Troubleshooting Machining Problems

PMPA NTC 2016
The Machining System- 8-M’s

Man
Machine
Material
Method
Measurement
Maintenance
Millieu
Management
This session focus

- We’re going to concentrate on
- Machine
- Method
- And how to recognize symptoms and what they mean
Machine Problems

These four distinct problem areas are listed here in what I have found to be their ORDER OF IMPORTANCE, or rather, THEIR ORDER OF FREQUENCY.

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<th>Tool Life</th>
<th>Variation</th>
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<th>Surface Finish</th>
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Types of Problems

• Tool Life
  • Not getting hours of use as expected

• Variation
  • Length and/or diameters fluctuate excessively

• Concentricity
  • Features aren’t coaxial to each other

• Surface Finish
  • Not able to meet the surface roughness tolerance
Tool Life

I would add:

- Variables
  1. Spindle Speed
  2. Feed
  3. Coolant
  4. Tooling
  5. Machine
  6. Part
  7. Human
  8. Depth of Cut
  9. Work Holding
  10. Work hardening
Quick Question

• Would you rather change the tool more often, or less often?
• Let’s think about this for a few slides…
How Should Tools Fail?

- Flank Wear! (Abrasive wear)
- Flank wear is *predictable*,
- Wear occurs as tool is abraded by material being cut over time
- Rapid Flank wear is result of abrasive materials—Reduce your surface footage (speeds)
- Do not confuse with “Chipping”
Flank Wear

- Higher Sulfur = higher speeds (revs)
- As sulfur rises beyond 1% volume fraction, surface finish improves, chips formed are smaller with less radius of curvature, and the friction force between cutting tool and chip decreases due to lower contact area.
Tool Life & Economics

• Long tool life isn’t necessarily the goal
  • Often slowing down the machine adds more cost to the workpiece than the money saved on tooling and downtime.

• Form tools have different economics than off the shelf drills and insert tooling.

• Remember that a stable process is still important.
Optimizing cutting speed is formulated by W. Gilbert with respect to Taylor’s tool life formula. There are two objectives in this optimization:
- Maximizing production rate
- Minimizing unit cost

Both objectives seek a balanced MRR and tool life.

**Maximizing Production Rate**
- Choose cutting speed to minimize machining time per production unit.
- In turning 3 elements contribute to the total production cycle time for one part:
  - Part handling time (loading+ unloading+ starting the machining)=$T_h$
  - Machining time (actual machining)=$T_m$
  - Tool change time (at the end of tool life, the tool must be changed)=$T_t$. 
Predictability of tool performance is the goal

• More uptime
• More parts per shift
• What is worth more $$$ to your shop?
• Getting the maximum parts per tool, or getting the most parts per shift?
Rule of Thumb

• 20-25 Minutes of tool life is the best balance between cycle time and tool cost
Example Calculation
-20 minute tool life

- Example:
  - CNC Lathe
  - $75.00 Hour shop rate ($1.25 per minute)
  - $18.00 insert/4 edges = $4.50 per edge
  - 1.5" Diameter turn x 2.0" long
  - 1528 rpm x 0.007" IPR = 10.696 IPM
  - 2.1”/10.696 = .196 minutes
  - 20 min tool life / .196 = 102 parts per edge
  - $4.50/102 = $.044
  - Exchange time 3 min x $1.25 /102 parts =$.037
  - Cost of cut time $1.25 x .196 = $.245

- Cost per piece - $.326
Example Calculation - Maximize tool use

- Let’s improve tool life:
  - CNC Lathe
  - $75.00 Hour shop rate ($1.25 per minute)
  - $18.00 insert/4 edges = $4.50 per edge
  - 1.5” Diameter turn x 2.0” long
  - 1000 rpm x 0.005” IPR = 5 IPM
  - 2.1”/5 = .42 minutes
  - 200 parts per edge
  - $4.50/200 = .023
  - Exchange time 3 min x $1.25/200 parts = $.019
  - Cost of cut time $1.25 x .42 = $ .525

- **Cost per piece - $ .567**
Conclusion

• Cost per piece - $.567 with better tool life
• Cost per piece - $.326 with faster cycle time
• $.241 higher cost per part
• On a 1,000 piece order that’s $241.00
• It’s also 3.73 hours of future capacity lost or $280.00
• *It is false economy to slow down a job to get more parts per tool.*
• *We sell time on our machines, we need to minimize the time for the job, not maximize the life of our tools!*
False Economy!

- It is false economy to slow down a job to get more parts per tool.
- We sell time on our machines, we need to minimize the time for the job, not maximize the life of our tools!
- Predictive tool replacement will make you money!
Tool Wear Mechanisms- 3 of these are heat related!

- **Abrasions**
  - Hard inclusions in the work material plow into the tool face

- **Adhesions**
  - Work material welds to the tool

- **Diffusion**
  - Atoms exchange between the work material and the tool material. Increases exponentially with speed.

