Effect of multiple jet passes treatment in waterjet peening on fatigue performance

A. Azhari\textsuperscript{1}, C. Schindler\textsuperscript{2}, C. Godard\textsuperscript{3}, J. Gibmeier\textsuperscript{4}, E. Kerscher\textsuperscript{3}

\textsuperscript{1}Faculty of Manufacturing Engineering, Universiti Malaysia Pahang, 26600 Pekan, Malaysia
\textsuperscript{2}Chair of Design in Mechanical Engineering, University of Kaiserslautern, 67663 Kaiserslautern, Germany
\textsuperscript{3}Working Group of Materials Testing, University of Kaiserslautern, 67663 Kaiserslautern, Germany
\textsuperscript{4}Institute for Applied Materials IAM-WK, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany

28\textsuperscript{th} July 2015
1st International Conference on Applied Surface Science, Shanghai, China
Content

Overview
Introduction
Motivation
Methodology
Results and discussions
Conclusion
Outlook
The present work is a continuation from the previous work of the same authors.

Water is normally compressed up to about 600 MPa and discharged from a small orifice [2].

Started in early 1960s [1].

Applications:
- machining
- coating removal
- cleaning
- peening (WJP)
- etc.

High impact water drops on the surface causing local plastic deformation

A new mechanical surface strengthening process [4]

High compressive residual stresses are induced leading to enhanced fatigue life [5]

Waterjet peening (WJP)

Illustration of WJP process

Motivation

Research on WJP has started about two decades ago [4].

Other peening processes (e.g. shot peening (SP), and laser shock peening (LSP)) are more established.

Still, a detailed knowledge is not comprehensively reported.

Also, all the works reported in literatures were carried out in a single-pass treatment.

In shot peening, multiple shot peening passes resulted in larger surface roughness and coverage [8].

Also, more number of passes increased the maximum compressive residual stress as well as the thickness of the strengthening layer [8].

---

In LSP, using multiple laser shocks resulted in an increase in the hardness and magnitude of the residual stress [9].

Also, the fatigue life of the laser peened specimen with multiple laser shocks was higher [9].

Therefore, it is interesting to investigate the effect of multiple passes treatment in waterjet peening on fatigue performance of metals.
Arola et al. [10] reported the improvement of fatigue strength in abrasive waterjet peening of stainless steel 304 and titanium alloy Ti6Al4V. They found a rather limited increase in the fatigue strength for both materials (< 10 %).

Kunaporn et al. [11] reported a maximum increase in the fatigue strength by 20-30 % in waterjet peening of aluminium alloy 7075-T6.

During oil jet peening of carbon steel 1040, an improvement of fatigue strength by about 19 % was reported Grinspan [12].
Han et al. [13] reported an increase of fatigue life of about 15-20 % in water cavitation peening of carbon steel 1045. They also noticed that the improvement of fatigue life was obviously apparent at higher cycles.

The fatigue strength of stainless steel 316 under cavitating jets in air (CJA) and water (CJW) has been investigated by Soyama [14]. The cavitation peening in water takes place inside a water-filled chamber. It was found that the improvement of the fatigue strength using the cavitating jet is better in air than in water.
Methodology

Materials:
- Stainless Steel 304 (DIN 1.4301)

Equipment:
- UHDE Waterjet machine

Responses:
- Roughness
- Erosion
- Microstructures
- Hardness
- Fatigue life

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Ranges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of jet passes</td>
<td>2 – 6 passes</td>
</tr>
</tbody>
</table>
Results and discussions

Effect of peening parameters on hardness & microstructures

The treated specimens showed an increase in surface hardness between 12 to 22% with respect to the base material [15].

![Graph showing the effect of peening parameters on hardness](https://example.com/graph.png)

![Subsurface microstructures images](https://example.com/microstructures.png)

Subsurface microstructures, a) 2 passes, b) 4 passes, c) 6 passes

Effect of peening parameters on residual stresses

The introduction of compressive residual stresses in the treated specimens were observed between 56 to 417 MPa. However, the strengthening layer is limited within 50 μm below the surface.
Results and discussions

Effect of peening parameters on fatigue life

All waterjet treated specimens had shown lower fatigue strength than the original specimens.

Specimens with the highest increase in hardness as well as surface roughness resulted in the largest decrease in the fatigue strength.
Results and discussions

Surface fracture analysis

- Untreated
- 2 passes
- 4 passes
- 6 passes
Treated surface analysis

<table>
<thead>
<tr>
<th>Specimens</th>
<th>Surface roughness, Ra (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original</td>
<td>0.14 – 0.16</td>
</tr>
<tr>
<td>W1 (2 passes)</td>
<td>0.78 – 0.94</td>
</tr>
<tr>
<td>W2 (4 passes)</td>
<td>1.60 – 2.62</td>
</tr>
<tr>
<td>W3 (6 passes)</td>
<td>2.34 – 4.86</td>
</tr>
</tbody>
</table>

Erosion tracks for different no. of passes, a) 2, b) 4, and c) 6 passes

Rougher surfaces are expected to encourage fatigue crack initiation [16].

Although, specimen W3 had the highest increase in hardness and compressive residual stresses, they also produced the highest roughness and erosion.

Perhaps, this leads to overpeening effect [17].

Conclusion

It also increases the surface roughness and erosion.

Multiple passes treatment results in increase of hardness and residual stresses.

Due to overpeening effect, the treated specimens had shown lower fatigue strength than the original specimens.

The increase in hardness is not possible without a corresponding increase in surface roughness.
Multiple passes treatment can be used with a combination of the effect of WJP and smoothening action.

How to increase the hardness without increasing the roughness?

Initial steps: peening action
Later steps: smoothening action

Multiple passes treatment is applied in steps
“The more we know, the more we realize how little we know...”

Thank you very much for your kind attention!