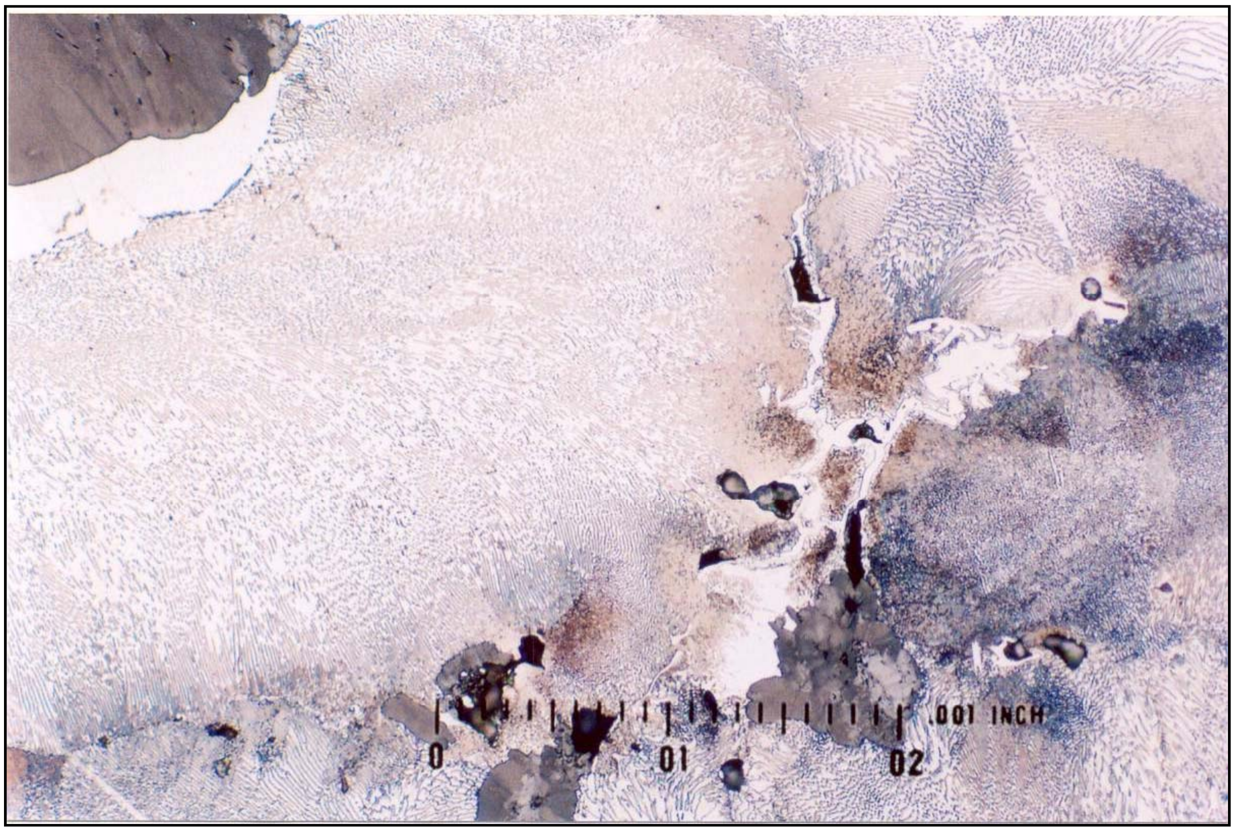
Description of Problem

Complaints of poor machinability are often related to factors that:

1. Cannot be characterized by the foundry with current standard tests, or
2. Are not controlled by the foundry in the machining process.

Bad Machinability

Investigators found carbides from tramp elements



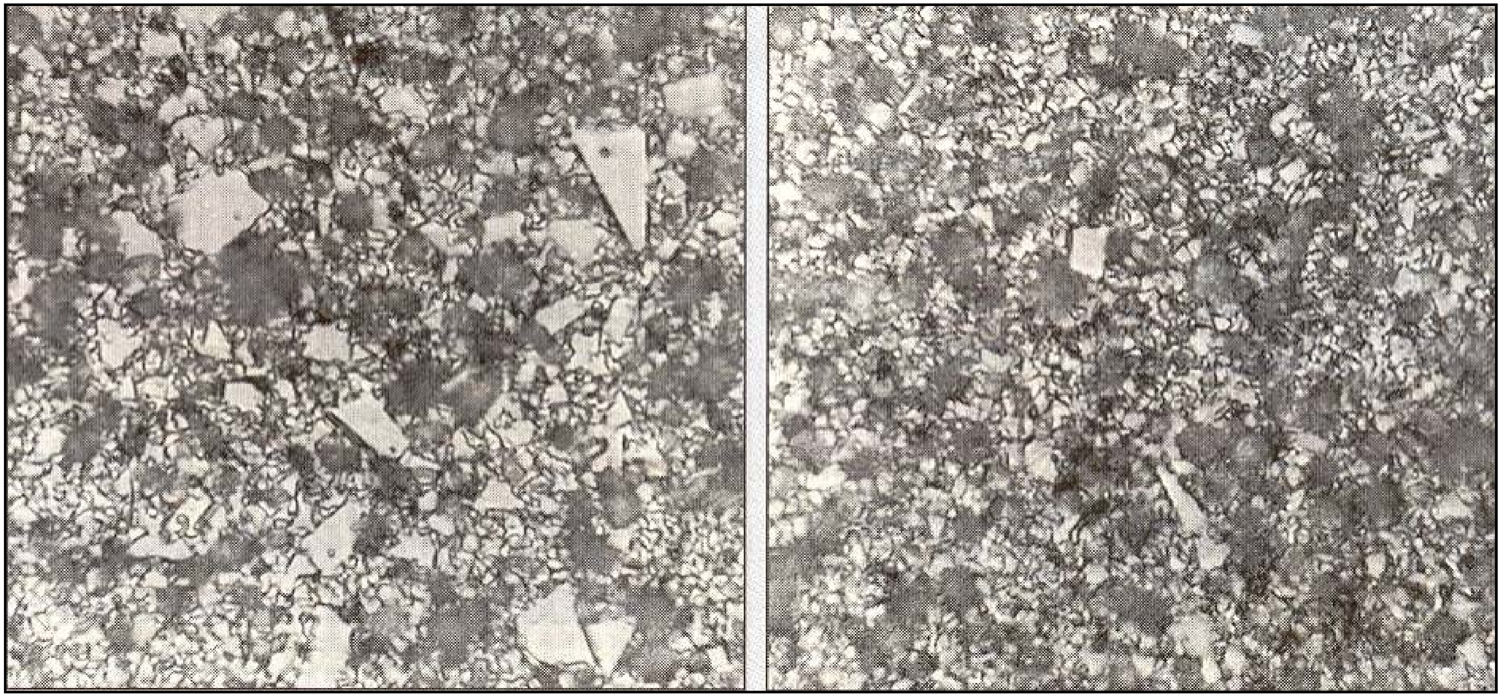
Engineering Improved Machinability

Change processing in foundry

- Melting conditions
- Charge Materials

Bad Machinability

Investigations revealed different cemented carbide cutting tools



Engineering Optimized Machining

Change processing in machining house

- Selected best cutting tool grade
- Specified cutting tool grade

Current Response to Complaints

After receiving a customer complaint for bad machinability. The foundry metallurgical staff usually checks compliance of material properties, which affect machinability.

