Long Products Market Development Group

David Anderson
LPMDG Background

• Formed in 1997
• Long Products Market Development Group (LPMDG) goal is to grow the market for value-added bar and rod products
• Task Forces
  – Construction/Infrastructure/Energy
  – Automotive/Heavy Equipment
• Integrated into SMDI Automotive Applications Council in 2010
MISSION

• Grow the Market for powertrain and chassis components concentrating on crankshafts, connecting rods, steering knuckles, control arms and innovative applications.
Current/Ongoing Activities

• Forged Steel vs. Alternate Technologies
• Innovative Forging Design Studies
• Bar Steel Core Data
• Leverage Resources in Support of AAC & A/SP
• Automotive Benchmark Reports
• Joint SMDI/FIA Development
• Joint SMDI/CRSI Development
• Wire Rod Initiatives
• Technology Transfer
Recent LPMDG Accomplishments

• Successfully Integrated into the SMDI within the Automotive Applications Council Program
• Completed Surface Finish Project – joint LPMDG/FIERF (Forging Industry Education and Research Foundation) program
• Completed and Published the updated Bar Steel Guidelines
• Leveraged limited resources in support of A/SP suspension and AAC materials content projects
Recent LPMDG Accomplishments

• Enlarged the Fatigue database and reenergized the Fatigue – web log (BLOG)
• Enlarged the Machinability database and expanded the test matrix
• Supported AAC one-on-one Technical Transfer days at Chrysler, AAM and DANA with long product specific presentations
Forged vs. Alternate Technologies

STEERING KNUCKLE PROJECT
• Forged steel steering knuckle exhibits approx. 100 times longer fatigue life than aluminum.

CONNECTING ROD PROJECT
• Mechanical and fatigue properties greater for forged steel connecting rods.

CRANKSHAFT PROJECT
• Component fatigue tests show fatigue strength based on crack initiation for the forged steel crankshaft to be 27% higher than that of the cast iron. This results in a factor of 6 longer life.
TRANSMISSION FLANGE STUDY
• Design innovation improves weight (static and reciprocating) and cost.
• NEW Parts Used in Ford F250/350.

DIFFERENTIAL CASE/RING GEAR STUDY
• Design innovation improves performance.
• Offers an approximate 25% weight savings
BAR STEEL FATIGUE DATABASE
- Provides accurate, up-to-date strain controlled fatigue data for lightweight, low cost bar applications.
- Partnership with key ground vehicle manufacturers and Universities of Toledo and Waterloo

BAR MACHINABILITY DATABASE
- Provides accurate, controlled single point turning comparison for common automotive steels.
- Partnership with key ground vehicle manufacturers.

AUTOMOTIVE BENCHMARK DATA
- Provides detailed analysis of automotive subsystems from over 110 vehicles.
- Partnership A/SP and AAC members and University of Michigan
• Support SMDI Market Innovation Task Force
  – Develop Market Growth initiatives in Natural Gas and Wind energy
  – AWEA (Wind Energy market support)

• Build on Industry Partnerships
  – CRSI (Continuously Reinforce Concrete Pavement)
  – AWPA (Wire Rod/Product market growth)

• Do not duplicate Efforts
  – Let industry partners lead technology development
  – AISI/SMDI lead public policy
  – SMDI lead market growth initiatives
FY2012/13 LPMDG Program Goals/Objectives

• Continue work in bar fatigue and machinability databases. Leverage ground vehicle industry support (financial and personnel)
• Analyze the “other” motive Market Assessment report from Power Systems and develop market growth opportunities
• Continue joint LPMDG/FIERF technology development
• Continue work with AAC and A/SP on lightweight suspension design optimization projects
• Explore steel intensive engine design project
AISI Bar Machinability Database of Steels Using Sintered Carbide Tools in Single Point Turning

