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Effects of peening methods on residual stress and microstructures of Alloy 600

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- **Alloy 600 widely used in relatively high temperature or severe corrosive environments.**
- **In NPPs, various components were made of Alloy 600, However this material appeared to be susceptible to stress corrosion cracking (SCC).**
- **Mitigate the SCC in Alloy 600**
  - ✓ Replace with Alloy 690
  - ✓ Surface peening techniques

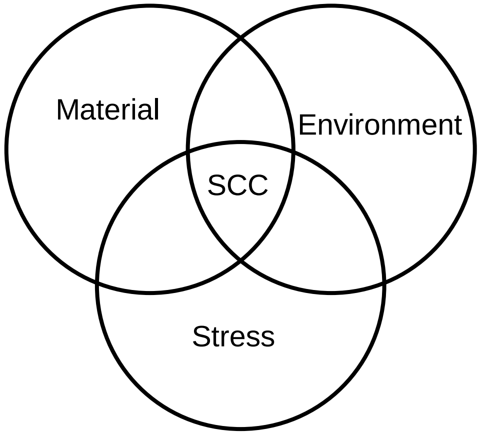


Fig. Factors affecting stress corrosion cracking

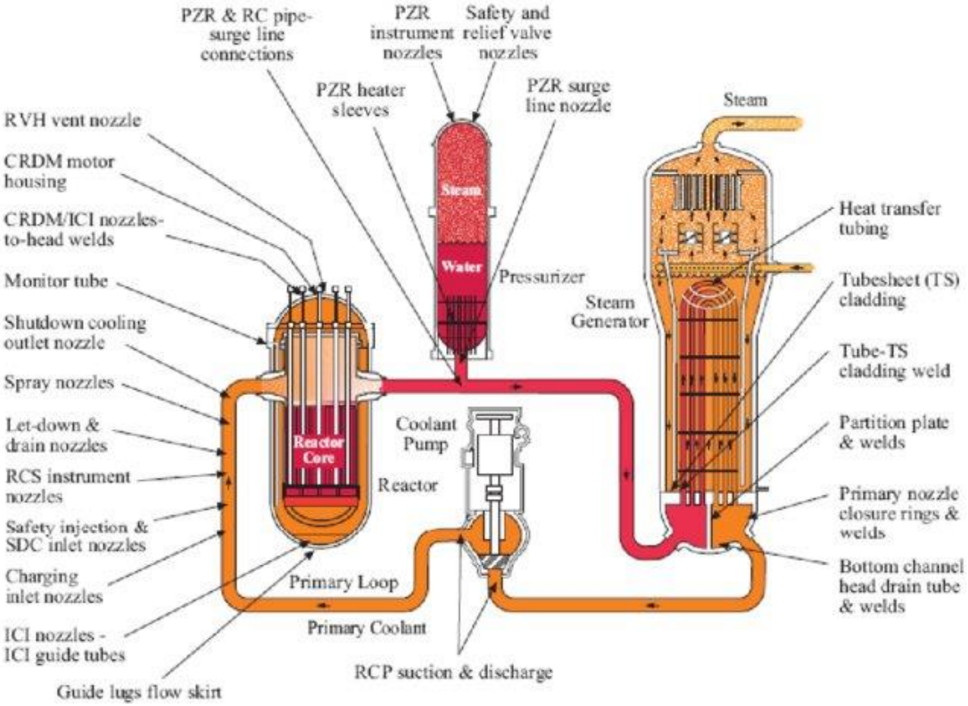


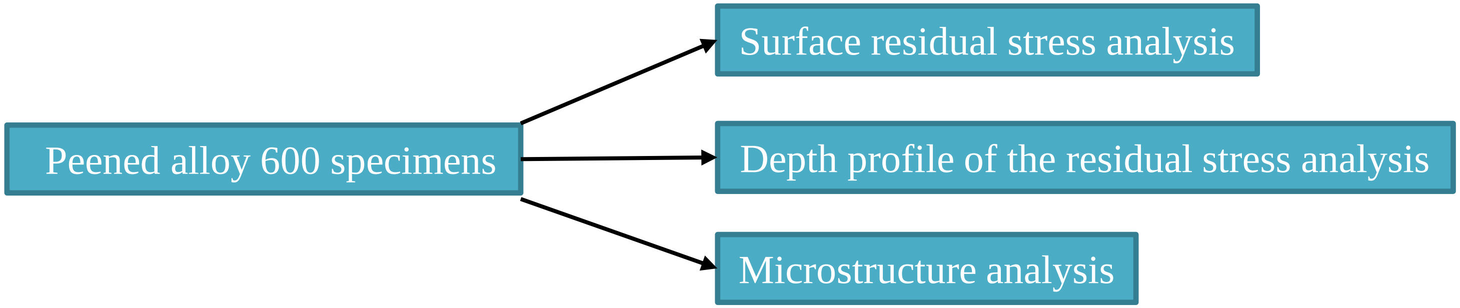
Fig. Applications of alloy 600 in PWR primary system*

* R. G. Ballinger. Light water reactors: materials of construction and their performance. In International conference on plant materials degradation - Application to the stress corrosion cracking of Ni-base alloys, EDF R&D centre of Les Renardières, Moret–Sur–Loing, France, November 2008. 29, 30

I. Introduction

- **Peening methods on Alloy 600**
  - ✓ Can prevent SCC by generating compressive stress on the surface.
  - ✓ However, the peening effects on the material properties and SCC behavior have not yet been well-known.