Material Property Checks for Bad Machinability

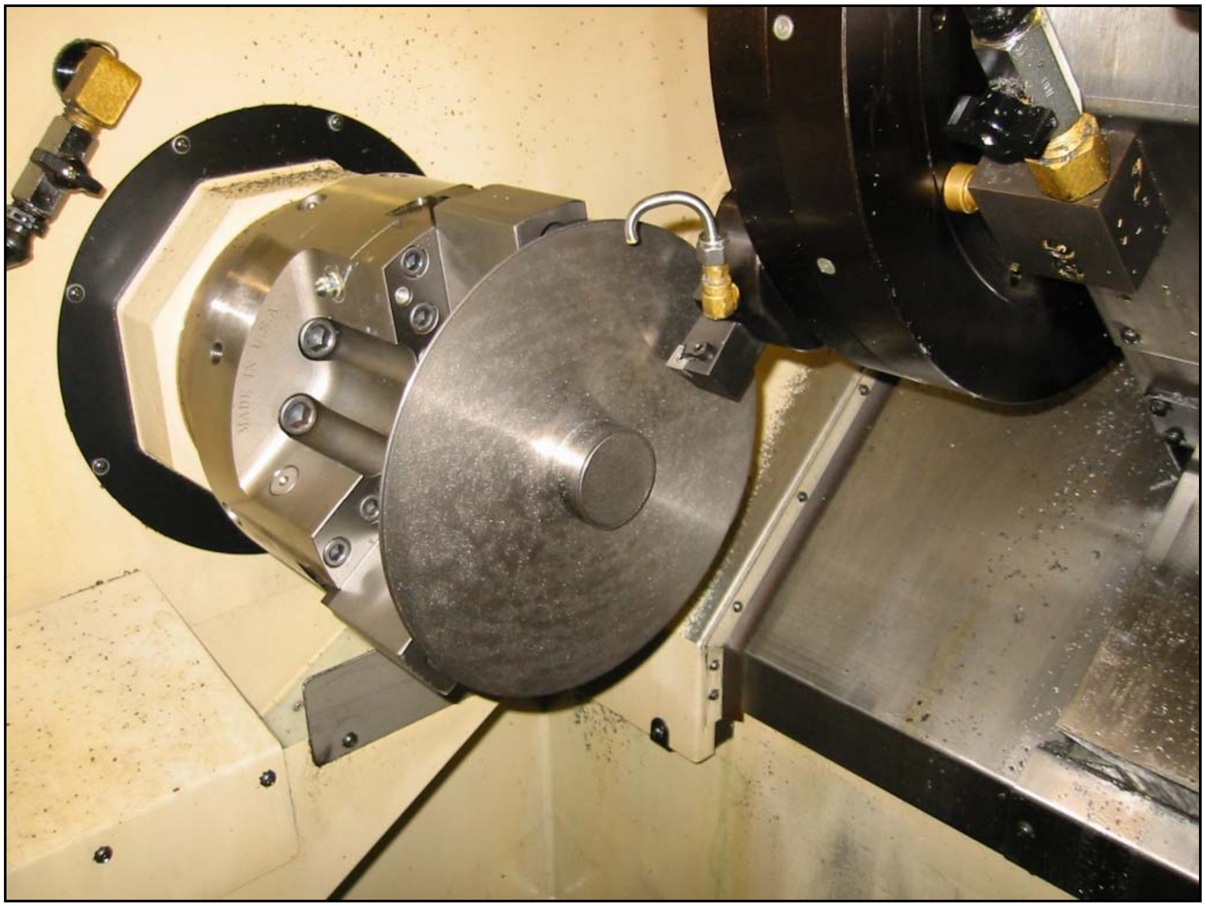
- Chemical Composition
- Hardness
- Strength
- Ductility
- Toughness
- Microstructure

Description of Problem

A standard machinability test would provide cast iron producers with an additional measurement tool to detect material and processing concerns affecting machining!