Authors:
Roger A. Joseph - Consultant
Ronald Stout - Ispat Inland, Inc.
Introduction
Test Procedure
Materials Tested
Test Results
Analysis and Discussion
Conclusions
Acknowledgments
• 1991 AISI Machinability Roundtable
• Goal: Establish Automotive Industry Needs for Bar Steel Machinability Data
• Participants: Auto Makers, OEMs, Steel Makers, and Academia
• Outcome: Formation of the AISI Bar Machinability Sub-committee
• Devise a standardized single point turning machinability test
• Conduct a round robin test involving three materials and ten test labs to develop tool life data for un-coated sintered carbide tools
• Develop a data bank of machinability data on industrially significant bar steel materials for the automotive industry
• WORKPIECE MATERIALS
  – Characterization
    • Steelmaking practice
    • Chemistry
    • Microstructure
    • Cleanliness
    • Hardness
    • Tensile properties
• WORKPIECE MATERIALS
  – Test Bar Size (nominal)
    • Diameter: 2.75 in. (90 mm)
    • Length: 16 in. (406 mm)
    • Cutting length: 12 in. (305 mm)
    • Cutting length to diameter ratio: 10
    • Chatter not permitted
• CUTTING TOOLS
  – Tool holder: Kennametal DSRNR(L) or equivalent
  – Insert style: SNMG 432 (uncoated, with molded chip breaker)
  – Insert grade: Valenite VC-5

• CUTTING FLUID
  – No cutting fluids were used
• CUTTING CONDITIONS
  – Depth of cut (DOC) = 0.100” (2.54 mm)
  – Feed rate (ipr) = 0.010 inch per revolution (.254 mm/r)
  – Cutting speed
    • Determined from the workpiece surface to be cut
    • Minimum of three test speeds
    • Tool life range: 5 min. ✝ TL ✝ 45 min.
• TOOL-LIFE MEASUREMENT
  – Method: Tool-makers microscope
  – Magnification: 20X minimum
  – Measure: Average and maximum flank wear
Flank Wear Zones and Wear Measurements

![Diagram of Flank Wear](image)

- **Depth of cut notch**
- **Tangent point**
- **Zone C**
- **Zone B**
- **Zone A**

**Original insert face**

- **\( V_{B_{AVG}} \)** = Average Uniform Flank Wear
- **\( V_{B_{MAX}} \)** = Maximum Flank Wear

For Average Flank Wear (\( V_{B_{AVG}} \)),

\[
\text{Area } \begin{array}{c} \blacksquare \end{array} = \text{Area } \begin{array}{c} \blackblacksquare \end{array}
\]
• TOOL-LIFE END POINT CRITERIA
  – Average flank wear of 0.012” (0.3 mm) within Zone B
  – Maximum flank wear of 0.024” (0.61 mm) within any Zone
  – Catastrophic tool failure
TOOL-LIFE END POINT CRITERIA

- Minimum cutting time between measurements not less than one minute
- Tool-life signature and a log-log plot of tool wear vs. cutting speed was recorded
- Individual data points at each speed used in the regression analysis
- The V30 speed and the 95% confidence intervals were calculated
Materials Tested

• 34 bar steel grades and variants tested
  – Plain carbon and C/Mn steels
  – Resulferized C/Mn steels
  – Alloy steels
  – Microalloy steels
  – Free cutting steels

• Materials were provided by steel producers from stock or heats produced specifically for this project
# Materials Tested

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<th>Alloy</th>
<th>MA</th>
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<tr>
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<td>4620</td>
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<tr>
<td>1541</td>
<td>1144</td>
<td>5160</td>
<td>12Bi14</td>
</tr>
</tbody>
</table>
• Desire to correlate machinability with material chemistry and properties
• Bethlehem Steel study mid 1900s
  – Extensive automatic screw machine test data base used
  – Correlated machinability index (MI) with material’s carbon equivalent
  – Used B1112 as MI=100%
  – Used high-speed-steel tools
Analysis & Discussion

As-Rolled, Cold-Drawn Steels
- Carbon
- Alloy

Machinability Rating, Per Cent (6112 = 100% = 170 fpm)

