Metallurgy for the Non-Metallurgist

Brass Rod and Bars
Outline

- Machinability Overview
- What makes C36000 so machinable?
- Manufacturing Process and Material Properties
- Questions
Machinability

- “Machinability” is ubiquitous term often used to rate or compare brass alloys
- 4 main metrics characterize the term ‘machinability’
  - Tool Wear
  - Chip Formation
  - Cutting Forces
  - Conditions of the Work Material (i.e. microstructure, hardness)
- Although uniquely identified, the metrics themselves are mutually interdependent
- The values or ratings established serve as a comparative ranking system to characterize the term ‘machinability’
In 1977, ASTM developed a testing protocol (ASTM E618) where the machining performance of different steels were compared under production conditions.

The CDA applied this test to a variety of copper based materials so that they could be relatively compared to each other and to other materials.

The premise of the CDA test is based on a volume production of a part designed to reflect the most common fabrication operations on automatic screw machines.
Machinability of Brass (con’t)

- Production was conducted with standardized parameters (i.e. tooling, machines, duration, etc.) to determine the maximum number of parts per hour that could be produced.

Fabrication Operations
- Rough Turning
- Fine Turning
- Drilling
What Makes C36000 So Machinable

- Tooling
- Machinability
- Chip Form
- Cutting Forces
- Condition of the Work Material
What Makes C36000 So Machinable

- Microstructure
- Machinability
- Chemistry
- Mech. Properties
Brass Rod Manufacturing Process

1. Raw Material
2. Melting
3. Billets
4. Extrusion
5. Coil
6. Straight
7. Drawing
C3600 Brass is a ‘binary alloy’

Perfect ratio of Cu and Zn to maintain the ductility and malleability of copper and added strength provided by the zinc

Addition of Pb as a chip breaker and added lubricity
Microstructure

• As the molten material begins to cool and solidify, the crystalline structures of the material begin to form

• C36000 being a binary or dual phase alloy exhibits both Alpha Phase and its attributes for high ductility and the excellent hot working properties of Beta Phase

• The ‘cast’ material ‘created’ (billet) exhibits excellent machinability (removal of metal) due to the lead content, but exhibits very low mechanical properties due to lack of recrystallization and cold working
Microstructure

Transformation from Cast to Wrought Product

Micrograph of Cast C36000 Brass

Micrograph of Wrought C36000 Brass

Recrystallization
Cold working process brings the extruded rod to finished size and establishes the final mechanical properties for the drawn bar.

These are the mechanical properties which then contribute to the material attributes desired for machining while maintaining the strength and integrity required by the finished part.
Balancing Act

Forming
- Softer Material
- Higher Copper

Better Cutting
- Harder Material
- Lower Copper

Drilling Small Holes
- Harder Material
- More Alpha Phase

Drilling Larger Holes
- Softer Material
- More Alpha Phase
Conclusion

- “Machinability” of a material cannot be described adequately by any one term or single characteristic parameter.
- Any assessment of ‘machinability’ has to take into account any number or combination of different criteria.
- The criterion or criteria deemed most important will be dependent on the particular machining operation, sequence or application being considered.
Conclusion (con’t)

- From the material’s perspective, there is ‘some latitude’ to make the material more conducive for specific operations provided it is within the scope of the alloy specification and applicable standard.

- Beyond that ‘latitude’, amendments in elemental percentages and additions/removal of alloying elements will lend itself to a better suited established alloy for the desired process or application.
Questions??

www.muellerindustriesipd.com

- Information on the Mueller - Mueller family of businesses
- Product information on copper and brass rod and bar products
- Certifications (ISO, PED, TS) and SDS Sheets
- Industry information (i.e. Lead Free, Conflict Minerals, REACH, etc.)
- Links to websites to Mueller Industries and other Mueller businesses
STAINLESS & ALUMINUM

John Collins

MACHINING ALUMINUM
Questioning Machinability
This is a Chip Breaker CAM Made by a CAM Maker. Where the rise stops to pull back, the rise restarts at the same point. This is the type of CAM you want to use.
Another View from Different Angle.
This is a CAM that was not a Chip Breaker CAM, but where the chip breaks were ground in the shop. Where the rise restarts, the point is higher than the point at where it stopped cutting. This results in the tool plunging back into the cut... NOT GOOD!
Another View:
Of the “POOR” Chip Break CAM.
Garr Alumastar 3 flute drill, breaks chips without Chip Breaker CAM.
Machinability Questions?
Machinability of Stainless Steels
PMPA Technical Conference
April 23, 2018

Ray Schnell
Materials Technical Specialist
Valbruna Stainless Inc.
Topics to be Covered

