Margini di miglioramento tecnologico: innovazioni dalla ricerca
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New trends: high precision WJ cutting

**AWJs:** diameter > 300 micron  
**FAWs:** 50 < diameter < 300 micron  
**MAWs:** diameter < 50 microns


"Waterjets: evolving from Macro to Micro, cutting smaller, faster and deeper",  
Manufacturing Engineering, SME, November 2009 Vol. 143 No. 5
High precision WJ cutting
(tolerance = 0.01 mm on the workpiece)

Improvement of the current components:
- Orifice
- Mixing chamber
- Focuser

By means of:
- CFD simulations
- Experimentations
  - Fluid-dynamic validation of simulations
  - Cutting performance
CFD simulations
Constricted water jets (transient state)

Cone: 60°
Aspect ratio = 1.5
Diameter = 0.15 mm
P = 300 MPa

CFD simulations
Jet and droplets formation

In collaboration with:

Politecnico di Milano - M. Annoni
Camera and Settings
SensiCam by PCO (www.pco.de)

- 1280x1024 pixels maximum
- Frame rate 1 Hz
- Delay flash-exposure 6 microseconds
- Exposure time 0.3-1 microsecond depending on nozzle diameter and configuration

Zoom:
- Focal 80, f/a 4 (completely open)
- Distance water jet - camera body 136 cm
- Resolution 11.4 pixel/mm (11.5 the preliminaris)
- Image size 1280x576 pixels (x544 on the scale)

Flash position:
- Preliminari 2x Flash high, side +90 -90, distance 11 cm:
- And 2x Flash high, side +100 -100, distance 11 cm:
Experimentation
High speed camera observations

50 MPa

160 MPa

100 MPa

220 MPa

d = 0.080 mm
Experimentation
High speed camera observations

![Graph showing spray width vs. image length for different pressures: P220 (red), P160 (blue), P100 (pink), and P050 (black).]
Experimentation
Water jet observations

Air effect

Vahedi Tafreshi et al. (2004)

Nozzle Exit

A.H. Osman et al. (2003)

Spray Onset

Breakup Length

Abrasives

Mixing tube inlet

Water jet

Tube wall

A.H. Osman et al. (2003)

15 mm

1.5

V_t = 35 m/s
Q_a = 8.0 l/min
Experimentation Laser Doppler Velocimetry

\[ P_{\text{cin}} = \frac{\rho V_1^2}{2} Q_1 \]

\[ \eta = \frac{p_1 Q_1}{P_{\text{el}}} \]

\[ \eta_N = \frac{\frac{1}{2} V_1^2}{\frac{1}{2} V_{1s}^2} = \frac{h_0 - h_1}{h_0 - h_{1s}} \]

\[ C_c, C_v, C_d \]

Experimentation Laser Doppler Velocimetry


Massimiliano Annoni, 9° Convegno AITEM, 2009

- $\lambda = 780$ nm
- $L = 2581$ mm
- $s = 35$ mm
- $p = 100$ MPa
- $d_w = 0.15$ mm
- sod = 60 mm
\[ V = D \cdot F \]
## Orifice characterization

<table>
<thead>
<tr>
<th>Experimental conditions (B orifices)</th>
<th>$C_d$</th>
<th>$\psi$</th>
<th>$C_v$</th>
<th>$C_c$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>St. Dev.</td>
<td>Mean</td>
<td>St. Dev.</td>
</tr>
<tr>
<td>0.30 mm @ 200 MPa</td>
<td>0.67</td>
<td>&lt; 0.01</td>
<td>0.98</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>0.30 mm @ 300 MPa</td>
<td>0.68</td>
<td>&lt; 0.01</td>
<td>0.97</td>
<td>&lt; 0.01</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Experimental conditions (B broken orifices)</th>
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<th>$C_v$</th>
<th>$C_c$</th>
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<td></td>
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<td>Mean</td>
</tr>
<tr>
<td>0.30 mm @ 200 MPa</td>
<td>0.72</td>
<td>0.98</td>
<td>0.89</td>
<td>0.82</td>
</tr>
<tr>
<td>0.30 mm @ 300 MPa</td>
<td>0.70</td>
<td>0.97</td>
<td>0.93</td>
<td>0.78</td>
</tr>
</tbody>
</table>

**Good conditions**

**Broken orifice**

Experimentation
Static pressure measurements

High pressure water

Mixing chamber

Air control valve

Air suction port

Mixing tube

Pressure taps

p1

p2

p3

p4

p5

p6

p7

Custom made LabVIEW program