Per Cent Equivalent Carbon
(Calculated from ferrite hardening effects of C, Mn, Si, Cr, Ni, Mo, and V.)

www.autosteel.org
• Several carbon equivalent equations investigated
• Ito-Bessyo equation modified for sulfur content used

\[ CE_{I-B} = C + \frac{Mn_{eff}}{20} + \frac{Si}{30} + \frac{Ni}{60} + \frac{(Cu+Cr)}{20} + \frac{Mo}{15} + \frac{V}{10} + 5B \]

where

\[ Mn_{eff} = Mn - (1.71*S) \]
Comparison of Brinell Hardness to Ito-Bessyo CE

Analysis & Discussion
• The Ito-Bessyo Carbon Equivalent was calculated for each steel grade in the study

• The $V_{30}$ Tool-Life and 95% confidence interval for each steel grade was determined using the SAS statistical package

• The $V_{30}$ vs. CE was plotted for the carbon and alloy steels
V30 vs CE for Carbon and Alloy Steels

Analysis & Discussion

$R^2 = 0.8025$
• Result similar to Bethlehem study
• Data fitted to a 3\textsuperscript{rd} order polynomial using MS Excel software
• The fitted curve has an $R^2 = 0.8$
• Maximum $V_{30}$ at 0.26 CE
• Bethlehem study maximum at 0.40 CE
• Postulate difference due to carbide vs. high speed steel tooling
V30 vs CE for Resulferized & MA Steels

Analysis & Discussion
• $V_{30}$ decreased for 1215 grade
• $V_{30}$ of 11XX grades fall on curve
• Unexpected result for free cutting steels
• The extreme conditions that exist in the cutting zone with carbide tooling likely exceed the capabilities of MnS to significantly influence tool life
• Other effects of MnS were not studied
• $V_{30}$ of microalloy grades fall on curve
• The higher strength of MA steels results from precipitation strengthening by V, Ti and/or Cb carbides
• Microalloy steels have a $V_{30}$ tool life with carbide tooling commensurate with their Ito-Bessyo Carbon Equivalent
• More testing needed to verify
Conclusions

• Machining data generated with high speed steel tooling can not be directly extrapolated to applications involving carbide tooling

• Plain carbon and alloy steels were found to have a $V_{30}$ tool life that correlates well with their Ito-Bessyo Carbon Equivalent when fitted to a 3$^{rd}$ order polynomial
Conclusions

- The $V_{30}$ tool life of 1200 series, 1100 series and microalloy steels follow the same relationship.
- The $V_{30}$ tool life of steel grades can be approximated by calculating their Ito-Bessyo Carbon Equivalent and plotting them on the fitted curve of this study.
The authors wish to thank the American Iron and Steel Institute for its generous support of this study.

The contribution of steel bars for the project from Ispat Inland, Inc., Macsteel, North Star Steel, Republic Engineered Products, Inc., Slater Steel, Stelco, Inc., The Timken Company, and USS-Kobe Steel are gratefully acknowledged.
Also to be commended for their time, effort and invaluable contributions to the project are the past and present members of the Bar Machining Sub-committee and their sponsoring affiliations: D. Anderson and T. Mackie, AISI; L. Brossard and J. Hansotte, Republic Engineered Products; W. Peppler and S. Gieman, North Star Steel; J. Christopher, Machining Research Inc.; P. Boppana, Valenite, Inc.; M. Burnett, C. Rupert, J. Brusso and P. Jarocowicz, The Timken Company; M. Marchwica and G. Millar, Stelco, Inc.; J. Tarajos, K. Goulait and M. Kniffen, DaimlerChrysler Corp.; J. Johnson, Ford Motor Co.; I. Shareef, Bradley Univ.; M. Crews, Metaldyne; M. Holly and D. Stephenson, General Motors Corp.; and M. Finn, IAMS.
Single Point Turning Tests using Coated Carbide Tooling