- Not the Do’s and Don’ts of Machining
- Basic Metallurgy of Stainless Steel
- General Guidelines
- Conclusions
- Questions
Stainless Steel

- A group of more than 350 different iron-based alloys, which typically contain a minimum of approximately 12% chromium (Cr).
Alloying elements that are used to enhance machinability

- Tellurium (Te) - Poisonous
- Selenium (Se) - Poisonous
- Sulfur (S)
5 Major Families of Stainless Steels

- Austenitic
- Ferritic
- Martensitic
- Precipitation Hardenable (PH)
- Duplex (not included in discussion)
Austenitic

- Best corrosion resistance
- Virtually Nonmagnetic
- Hardenable only by cold work
## Common Austenitic Machining Grades

<table>
<thead>
<tr>
<th>AISI Type</th>
<th>C</th>
<th>Mn</th>
<th>Si</th>
<th>P</th>
<th>S</th>
<th>Cr</th>
<th>Ni</th>
<th>Mo</th>
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<td>.045</td>
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<td>1.00</td>
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<td>Max.</td>
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Ferritic

- Intermediate Corrosion Resistance
- Magnetic
- Hardenable only by cold work
# Common Ferritic Machining Grades

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<th>AISI Type</th>
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<th>S</th>
<th>Cr</th>
<th>Mo</th>
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<td>.030</td>
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<td>.060</td>
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<td>16.00</td>
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Martensitic

- Relatively low corrosion resistance
- Magnetic
- Hardenable by heat treatment
Common Martensitic Machining Grades

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<th>AISI Type</th>
<th>C</th>
<th>Mn</th>
<th>Si</th>
<th>P</th>
<th>S</th>
<th>Cr</th>
<th>Mo</th>
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<td>410</td>
<td>.15</td>
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<td>12.00</td>
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<td>.040</td>
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<td>12.00</td>
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<tr>
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<td>Max.</td>
<td>Max.</td>
<td>Max.</td>
<td>Max.</td>
<td>Min</td>
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<tr>
<td>420F</td>
<td>.15</td>
<td>1.25</td>
<td>1.00</td>
<td>.060</td>
<td>.15</td>
<td>12.00</td>
<td>.60</td>
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<tr>
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<td>Min</td>
<td>Max.</td>
<td>Max.</td>
<td>Max.</td>
<td>Min</td>
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<td>Max.</td>
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<td>.75</td>
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<td>1.20</td>
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<td>Max.</td>
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<td>18.00</td>
<td></td>
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</tbody>
</table>
Precipitation Hardenable (PH)

- Relatively low to intermediate corrosion resistance
- Magnetic
- Hardenable by heat treatment (Aged)
- Condition H-1150-M is considered the optimal age for improved machinability.
## Common PH Machining Grades

<table>
<thead>
<tr>
<th>Type</th>
<th>Cr</th>
<th>Ni</th>
<th>Mo</th>
<th>Cu</th>
<th>Cb &amp; Ta</th>
<th>Other</th>
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<td><strong>17Cr-4Ni</strong></td>
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<td>3.00</td>
<td>5.00</td>
<td>3.00</td>
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<td>17.50</td>
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<td></td>
<td>5.00</td>
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<td></td>
<td>16.00</td>
<td>7.00</td>
<td>1.00</td>
<td>1.75</td>
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<td>2.50</td>
<td>.15</td>
<td>.45</td>
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<td>15.50</td>
<td>5.50</td>
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<td>4.50</td>
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<tr>
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<td>Ti</td>
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<tr>
<td></td>
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<td>.50</td>
<td>.80/1.40</td>
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<td><strong>Ph13-8Mo</strong></td>
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<tr>
<td></td>
<td>13.25</td>
<td>8.50</td>
<td>2.50</td>
<td></td>
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</tbody>
</table>
Stainless Applications

- Automotive
  - Exhaust Systems
  - Air Bags
- Screw Machine Parts
- Construction
  - Bridges
  - Residential
  - Commercial
- Firearms
- Food Processing
- Marine
- Power Generation
- Aerospace
  - Landing Gear
  - Maintenance
What is Machinability
Machinability can be:

- Productivity
- Tool life
- Surface finish
- Cycle time
- Chip removal

Whichever is critical to you, it all boils down to the final cost ($$$) to make the part
General Guidelines — especially on Martensitics, PH’s, etc.

- Tooling should be rigid
- Feed should be maintained
- Lower cutting speeds (in comparison to Aluminum, Copper, Brass, etc.)
- Tools should be sharp
- Keep tools cool
Where to get speeds and feeds

- Material suppliers
- Tooling suppliers
- Machine builders
- Technical organizations
- Reference books
Machining Stainless Steel Requires Cutting Fluids.....