AFS Machinability Test – Phase 1

Modified ISO 3685-E Spec for steel bar turning to face turn cast iron disc

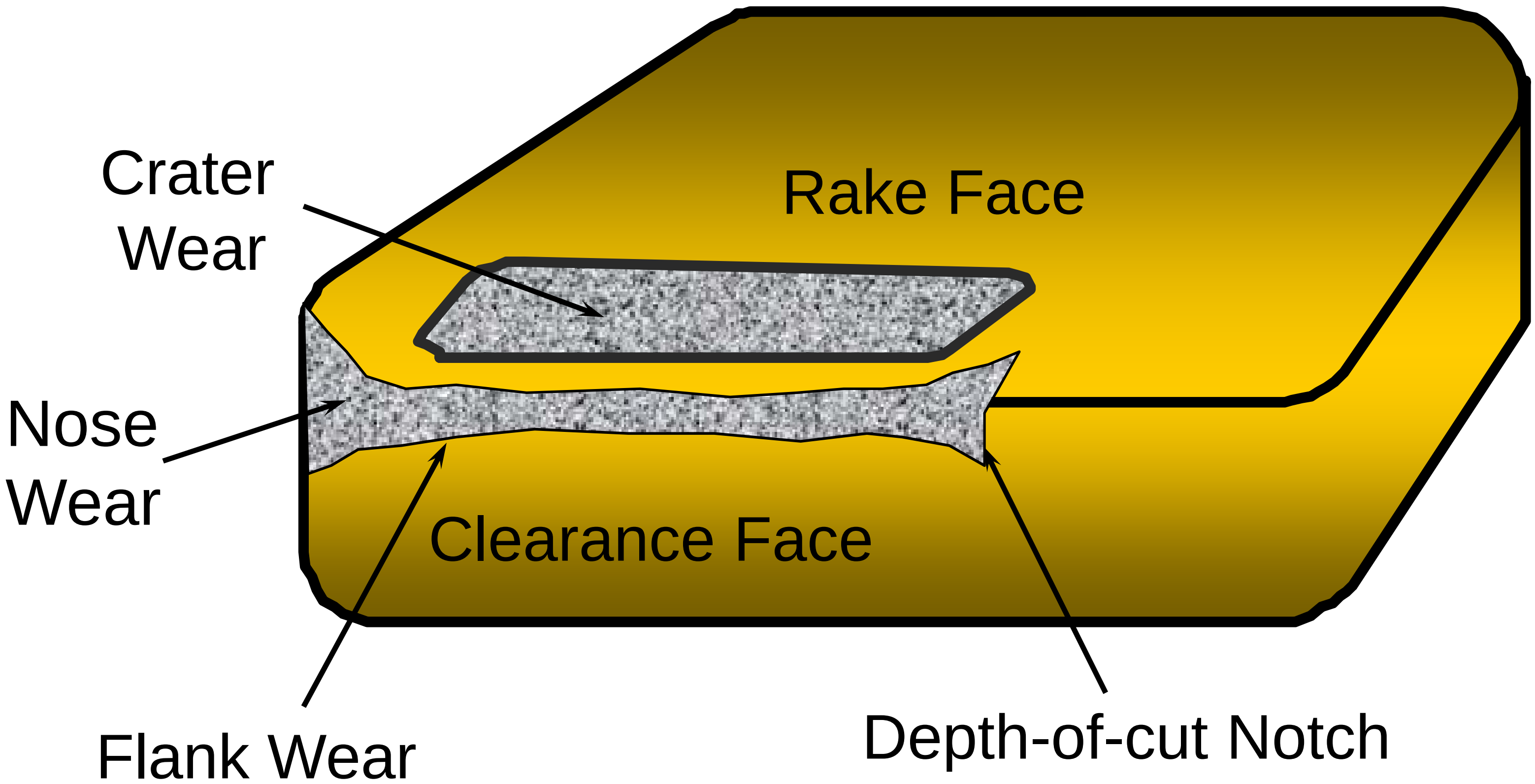


AFS Machinability Test – Phase 1

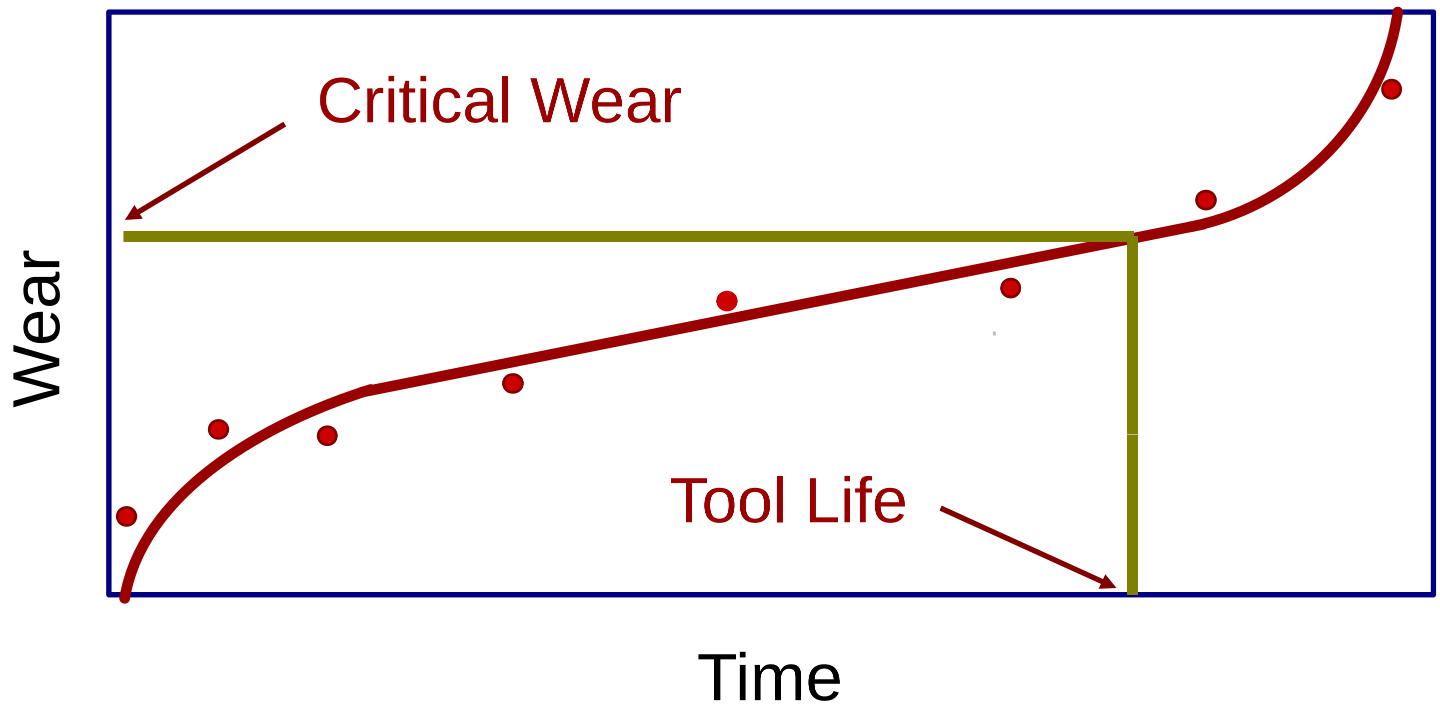
Established method

- Workpiece
- Cutting Fluid
- Cutting Tool
- Cutting Parameters
- Wear measurement procedure