M. E. Burnett
Testing History

• As presented previously, the committee started testing using un-coated carbide tools around 20 years ago
• Around 7 years ago it was decided to attempt to add coated carbide tests to the test matrix due to their predominance of use in the industry
• The goal was to keep the test parameters nearly equal to that of the uncoated tests
Initial Coated Carbide Tests

• Initial tests using coated carbide inserts were largely unsuccessful due to a variety of factors including:
  – Insert/chip breaker style
  – Machining parameters
  – Uncertainty in measuring the flank wear

• These factors delayed obtaining successful coated carbide tests until around 2010
The final test decided upon utilized the following:

- Sandvik SNMG432-QM insert, 4215 Grade
- Identical parameters except a slightly higher feed rate of 0.012”/rev
- Collaborative testing and comparison of results between EMI and Timken with agreement to measure all flank coating wear
Coated Carbide Test Issues

Though a basic test was established, issues remained with coated carbide insert tests

• Higher testing speeds and resultant thermal affects contributed to the development of competing failure modes prior
  – Rapid crater wear once the coating was worn away
  – Bulging of nose and flank area as the test progressed
  – Occasional chipping of nose or DOC notching

• As a result, not all tests reach the 0.012” wear limit, and some extrapolation of flank wear is required for some tests
Coated Carbide Test Issues (cont.)

• In addition, a wider spread in test results between labs has been observed in some tests
  – Normal test-to-test or lab-to-lab variation is less than 10% V30 life
  – Some of these test results showed 15% to 20%

• As a result, after consultation with a Sandvik testing expert, a more rigorous documentation of the machine and testing condition for each lab will be performed going forward
Coated Carbide Test Results

• The following steels have been tested so far using the coated carbide inserts
  – 1018HR, 1080HR, 1080SA, 15V41HR, 5120HR, 4130Norm, 4142CD, 1144CD
  – Several internal tests are also shown on plot

• Additional tests are planned for steels:
  – 52100HR, 52100SA, 15V38

• Data was successfully fit to a microalloy steel Ceq equation used to predict as-forged hardnnesses
Coated Carbide Results

Turning Tests of Various Steel Grades Using Coated and Uncoated Carbide Inserts

Microalloy Carbon Equivalent Value vs 30 Minute Tool Life Cutting Speed (SFM)

Microalloy Ceq Value = C + Si/6 + Mn/4.5 + Cr/4 + (Cu+Ni)/15 + Mo/2.5 + 1.8*V

Low S Polynomial Predictive Equation

\[ \text{SFM} = 635.6 \text{Ceq}^2 - 2162.2 \text{Ceq} + 2261.7 \]

\[ R^2 = 0.8924 \]

Low S points above line represent annealed product tests

Low S points on or below the line represent hot rolled or normalized product tests
Coated Carbide Results

• The graphic illustrates the successes of this testing, and some of the current limitations

• The most impressive factor is superiority of the coated results to un-coated carbide
  – Machining of very abrasive steels is possible, and extremely high speeds are possible for low Ceq grades

• This testing is nearing completion, and a calculator may be added to the website soon
Machinability Testing of Steel

Michael E. Finn
Finn Metalworking and Cutting Solutions
Machinability of Steel

Machinability is often considered as the ease of removing material with a cutting tool.
Material Properties that Affect Machinability

- Chemical Composition
- Hardness
- Strength
- Ductility / Toughness
- Abrasiveness
- Microstructure
- Thermal Conductivity
Composition Affects Machinability

![Graph showing the relationship between Carbon Equivalent and Machinability Rating. The x-axis represents Carbon Equivalent (Percent) ranging from 0.10 to 0.70, and the y-axis represents Machinability Rating (Percent) ranging from 30 to 80. Key points include 1015, 4012, 1016, 1026, 4023, 1030, 8620, 1040, 4320, 1050. The graph illustrates a curve that reaches a peak around a Carbon Equivalent of 0.30.]
Microstructure Affects Machinability