- To reduce heat - on the cutting tool – workplace interface

- Lubricate – to reduce the friction generated by the cutting tool on the surface of the material being machined
Conclusion

- Machining Stainless Steels...
  - Can be very profitable, if you grow your expertise; with rigid cutting tools and workholding capable of the job; proper speeds and feeds; removing heat through good cutting fluids; and using the correct material mechanical properties.
Metallurgy for the Non-Metallurgist

Steel Factors

Chemistry:

- Carbon is greatest influence on mechanical properties
- Mechanical properties major influence on machining
- Free machining steels have additives that reduce the forces needed to separate the chip
- Non-free machining steels do not
- Free machining resulfurized steels require 25% less force because of Sulfur combining with Manganese to make MnS particles that help the chip break and ‘self-lubricate” the tool edge
- In non-resulfurized steels, the sulfur is held to much lower limits- but getting sulfur at or above 0.02 wt % will be noticeably improved over steels where sulfur is 0.015 wt % or less.
- Lead is also added and results in a further 25% boost in machinability. It is a separate constituent in the steel and is found on the MnS particles
- Phos Helps make the chip more brittle- so better surface finish on 12XX grades.
- Residual elements can be a clue to how the steel was originally melted. Not bad or good by themselves, but clues that 2 batches might be very different in how they were made.
- Silicon and Aluminum are used to remove the oxygen from the molten steel – and they do that by forming hard abrasive particles. That’s why you don’t want these in free machining grades.
- However to control Grain size, (fine grain size has a host of advantages for how many steel components function or are processed) Silicon and Aluminum, Niobium and Vanadium are used after deoxidizing with Silicon- so we run fine grained steels at much slower surface footage so these hard oxide particles don’t abrade off the edge of our tool.

Mechanical properties:

- Cold drawing boosts the Tensile strength a little, the yield strength a lot- the higher yield strength to tensile Strength ratio means that your tool has less work to do to get the chip to separate as it only has to raise the force from the new higher yield strength to the tensile to get it to break.
- When we strengthen by cold drawing, we also reduce the ductility- this makes the chips easier to remove- but also makes the parts less cooperative in subsequent cold work like crimping, swaging, staking etc.
- The higher the carbon content, and the higher the alloy content, the more susceptible the material will be to work hardening. Don’t let tools dwell or rub! Take sufficient depth of cut to get below the potentially work hardened zone created by the tool’s last pass.
- Hardness is resistance to penetration. It correlates with Tensile strength. Hardness can be achieved by cold working or by heat-treating.
- High carbon and alloy steels can also be softened by applying heat this is generally called annealing, but can also be called stress relieving. There are different types of anneal depending on the amount of carbon.
Your Shop Process Factors:

- Your shop can see the greatest variation between steels if you buy based on price and not on consistent supply.
- Yes steel is steel, but if supplier a melts to the high side, B to the middle, and C to the lowest part of a spec, you will see the full range of variation between these three suppliers. What worked fine on material from supplier C will not work on material from A.
- If you do not have rigid work holding, the work piece will slip and the tool will break and you will blame the supplier for “hard spots.”
- Cut the steel, it doesn’t really like to be rubbed- that just work hardens it making it even more difficult to machine.
- Look at your tools for built up edge and wear patterns. Upon change, shortly thereafter, about midway through their expected life, and near the end of their life. Changing a tool out before it makes parts needing to be inspected is powerful savings. Seeing the issue on the tool beats having to sort a couple of totes worth of parts for an unexpected “feature” as a result of the tool failing.
- Applying metalworking fluids where they are needed is just as important as getting tools properly aligned. Coolant in the hole is much more effective at removing heat and chips than coolant splashing around

Deeper Dive:

https://pmpaspeakingofprecision.com/2015/02/16/why-tool-life-can-vary-carbon-and-alloy-steels/
https://pmpaspeakingofprecision.com/2012/03/13/three-key-factors-to-understand-machinability-of-carbon-and-alloy-steel/
https://pmpaspeakingofprecision.com/2015/03/12/how-chemistry-determines-machinability-manganese-sulfides/
https://pmpaspeakingofprecision.com/2011/05/10/5-certification-aspects-to-check-when-performance-changes/
https://pmpaspeakingofprecision.com/2009/07/16/5-tips-to-improve-surface-finish-on-your-precision-machined-parts/
https://pmpaspeakingofprecision.com/2012/06/21/the-point-of-the-tool-seldom-cuts/
https://pmpaspeakingofprecision.com/2010/05/18/the-chatter-about-chatter/

_Have a question? Look up the word on my Blog at pmpaspeakingofprecision.com_