  - ✓ More studies are needed on the effects of the peening on the surface residual stress, depth profile of the residual stress, microstructure underneath the peened surface, and SCC behavior.

Analytical method



II. Experimental Method

- **Types of Alloy 600 peening specimens**
  - ✓ Water jet peening (WJP), Underwater laser peening (ULP), Ultrasonic nanocrystal surface modification (UNSM).
  - ✓ To study the effects of over-peening, specimens in which the peening was performed 1, 2, 4, and 8 times were prepared.
- **Sample analysis method**
  - ✓ The residual stress was measured using x-ray diffraction (XRD) and a hole-drilling method.
  - ✓ The cross-sectional microstructures of the specimens after peening were analyzed by using electron backscatter diffraction (EBSD).

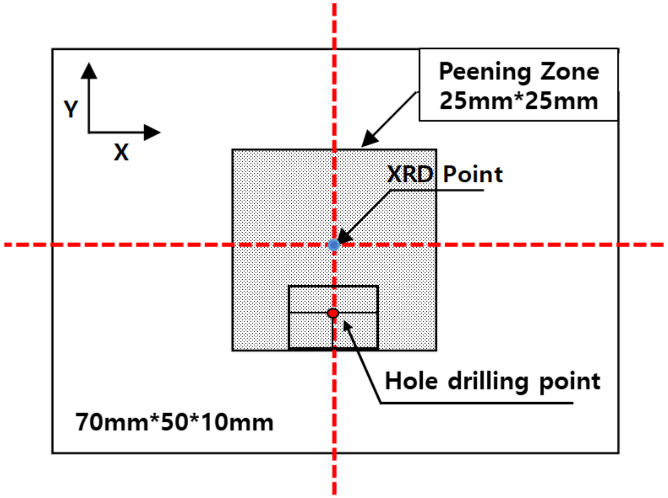


Fig. Schematic of alloy 600 peening specimen surface; x-direction: grinding and peening process direction,
y-direction: peening step direction.

- **Surface residual Stress(XRD)**

  ✓ UNSM produces the highest compressive residual stress value, while ULP and WJP show similar level of stress.

  ✓ WJP treatment show the least discrepancy between X and Y directions.

  ✓ The ULP and WJP methods show a gradual decrease in the surface compressive residual stress as the number of peening increases.

