Green Waterjet Machining Technology

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Merits of Waterjet

- Green machining process
  - Use no toxic machining fluid and produce no hazardous waste
  - Water and abrasive are recyclable
- Cold cutting with no HAZ
  - Preserve materials’ properties
- Material independent
  - Cut difficult materials, e.g., hardened steel with \( R_c \approx 58 \)
  - Cut titanium 34% faster than stainless steel
  - Cut most composites
- Single tool qualified for multi-mode macro to micro machining
- Preferred near-net-shaping tool for extremely precision parts
  - Remove bulk of materials
  - Finish part with light trimming - minimize wear of precision hard tools

Typical heat damage by \( \text{CO}_2 \) lasers
Merits (cont’d)

• Significant advancements in AWJ precision machining
  • Windows-based Intelli-MAX Software Suite is available for automation
  • Advanced cutting model for improving performance in cut quality and speed
  • Multi-head accessories for multi-mode (2D/3D) machining
  • Developed micro abrasive (µAWJ) technology for meso-micro machining (NSF SBIR Phase II/IIB)
    • Commercialization – Award-winning MicroMAX® JetMachining® Center
  • Waterjet often competes on equal footing with lasers, EDM, and other tools (i.e., for heat sensitive materials)
  • User friendly (PC-based CAD/CAM) - no steep learning curve
Facilities and Software

- Four US-made product lines of waterjet machines

ProtoMAX

Maxiem

MicroMAX

GlobalMAX

OMAX

§ Name Finalist of 2016 R&D 100 Awards
Waterjet Nozzles

Schematic and production nozzles

MAXJET 5i Nozzle (14/30)

MAXJET 5i MINIJET Nozzle (10/21)

7/15 MINI MAXJET 5 Nozzle (5/10 Beta)

MAXJET 5 Water Only Nozzle
Accessories for 3D Machining

Tilt-A-Jet (TAJ), A-Jet, and Rotary Axis
Window-Based CAD/CAM

• Window-based Intelli-MAX Software Suite – powerful yet intuitive and user friendly
  • CAD (LAYOUT) – create tool paths from designed or imported part files
  • CAM (MAKE) – prepare tool paths for automated machining
    • Incorporates advanced cutting model to assign machineability and pierceability based on material properties
    • Controls accessories and nozzle movement for precision 2D and 3D machining
  • Waterjet is cost effective with fast turnaround for
    • Small lots (R&D, prototyping, and reverse engineering)
    • Large lots (24/7 production runs)
Advanced Cutting Model

Indices of Machineability and Pierceability

Four Generations

G4 vs G2: 215%
G4 vs G3: 187%
G5: in development
Material Independence

Assortment of AWJ-cut parts for various materials
Wide Range of Part Size/Thickness

Taper-free aluminum blocks

Progress in meso-micro machining
Wide Range of Part Size/Thickness (cont’d)

Repair of Φ1.5m wind turbine gear
100 mm thick Bisalloy

Miniature planetary gear
.5 mm thick titanium
3D Parts Made with Rotary Axis and/or A-Jet

Slotted copper tubes for novel high-efficiency motors

Assortment of 3D parts

Courtesy of University of Hawaii Mechanical Engineering

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3D Parts (cont’d)

S S Soccer Ball

Global Map

Metal Weld Joints

PEEK Cranial Implants

Ti Mesh Cash

S S Stents
ASJ/AWJ Milling

Near-net-shaped glass lens

Aluminum nitride lens

Lightweighting of support of Hubble telescope
Multimode Machining

Aluminum chess set - facing, turning, slotting/grooving, ……
Difficult Materials (cont’d)

Bonding extender for lapping thin-film ceramic substrates (2.1mm 440C stainless steel hardened to $R_c$ 58)

- Cutting Time
  - AWJ (MicroMAX) – 23 min
  - Wire EDM (3 passes) – 6 hrs

Ratio: 15

Courtesy of Competitive Engineering
Delicate Geometry (NASA/JPL)

Cost for Cutting 10 parts

<table>
<thead>
<tr>
<th>Method</th>
<th>Cost</th>
<th>Cost Ratio</th>
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<tbody>
<tr>
<td>Wire EDM (3 passes)</td>
<td>$1400</td>
<td></td>
</tr>
<tr>
<td>µAWJ (Single pass)</td>
<td>$250</td>
<td>&lt; 1/5</td>
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Delicate Parts

Multi-Layered glass Sculpture

Soda Lime Glass Rotor

Carbon Fiber Ukulele
Precision Machining

Nonlinear Load Cells with five orders of magnitude force range

US Patent #20150233440

Courtesy of MIT Precision Engineering Research Group (PERG)
Deployment of Mobile AWJ in Battlefield

OMAX Mobile AWJ deployed at Camp Leatherneck, Afghanistan for in-theater Emergency rapid-response repair of heavy equipment (http://www.sme.org/MEMagazine/Article.aspx?id=78461)
Examples of Rapid-Response Repair

• Cut “grapping hooks” to find trip wires of IDEs
• Reinforced frames of heavy-duty M870 trailers
  • Waterjet cut four plates in 1-1/2 hours
  • Plasma-cutting, grinding, and welding could take 2 to 3 days to fabricate one plate
• The only option to cut holes on armor plates on site for cables to upgrade MTVR (Medium Tactical Vehicle Replacement)
• Machined 2000 titanium washers for a V-22 Osprey tilt-rotor aircraft
Summary

• Waterjet is a green machining process
• It has technological and manufacturing merits that are unmatched by most machine tools
• With the addition of μAWJ technology, OMAX has achieved full capacity of multi-mode machining of most materials from macro to micro scales (“7M” advantage)
• A single tool is qualified for “7M” machining
• For heat sensitive materials, AWJ with no HAZ cuts > 10 times faster than lasers, wire EDM, and plasma cutter
  • Lasers (thickness limited) must pulsed at high frequencies
  • Wire EDM must cut (conductive materials only) with multi-passes
  • Plasma cutting requires labor intense and time consuming grinding to remove HAZ
References


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