Percent Pearlite in Annealed Structure vs. Percent Excess Fe Carbide

Machinability Rating, Percent

Percent Pearlite in Annealed Structure
Percent Excess Fe Carbide

1035 1040 1045 1055 8740 8645 5147 4340 1080 1095 50100 52100
Factors Effecting Workpiece Machining

- Physical Properties
- Composition
- Mechanical Properties
- Microstructure
- Workpiece
Steel Machinability

Machining Process

Steel Chemistry and Matrix Microstructure
- Al₂O₃, SiO₂, Complex Oxides
- Soft Ferrite, Fine Pearlite
- Martensite, Bainite
  (Single Phases)

Inclusion Chemistry and Morphology
- MnS
- Pb, Bi, Te, Se
- CaO-SiO₂-Al₂O₃
- Hard Ferrite, Coarse Pearlite

Machinability
- -
- +
Quantifying Machinability

Machinability of a steel is affected by the machining process, such as

- Continuous (turning) or intermittent (milling)
- Cutting tool material and geometry
- Cutting fluid type and application
- Machining parameters (speed, feed, DOC)
- Rigidity of holder and machine tool
Quantifying Machinability

- Cutting tool wear
- Cutting tool life
- Cutting forces
- Surface roughness
- Chip shape and size
- Part tolerance
Cutting Tool Wear

- Flank Wear
- Crater Wear
- Nose Wear
- Clearance Face
- Rake Face
- Depth-of-cut Notch

Diagram showing the different types of wear on a cutting tool.
Cutting Tool Life

Time in cut (minutes) or work done (removed cubic inches, number of plunges,...) Until...

– Cutting tool wear reaches critical level
– Cutting tool breaks
– Cutting tool chatters
– Workpiece surface roughness increases
– Workpiece dimensions increase
– Chips change size and/or shape
Standard Machinability Tests

- ISO 3685-E Spec (Long Turning)
- ISO 8688-1- E Spec (Face Milling)
- ISO 8688-2- E Spec (End Milling)
- ASTM E618-81 Spec (Form Turning)
- Inland Steel Plunge Test (Plunge Turning)
- AFS Standard Machinability Test (Face Turning)
ISO Tests for Turning and Milling

• Select feed and speed from machining handbook for 5 to 60 minute wear test with 0.100 inch DOC

• Measure wear of flank until it reaches 0.015 inches and record time

• Repeat at different speeds (minimum of 5 tests, 2 at low, 1 at middle and 2 at high speed)

• Plot cutting tool life curves
ISO Test for Turning

![Graph showing wear, time, and tool life with critical wear and tool life points marked.](image-url)
ISO Test for Turning

Plot of Several Wear Curves
ISO Test for Turning

Comparing Two Workpiece Materials

![Graph showing tool life vs speed for two different materials. The graph includes two curves, one for each material, and several data points. The axes are labeled as follows: Tool Life on the y-axis and Speed on the x-axis. The graph indicates that as speed increases, tool life decreases. There are two labels, Ty, indicating specific tool life values for each material at different speeds.]
ISO Test for Turning

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<th>3 Spiral chips</th>
<th>4 Washer-type helical chips(^1)</th>
<th>5 Conical helical chips(^1)</th>
<th>6 Arc chips(^2)</th>
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Chip Forms
ASTM E618-81 Test

25.4 mm
DIA. BAR STOCK

FINISH FORM TOOL

METAL REMOVED
BY FINISH FORM TOOL

ROUGH FORM TOOL

(mm)
ASTM E618-81 Test

AISI 1070 Rod for Water Pump Shafts

Part Growth, inches

- Minor 0.005 Limit
- Major 0.003

Number of Parts

Minor 0.005 Limit

Major 0.003
Inland Steel Plunge Test

- Select cutting speed and feed from machining handbook
- Plunge cut full diameter with $\frac{1}{4}$ inch wide parting tool
- Measure cutting forces and cutting tool wear
- Plot cutting force and wear measurements taken during plunging campaign
Inland Steel Plunge Test