  ✓ Before the peening, the stress along the X direction, which is equivalent to the heavy grinding direction, shows higher value than the Y direction. This tendency is maintained only in the UNSM treatment.

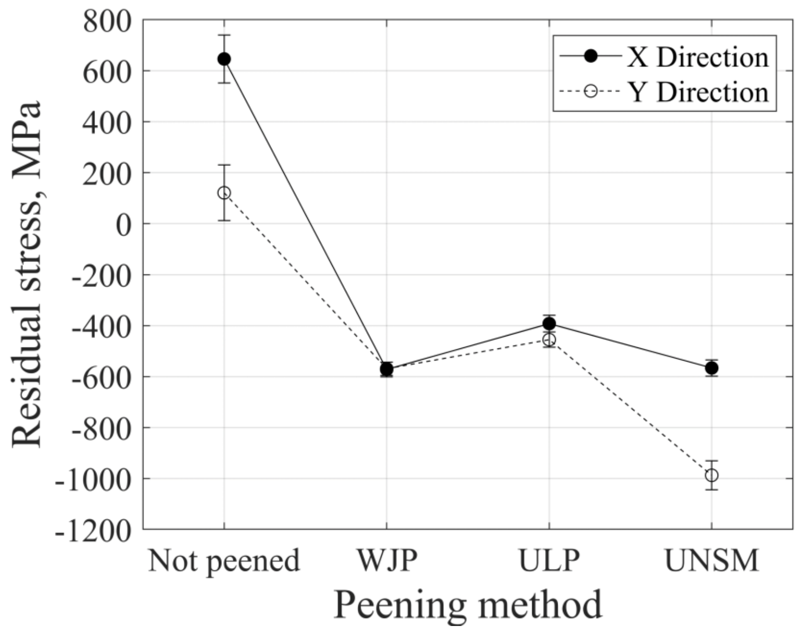


Fig. XRD surface residual stresses of specimens depending on peening methods.

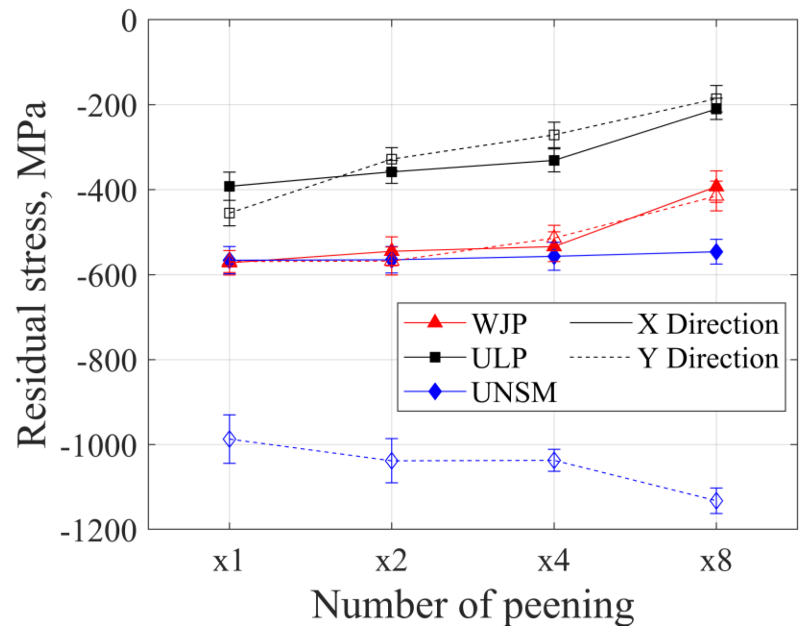


Fig. XRD surface residual stresses of over-peened specimens depending on peening methods.

