AISI Bar Machinability Database of Steels Using Sintered Carbide Tools in Single Point Turning

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Presentation Outline

- Introduction
- Test Procedure
- Materials Tested
- Test Results
- Analysis and Discussion
- Conclusions
- Acknowledgments
Introduction

• 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
Test Procedure

- 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

- Depth of cut notch
- Tangent point

Zone C  Zone B  Zone A

Original insert face

\[ VB_{AVG} = \text{Average Uniform Flank Wear} \]
\[ VB_{MAX} = \text{Maximum Flank Wear} \]

For Average Flank Wear (\( VB_{AVG} \)), Area \[ \boxed{\quad} \] = Area \[ \boxed{\quad} \]
• 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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• 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

Machinability Rating, Per Cent (8112 = 100% @ 170 fpm)

Per Cent Equivalent Carbon

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

(Calculated from ferrite hardening effects of C, Mn, Si, Cr, Ni, Mo, and V.)
Several carbon equivalent equations investigated

Ito-Bessyo equation modified for sulfur content used

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

where

$$Mn_{eff} = Mn - (1.71*S)$$
Comparison of Brinell Hardness to Ito-Bessyo CE
• 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
• Result similar to Bethlehem study
• Data fitted to a 3rd 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
Analysis & Discussion

V30 vs CE for Resulferized & MA Steels

Ito-Bessyo C.E.

- 1200
- 11XX
- MA
• $V_{30}$ 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 3rd 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.
Acknowledgements

• 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.
Sponsored by: American Iron and Steel Institute