- **Oxidations**
  - The tool material oxidizes at high temperature. The oxidized layer is easily knocked away.
Heat is probably the machinist’s #1 problem

- Heat is caused by friction as a result of speed
- Lack of coolant
- Heat softens tool, promotes diffusion and chemical reactions between workpiece material, toll coating and tool material
- Reduce and control heat to levels your process can handle
Heat Related Tool Failure Modes

- Crater wear
- Thermal Cracking
- Deformation
Crater Wear

- Crater Wear
- Crater Wear is a result of the combined effects of heat and chemistry and material “mechanical flow”
- The tool material actually “dissolves” into the chip
Corrective Action: Crater Wear

- What you can do with what you have:
  - Increase chip control
  - Increase back rake
  - Decrease feed
  - Decrease speed
  - Keep tool temperature down with coolant

- Also try
  - Harder tool material
  - Coating
Thermal Mechanical

- Temperature shocks overcome mechanical strength
- Tool materials (especially carbide) hate extreme temperature changes
- High speeds can create a steam envelope-thermal shock and cracking
Corrective Action: Thermal Mechanical

- Increase coolant lines
  - (Add to bottom)
- Hone tools
- Decrease speed
- Decrease feed
- Increase side cutting angle
- Apostasy: try running with no coolant to reduce thermal shocks- run at constant high temperature
Plastic Deformation

- Plastic Deformation
- Result of high temperatures and very heavy feeds
- “Hyper cratering”
- Reduce speed, reduce feed assure adequate coolant
Corrective Action: Plastic Deformation

- Heat related so reduce speed
  - (If carbide and must keep feed and speed the same, increase the TiC content )
  - Improve coating
- Decrease speed
- Decrease depth of cut
- Get a tooling professional to review
Work Hardening!

- Work hardening is real
- It’s a thing
- A couple of revs of tool dwell is all that it takes
- Especially an issue in Nickel containing grades and higher carbon steels
- Demonstration
Mechanical Tool Failure Modes

- Mechanical Breakage
- Can be Mechanical only – Chipping and Breaking
- Can be Thermal Mechanical as we discussed above
Mechanical Breaking

- Breaking is a function of weak setup for the speeds and feeds being used
- Increase rigidity
- Check tool and workholding
- Reduce tool overhang
- If repeats often could be ...
Mechanical Breaking
Chipping

- Caused by
  - Weak tool setup
  - Excessive Feed

- Corrective actions
  - Decrease feed and side relief angle
  - Increase speed
  - Increase nose radius and side cutting angle
  - Increase chip breaker width

- Try- hone edge
Chipping
Thermal Mechanical

- Temperature shocks and mechanical shocks
  - Weak setups can contribute to mechanical failure
  - Can be masked by evidence of heat.
  - Intermittent coolant flow
  - Reduce heat!
  - Increase coolant
  - Eliminate coolant
  - Increase wear resistance of tool
Thermal Mechanical
Corrective Action: Thermal Mechanical

• Increase coolant lines
  • (Add to bottom)
• Hone tools
• Decrease speed
• Decrease feed
• Increase side cutting angle
• Apostasy: try running with no coolant to reduce thermal shocks- run at constant high temperature
Special case- Built-Up Edge (BUE)

- Workpiece material pressure welds to edge of tool. Builds up, comes off, removing chunks of tool material bonded to
- Leaves rough or irregular, out of control surface finish
- Occurs typically
  - In softer, gummier materials
  - Lower speeds
  - Slower operations- threading and tapping
Built Up Edge

- **Built Up Edge (BUE)** is impacted by three primary factors: **material chemistry** (which you can’t change—you already have the material); **surface footage** (slower speed means hot chip is in contact with tool longer, creating higher BUE); and **tool geometry** (the point is to slice or cut, not rub off the material).
Corrective Actions: Built Up Edge

- Increase Speed SFM RPM
- Increase Back Rake Angle
- Polish / hone Back Rake Face
- Explore coatings
- More lubricity to coolant

Corrective Actions: Built up Edge (cont’d)

• Increase the speed SFM (especially on Carbide!). This will help reduce BUE.

• Reduce the feed per revolution (IPR- inch per revolution). This will help reduce the flank wear.

• Increase the top rake angle.

• Add a chip breaker / chip curler.

• Increase tool nose radius.
Surface Finish

• First step: Keep Build BUE (Built Up Edge) low and under control
  • Higher top rake angles
  • Reduced feed per rev
  • Higher speeds

• Low speed causes rough finish
  • Tool stress is higher
  • Longer contact with molten chip
  • BUE becomes higher increasing flank wear
Review: Effects on Tool Life

- **Speed:**
  - Heat related failures / deformation and cratering when too high
  - Built up edge and surface finish when too low

- **Feed:**
  - Mechanical failures tool breaking and chipping if setup not rigid

- **DOC:**
  - Tool breakage / deformation if too high

- **Work hardening**
  - Breakage and short tool life otherwise unexplained
Resources

- [http://www.productionmachining.com/articles/how-should-tools-fail](http://www.productionmachining.com/articles/how-should-tools-fail)
- [http://www.productionmachining.com/articles/problem-solving-or-waiting-for-rescue](http://www.productionmachining.com/articles/problem-solving-or-waiting-for-rescue)
- PMPA Troubleshooting Machining Problems Manual