III. Results

- **Depth-profiling residual stress(hole drilling)**
  - ✓ The three peening methods can produce compressive residual stresses to the depth of 1 mm regardless of the number of peening.
  - ✓ The single peening cases, as the depth increases, the compressive residual stress value gradually decreases.
  - ✓ 4 and 8 times peening cases, the compressive residual stress values of the ULP method also seem to be slightly larger than those of the WJP and UNSM methods.
  - ✓ Over peening seems to have insignificant effect on the stress depth profile.

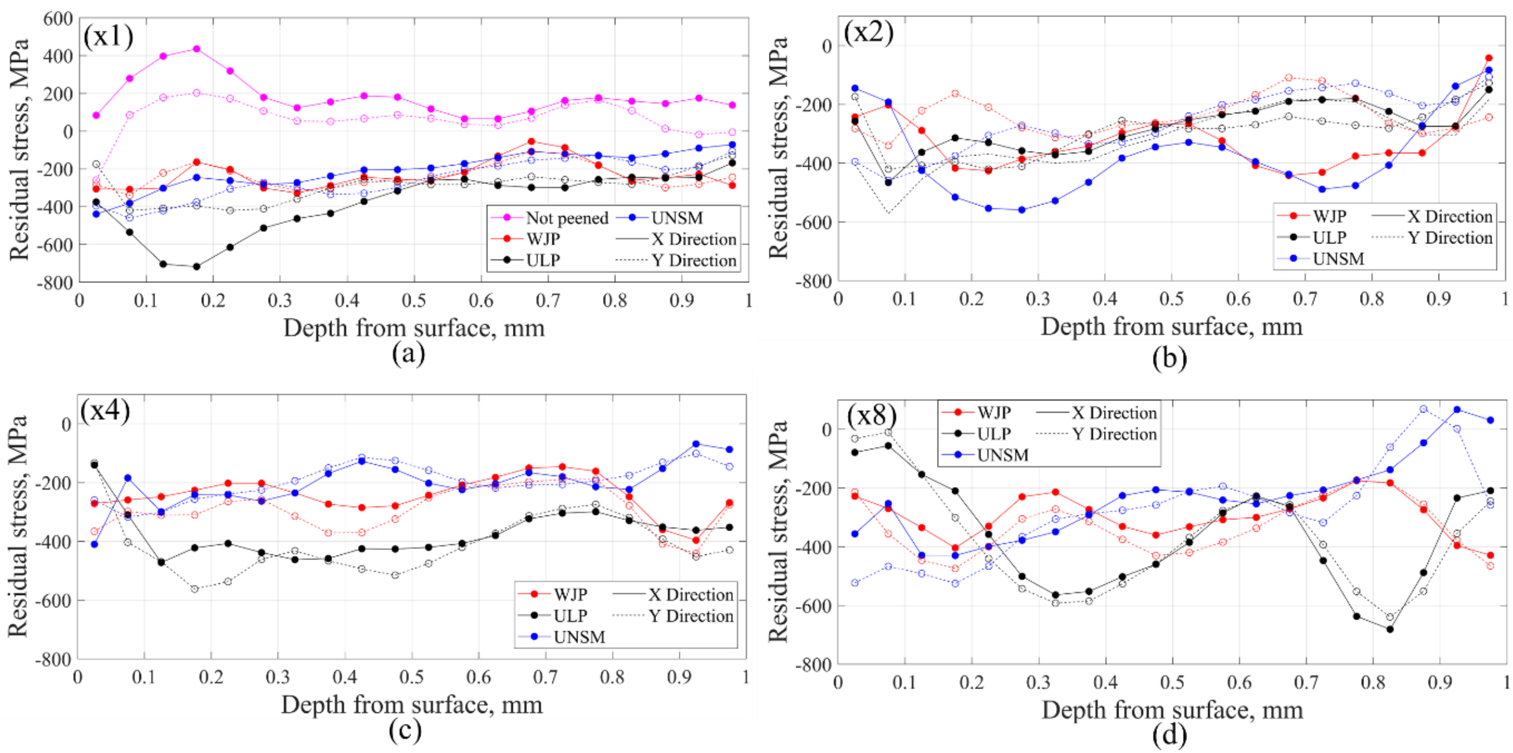


Fig. The hole drilling depth-profiling residual stress results. (a) single peening results, (b) 2-times peening results, (c) 4-times peening results, (d) 8-times peening results.