Cutting Tool Wear Mechanism



Cutting Tool Wear Curve

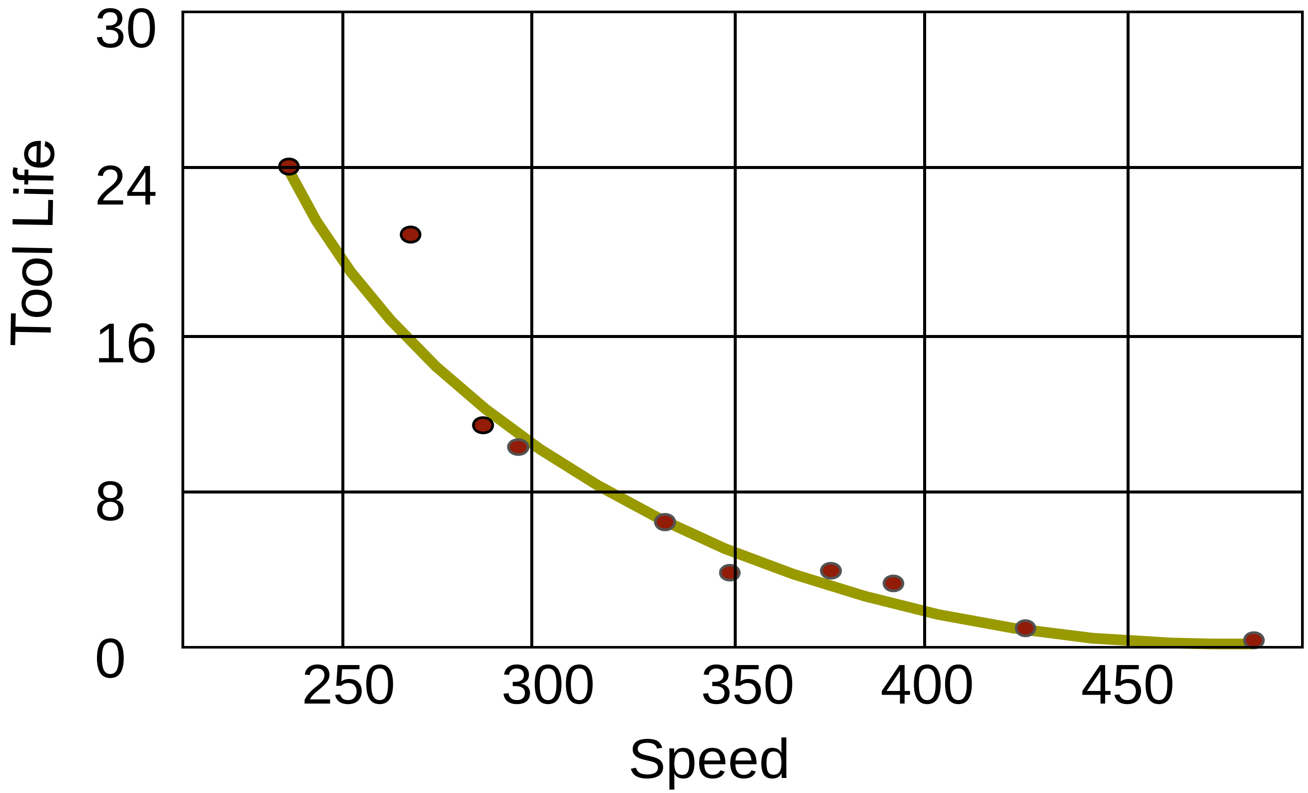


Uniform Flank Wear

Turning ASTM A159 G1800 Gray Iron at 415 sfpm

Cutting Tool Life Curve

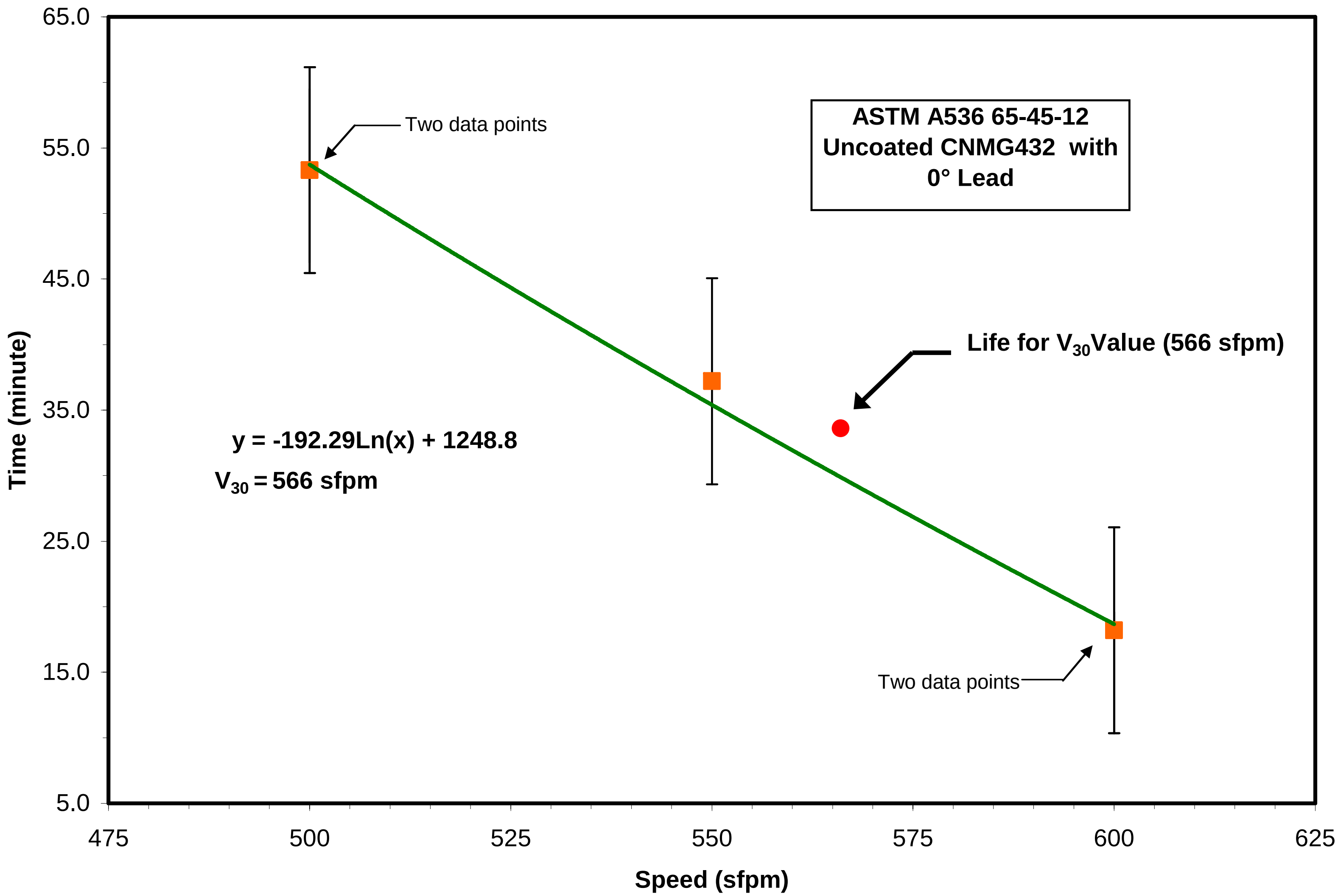
Plot of several cutting tool wear curves



