Economic tooling for high performance machining of Ti alloys

Increased material removal rate and production efficiency

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High speed steel end mills instead of solid carbide tools for initial rough machining

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Background

- Aubert & Duval, Erasteel = divisions of Eramet
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  – Aubert & Duval produces Ti forgings for airframe components
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  – Erasteel produces PM high speed steel for cutting tools

ROUGH MILLING OF INCONEL 718 WITH ASP 2052

Operation: Rough milling Inconel 718

Problem: Short tool life of milling cutters with TiN coated carbide inserts

Solution: Solid end mill ASP 2052 + TiCN

Cutting conditions:
Carbide + TiN: vc = 20 m/min, fz = 0.08 mm
ASP 2052 + TiCN: vc = 5 m/min, fz = 0.16 mm

Benefit: Longer tool life: 2.1 m for ASP 2052 instead of 0.45 m for carbide (eliminate edge chipping). Similar metal removal rate as carbide
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Background

• Aubert & Duval, Erasteel = divisions of Eramet
  – Aubert & Duval uses cutting tools to machine Ti forgings
  – Joint project to investigate potential for improved machining efficiency and cost benefits using HSS tools instead of carbide
Background

• Main interest = productivity improvements
  – A&D has machined forgings with carbide end-mills
    • Performance is reliable
    • Decreased machining time is goal
  – Erasteel promotes toughness of ASP high speed steels
    • Desired comparison against carbide tools
Project

• Compare performance of carbide versus HSS mills
  – Toughness of high speed steel better than carbide
    • Less chipping or breakage in difficult cutting conditions
    • Able to withstand heavier chip loads
  – Abrasion resistance of carbide higher than HSS
    • Longer edge wear
    • Improved by coatings
  – Temper resistance of carbide better than HSS
    • Higher cutting speeds permissible
Project

- "PM HSS" grades permit higher alloy content than conventional HSS (e.g. M7, M42)
  - Improved toughness despite high alloy content
    - Result of PM manufacturing
      - Freedom from carbide segregation
  - Improved abrasion resistance
    - Higher alloy content
      - Greater volume of carbides
      - Higher attainable hardness
  - Improved temper resistance
    - Higher alloy content
Project

• Select highest alloy PM grade
  – ASP 2060
    • Highest HRC
    • Highest abrasion resistance
    • Highest temper resistance
  – Closest HSS properties to carbide
Project

- 3 end mills:
  - ASP 2060 end mill
    Desgranges
  - End-mill with indexable carbide inserts
    Sandvik
  - ASP 2060 end mill
    Leclerc
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Project

• Sandvik cutter with indexable inserts

  – 3 cutting edges
  – End-mill with indexable carbide inserts
  – 3 helical rows of 7 inserts
  – Each insert of the front set is turned twice
  – All other insets are turned 4 times
  – Turning of inserts every 40 to 45 minutes
Project

- Desgrange ASP 2060 crescut end mill
  - 6-flute end-mills
  - 54 mm diameter
  - Crescut geometry
  - 67.5 HRC
  - Alcrona coating (Al Cr N)
Project

• Leclerc ASP 2060 roughing end mill

  – 6-flute end-mills
  – 50 mm diameter
  – Normal roughing geometry
  – 67 HRC
  – Alcrona coating (Al Cr N)
Project

• A350 airframes
  – Ti – 6Al - 4V
  – Site : Salvaire (France), machining subcontractor of A&D

• A350 landing gear parts
  – Ti – 10V – 2Fe – 3Al
  – Site : Aubert et Duval Les Ancizes
  – Milled before heat treat
Results

• Desgrange crescut mill results (Ti-10-2-3):
  – Chip removal rate is higher than carbide data: min + 25%
    ➔ it is even possible to increase feed speed or depth of cut
  – None of the 3 end-mill was used up to the limit wear
    • With first end-mill, chocks, vibration, bad evacuation of chips, end-mill N°1 has turned by 15° inside the chuck
    • Results averaged for 2\textsuperscript{nd} & 3rd cutters
Results

- Leclerc roughing mill results (Ti-6-4):
  - Chip removal rate can be 2 or 3 times higher than carbide data
  - None of the 3 end-mill was used up to the wear life limit
  - Chip removal problem (lubrication? High removal rate?)
  - Achieved Ra = 7,0 to 7,7 while Ra < 6,3 is expected
Results

• Positive results:
  – After 1 hour of milling, cutting edges of N°2 end-mill are still in good condition (light flank wear, very tiny built-up edge)
  – End-mill N° 2 was ready to mill 2 hours when we decided to stop after 1 hour.
  – Chip removal rate is equivalent or higher than carbide data
    ➔ it is possible to increase feed speed or depth of cut
  – None of the 3 end-mill was used up to the limit wear
    • First end-mill stopped because of bad chip disposal (cutting edges damaged)
    • Second end-mill still in good condition after 1 hour of milling
    • Third end-mill not used
Results

• Further work:
  – Modified geometries to optimize chip removal
    • Chip breakers on crescut mill
  – Alternate PM grades to compare substrate changes
  – Optimize cutting speeds
  – Eventual tool life comparison
Conclusions

- Tests conducted on A350 frame component in Ti-6-4 and landing gear component in Ti-10-2-3
- Testing results:
  - Chip removal rate is higher than carbide data: min + 25%
  - Chip removal rate can be higher than carbide data
  - None of the 3 end-mill was used up to the limit wear
Comments

- Test conducted specifically to improve machining efficiency, not tool life, but initial tests suggest tool life will still be acceptable

- Conclusions show PM HSS tool material can provide
  - High material removal rates,
  - Improved machining times,
  - Acceptable wear life

- PM high speed steels offer alternative between traditional conventional M42 tools and carbide tools
  - Cannot match edge wear and cutting speed capability of carbide
  - Longer edge life, higher cutting speeds than M42 HSS
  - Greater chipping resistance than carbide, more robust for difficult cutting environment