Cutting Forces

- Tangential Force
- Plunging Force
Inland Steel Plunge Test

Machinability of AISI 1215

The graph shows the average plunge force (in lb) over the number of plunges for three different steel plants. The x-axis represents the number of plunges, while the y-axis represents the average plunge force. The steel plants are labeled as Steel Plant 1, Steel Plant 2, and Steel Plant 3.
Modified ISO 3685-E Spec for bar turning to face turning a cast disc
AFS Standard Machinability Test

Workpiece for Machinability Testing of Cast Disc
✓ 8 in. dia
✓ 1-1/2 in thick
✓ Hub
  ✓ 2 in. dia
  ✓ 1-1/4 in long
AFS Standard Machinability Test

Test parameters:

✓ Skin pass: 0.020 in DOC
✓ Cutting tool: Uncoated tungsten carbide inserts (Type CNMG432) with 0° lead
✓ Cutting fluid: Water based cutting fluid
AFS Standard Machinability Test

✓ Feed: 0.008 ipr
✓ Depth-of-cut: 0.075 in. (0.050 in.)
✓ Plunge length: 3.50 in.
✓ End of life: 0.015 in. flank wear land
AFS Standard Machinability Test

✓ Speed: Three speeds (minimum)
  ✓ low with life of ~ 60 min
  ✓ mid with life of ~ 30 min
  ✓ high with life of ~ 10 min
AFS Standard Machinability Test

TAYLOR LINES - ASTM A48 CLASS 35B
BAG Machinability

June 26, 2012
Is machinability still an issue?

YES
How would you define Machinability?

• Material Property
  – Machinability is a property of a material, usually a metal, characterizing its ability to be machined, cut or ground by removing material to shape a engineered component.

• Manufacturing
  – Ease of machining while maintaining required tolerances and acceptable tool life
  – A combination of tool wear and chip control

• Performance
  – The ability to cost-effectively remove metal to create a component that meets all functional requirements.
What are your major issues in the machining of steels?

- How do I estimate power requirements?
- What is the best cutting tool material?
- How can I estimate tool life?
- Reducing cost of machining with longer cutting tool life, down time and reworks/rejects.
- Machinability consistency and improving quality of machined part.
- Heat
- Surface structure, integrity, and finish
- Dimensional control
- Chip control
- Tearing
- Slow cycle times
- Material (Hardenability, grain sizes, microstructures)
- Broaching
- Productivity
Future Trends

• Where do you see machining going into the future?
• Any comments regarding what would make steel more viable for applications regarding the machining characteristics?
• Can you identify trends in the industry for the various machining operations?
  – What machining operations are performed the most?
  – What are current costs associated with machining operations?
What areas are of the most interest?

• Turning
• Milling
  – Pocket milling
• Drilling (most responses)
  – Holemaking
  – Reaming
  – Burrless holes
• Broaching
AISI Database

• Are you aware that AISI data exists?
• Is the AISI data valuable to the industry
  – Are there suggestions for promotion?
  – Autosteel.org
• Have you found the Bar Machinability Estimator user friendly?
  – No one has used it / found it
• All testing to date has been done with turning. Is there value in looking at other processes?
Machining Set-up

Do you consider any of the following when considering steel machinability?

• Hardness and hardenability
• Steelmaking methods
• Residual elements—BOF vs Electric Furnace product
• Continuous cast vs billet/bloom cast
• Alloy additions-calcium for cleanliness or inclusion engineering
• Grain size control – heat treatment and/or alloying
• Grain strength—microalloyed
• Micro structural considerations (heat treatment—controlled cool)
Standardization

• Are there recommended standardized tests for evaluation?
  – We have our own internal standard tests.
  – Tool life testing
  – You are currently using the industry standard
  – Three direction force dynamometer testing for all materials to give a good comparison of relative machinability.

• Is standardization for these processes possible?
What grades of steel do you feel should be evaluated?

• All major material grades utilized by the automotive industry.
• Newer steels used in the auto and oil/gas industries.
• Low carbon steels
  – 4140, 4340, 8620, 52100
• Carburizing/nitriding grades.
• Microalloyed and inclusion engineered steels
• Stainless steel
  – Duplex stainless steel
  – PH stainless steel.
• Tool steels
  – H13, M2, M42
Where should AISI BAG go from here?