- **Microstructure(EBSD)**
  - ✓ The KAM* map shows that the UNSM peening method produces the most significant plastic deformation to the depth of about 300 μm.
  - ✓ The depth of plastic deformation caused by the WJP peening method is only 20~30 μm, which is the smallest among the three peening methods.
  - ✓ The depth of the affected layer by ULP is about 200 μm.
  - ✓ After UNSM peening, the grain size near the surface is much smaller and almost unidentifiable, and the degree of cold working is much greater than those of ULP and WJP.

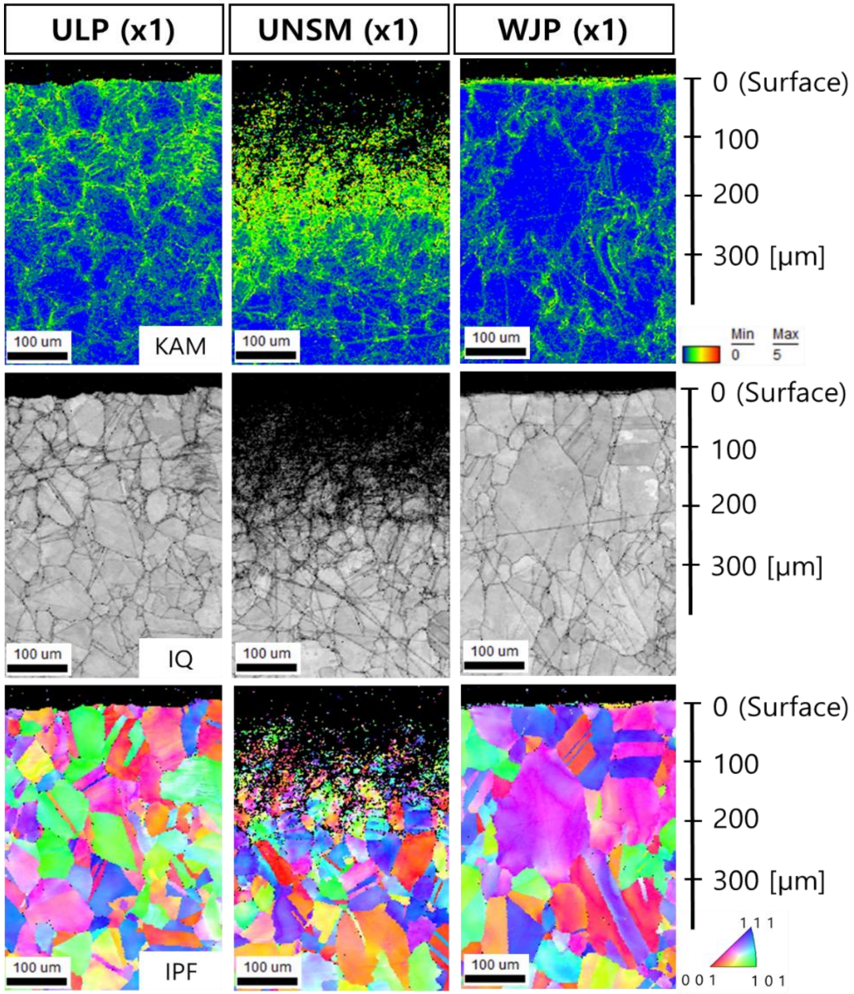


Fig. EBSD microstructure analysis result of one-time peened specimen.