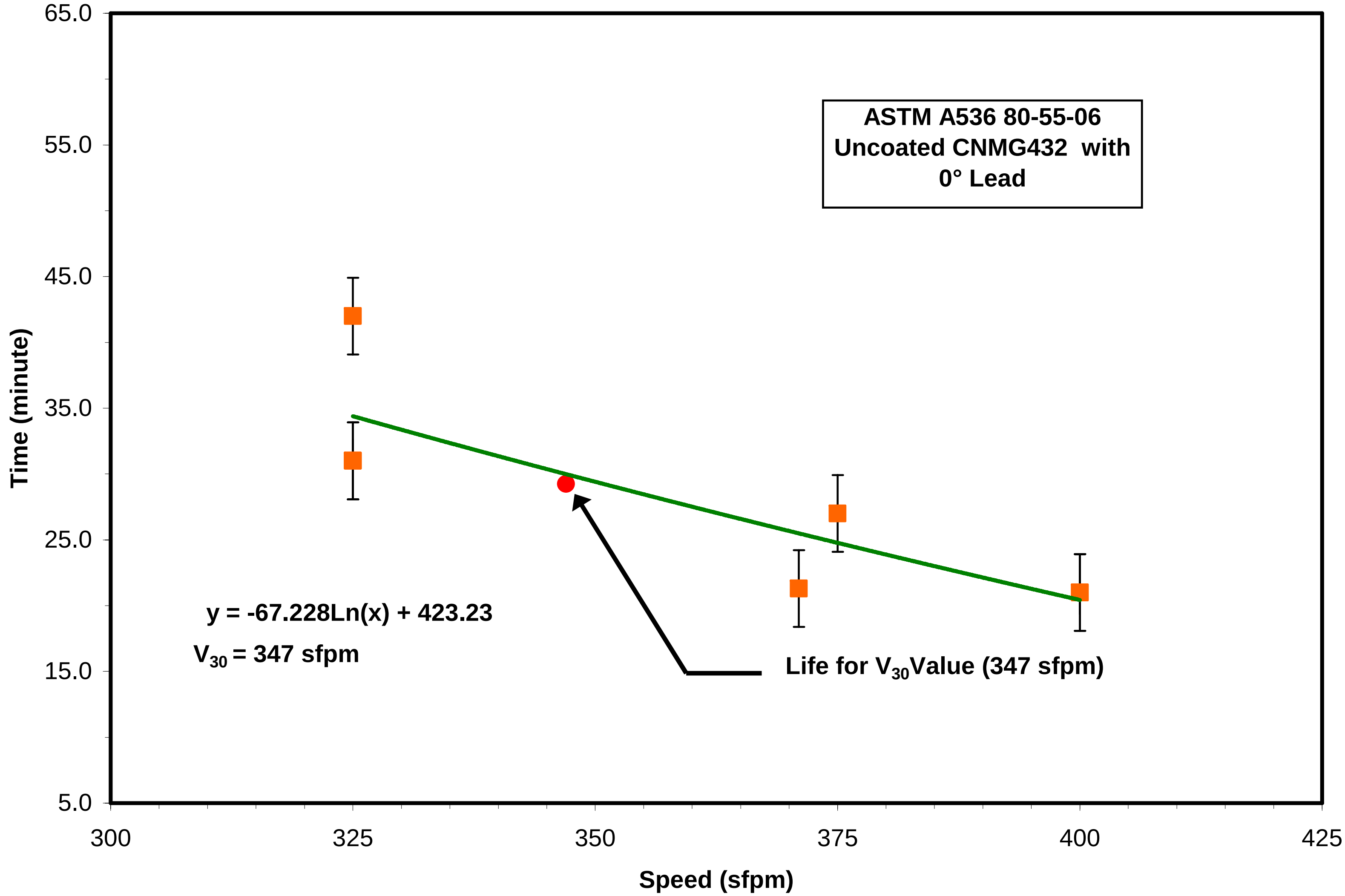
AFS Machinability Test - Phase 1

- Determined machinability values
  - Two grades of ductile cast iron; ASTM A536 65-45-12 and 80-55-06
  - Two grades of gray cast iron; ASTM A159 G1800 and G3000
- Validated values in blind testing