- Are there any other machining issues you would like to address
  - Steel bar treating to optimize the machinability (steelmaking, heat treating, cold working)
  - Coolants
  - Chip control
    - High pressure coolant applications for chip breaking
  - Surface Finish
  - Dry machining
- Should we look at cold drawn product with different reduction ratios?
- Heat treatments for improved machinability?
- Comparisons with competitive materials? Steel vs powder metal for connection rods or ductile iron vs steel for crankshafts or chassis components?
- Is there information out there that you use currently? Would more focused information be desirable?
AISI BAG Machinability

• Would your organization consider becoming active in the AISI BAG effort on machinability?
• Committee membership?
• Lab/data generation effort?
• Data analysis?
Machining Set-Up

• Who establishes the cutting parameters for a machining line?
• How are the initial parameters determined?
• How valuable are outside machining centers?
Other Questions

• We have heard comments that modern cutting tools are so good, that tool life is not the issue that it used to be. Other aspects of machinability now take center stage (ie chip formation, surface finish, etc.) How would a group like ours approach this application specific issue? Thoughts?

• We have only looked at green machining in the testing done to date. How important is hard turning? Is there a need to focus on the machinability on hard turning steel? Is this even feasible?

• Have the cutting tools maintained pace with multi-axis high productivity and high speed machine tools?

• When setting up an operation to machine your parts, how much of the cost to do so is driven by the raw material and the tooling used, versus other non-material factors, and do you consider the material/tooling costs to be acceptable or excessive” – i.e. do you feel there is still much room for improvement here, or are you in a diminishing returns realm.

• We have heard machining processes can be as much as 50% of total part costs! Does it result in purchase decisions to alternative materials? How much of the decision is process driven versus product driven (performance, weight considerations, cost etc)

• Do you take machinability into consideration when looking at modular machining cells versus dedicated machining lines? Is machinability a key factor?

• Are you encountering any machining issues as a result of the dimensional characteristics of the bars being produced by the steel industry?
Technical Roadmap

• Define the technical gaps (needs)
• Prioritize the technical gaps
  – Which gaps represent the most value to your respective companies?
• Select the technical gaps (scope)
  – Which gap(s) should be addressed by the group?
  – What is the goal(s)
  – When should the gap be closed?
APPENDIX
Define Approach

• What tasks are needed to close the gap?
• What is the success criteria (requirements)?
  – Are there milestones?
  – Are there decision gates (go/no-go decisions)?
    • Are there a recovery plans?
• What resources are available?
  – Funding
  – Who is the project lead
  – Are there technical/task lead(s)?
• How will the information be transferred?
How would you define Machinability?

- Baseline/Reference (i.e. B1112 Steel)
- Tolerances
- Cost
- Tool life
- Material Variation
- Chip Control
Relationship between definition and issues

**Definition**
- Within or company we define machinability as the difficulty of machining a material relative to B1112 steel.
- Ease of machining while maintaining required tolerances and acceptable tool life.
- A combination of tool wear and chip control.
- Machinability is a property of a material, usually a metal, characterizing its ability to be machined, cut or ground by removing material to shape an engineered component.
- How difficult a material is to machine. How much power is required? What tool life can I expect? How do normal variations in material hardness affect tool life? What cutting tool materials are required to economically machine the material?
- The ability to cost-effectively remove metal to create a component that meets all functional requirements.

**Issues**
- How do I estimate power requirements?
- What is the best cutting tool material?
- How can I estimate tool life?
- Reducing cost of machining with longer cutting tool life, down time and reworks/rejects.
- Machinability consistency and improving quality of machined part.
- Heat
- Surface structure, integrity, and finish
- Dimensional control
- Chip control
- Tearing
- Slow cycle times
- Material (Hardenability, grain sizes, microstructures)
- Broaching
- Productivity