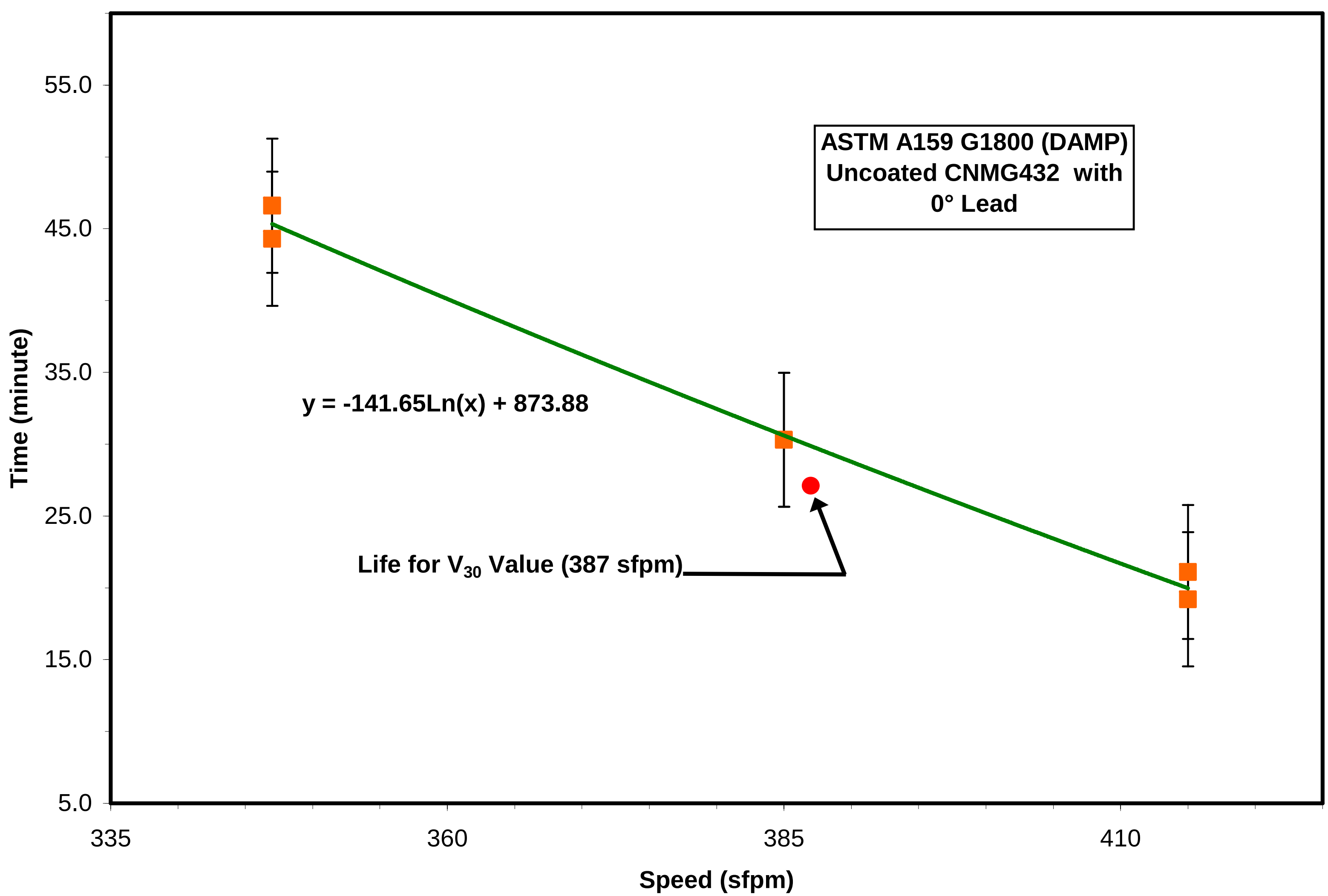
V_{30} Machinability Value



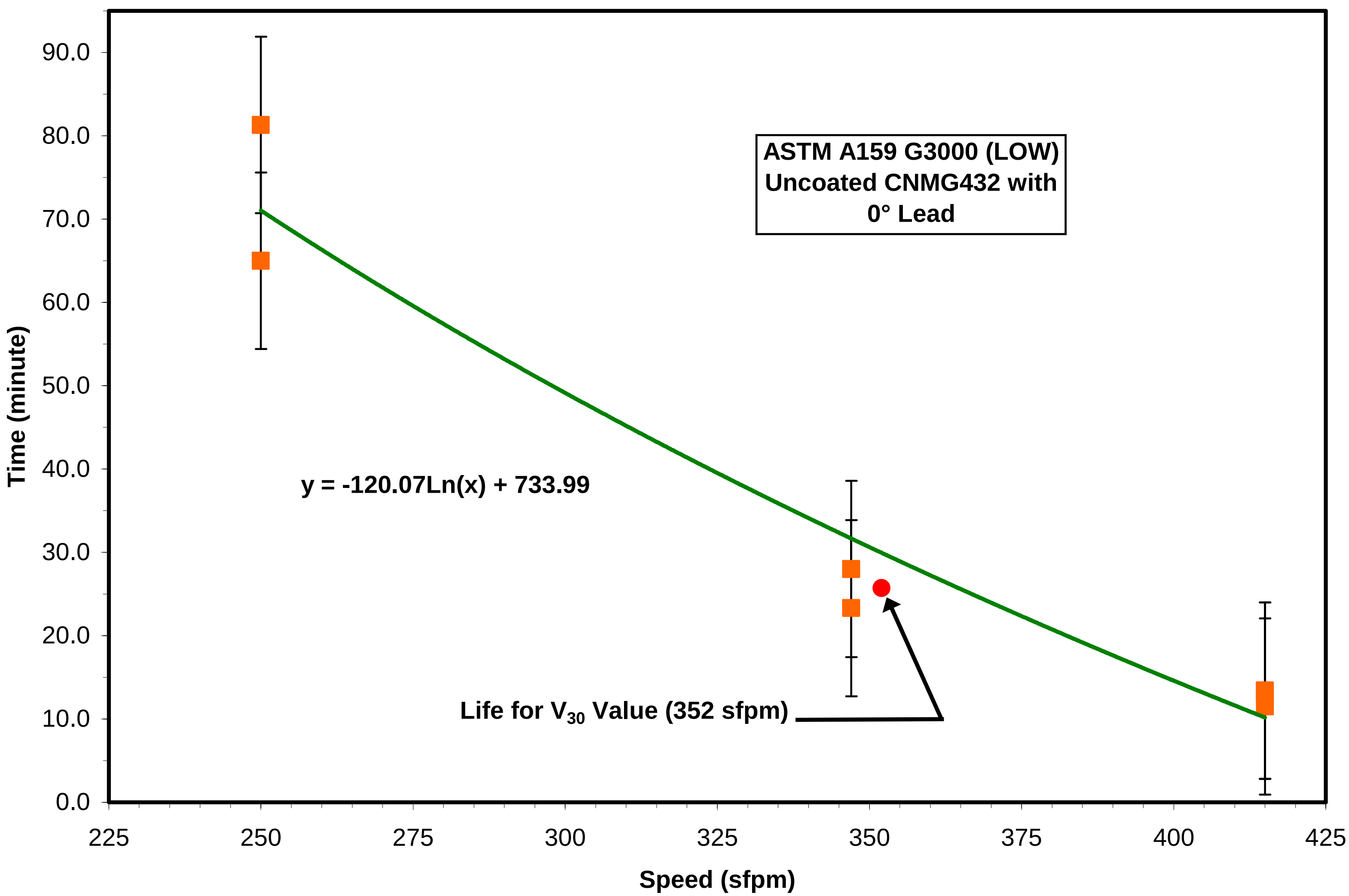
V_{30} Machinability Value



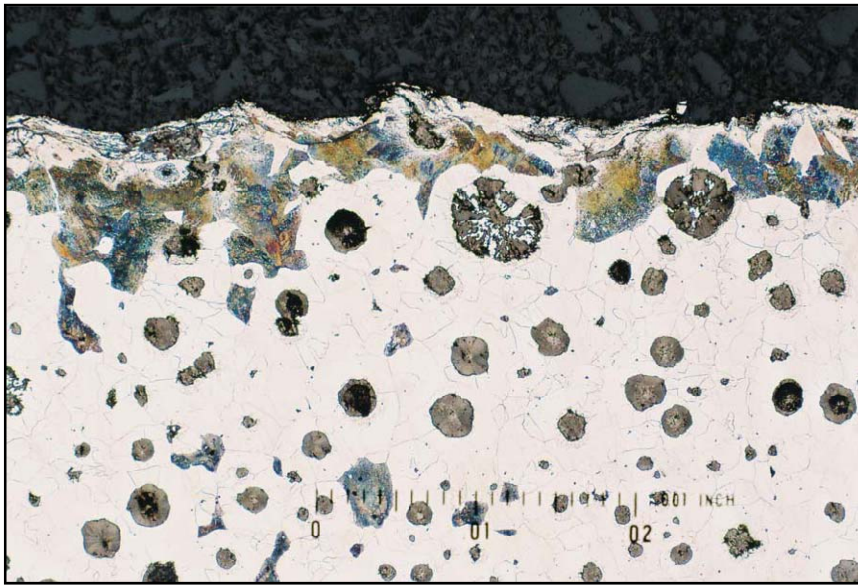
V_{30} Machinability Value



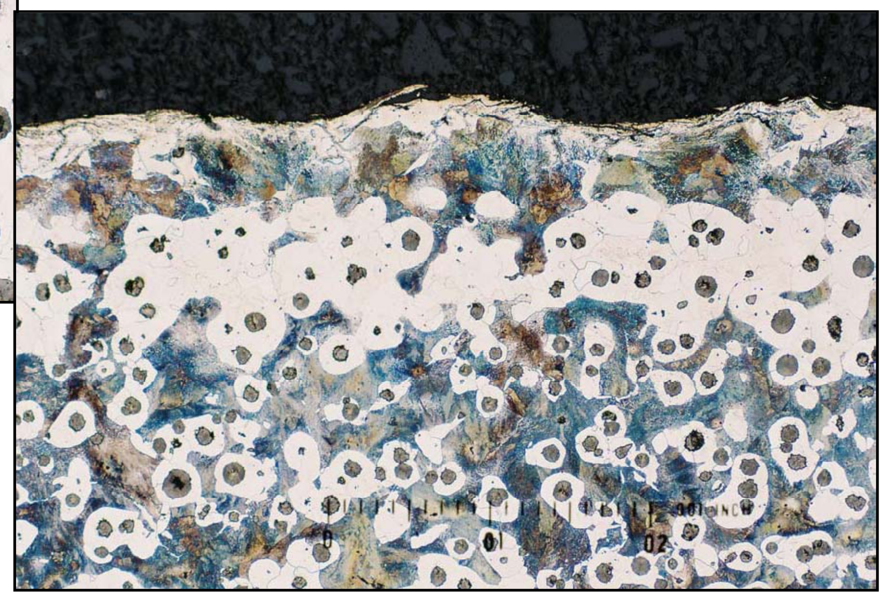
V_{30} Machinability Value



Subsurface Microstructure



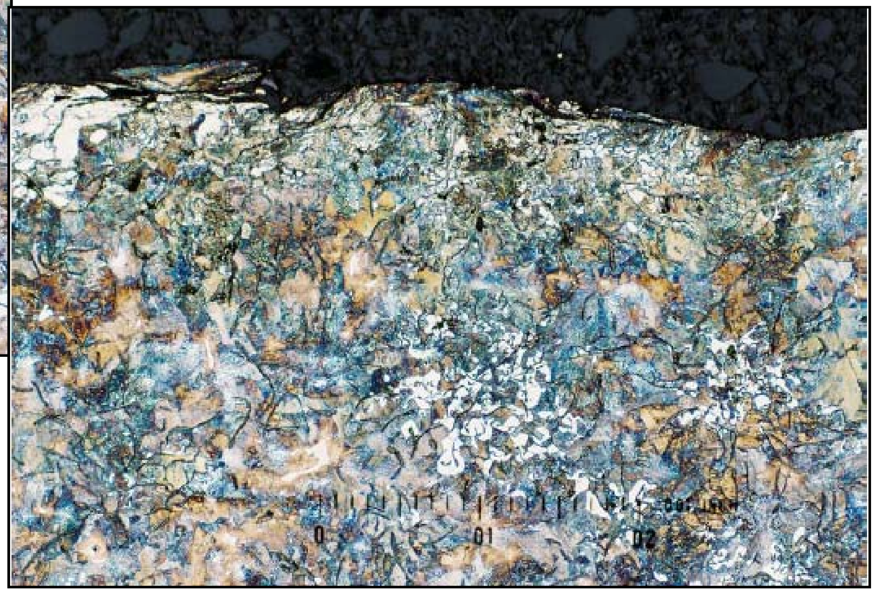
ASTM A536 65-45-12



ASTM A536 80-55-06

Subsurface Microstructure

ASTM A159 G1800

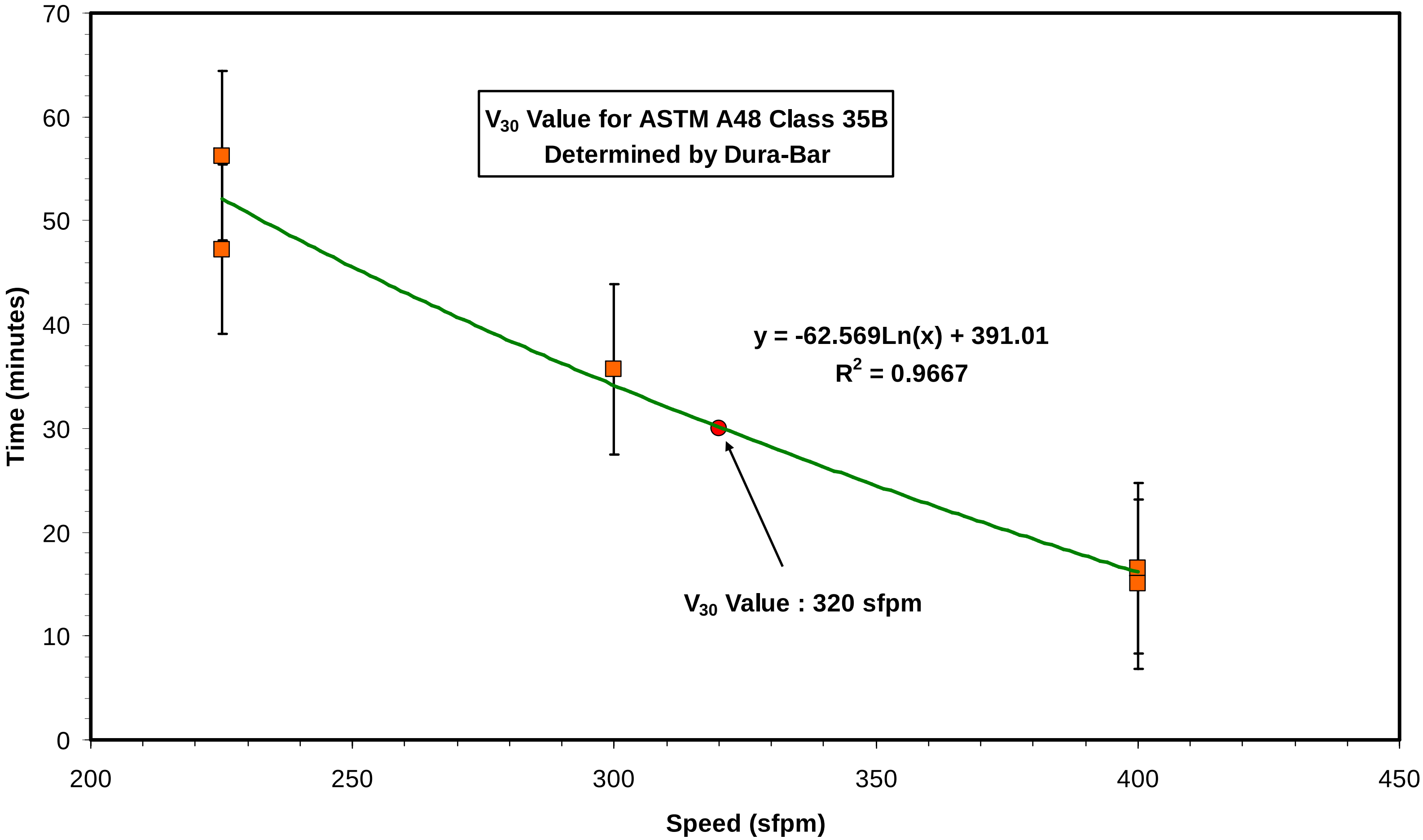


ASTM A159 G3000

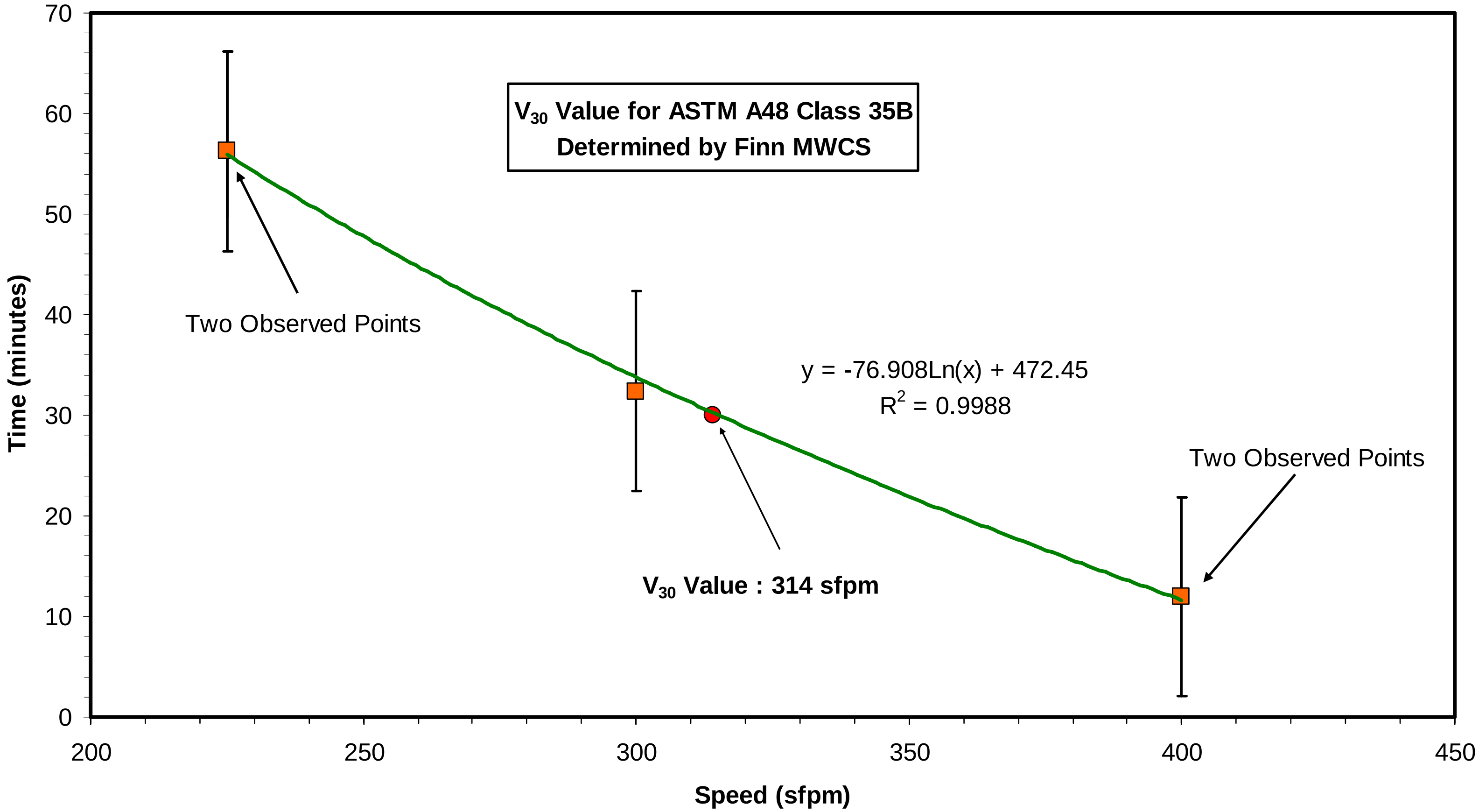
AFS Machinability Test - Phase 2

- Develop Taylor curves and V_{30} values for ASTM A48 Class 35B gray iron at 3 different machine facilities
- Determine the reproducibility and repeatability of the V_{30} values on additional lots of ASTM A48 class 35B gray iron at the 3 machining facilities

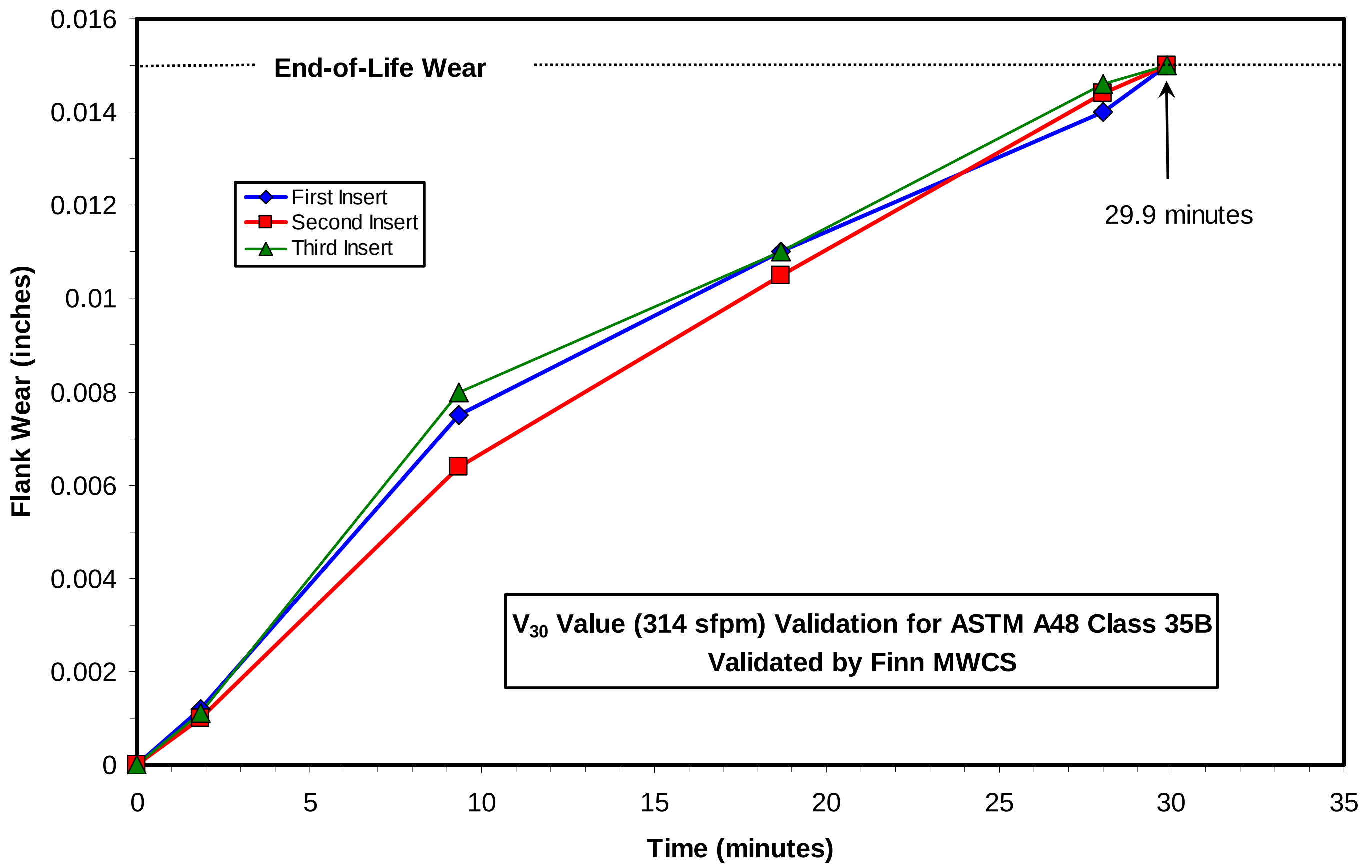
AFS Machinability Test - Phase 2



AFS Machinability Test - Phase 2



AFS Machinability Test - Phase 2



AFS Machinability Test - Phase 2

V_{30} values for ASTM A48 Class 35B gray iron

Machine Shop	V_{30} Value, sfpm	Tool Life at V_{30} Value, minutes
Citation IMC	Pending	Pending
Finn MWCS	316	29.9
MW Dura-Bar	320	Pending

ASTM A48 Class 35B Discs

Chemical Element, wt %					
C	Si	Mn	P	S	Ni
3.47	1.98	0.55	0.05	0.09	0.06
Mo	Cr	Cu	Al	Ti	Sn
0.02	0.16	0.18	0.003	0.009	0.014

ASTM A48 Class 35B Discs

- Tensile strength of two cast B-bars is 30,500 and 40,000 psi
- Hardness for the discs ranges from 217 to 201 HB.

Current Quarter Plans

- WM Dura-Bar will validate the V_{30} value.
- Citation IMC will determine the V_{30} value and validate it.
- Finn MWCS will validate the V_{30} value on a 2nd lot of Machinability Discs cast from another heat of ASTM A 48 Class 35B Gray Cast Iron.

The safest place to be!

Thanks for listening!

Michael E Finn

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