* Kernel Average Misorientation

III. Results

- **Microstructure(EBSD)**
  - ✓ As the times of ULP increases, the depth of the microstructurally affected layer also seems to increase, while this tendency is less apparent during UNSM and WJP.
  - ✓ Results of UNSM and ULP specimens show that the number of dislocation, KAM level, and the number of small-sized grains increase near the surface.

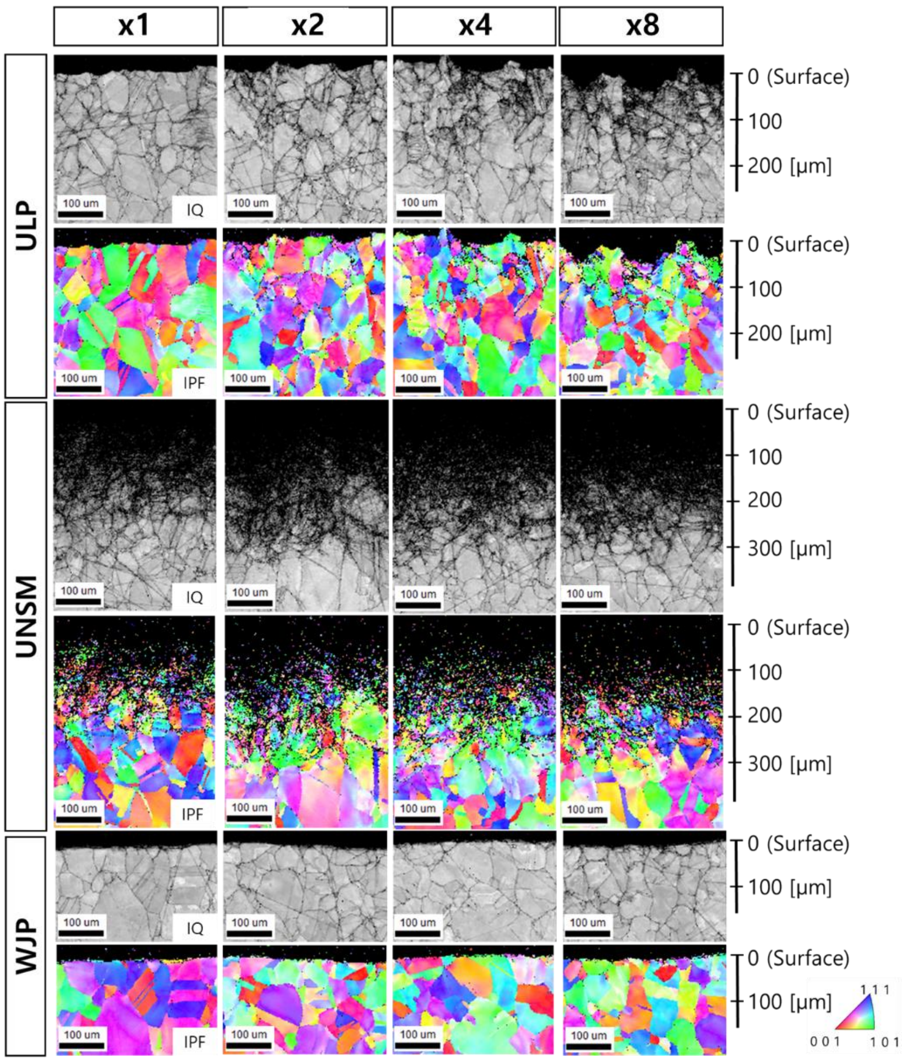


Fig. EBSD microstructure analysis result of the over peened specimen

IV. Conclusion

- WJP, ULP, and UNSM can generate compressive residual stresses at least to a depth of 1mm on Alloy 600.
- The XRD-based compressive stress values generated by different peening methods on Alloy 600 surface is in the order of UNSM > WJP > ULP. However, the depth profiles measured by the hole drilling method did not clearly show this trend.
- With the increase in ULP and WJP peening times, the compressive stress value generated on the surface after peening decreases slightly, but UNSM specimen maintains the initial stress level even after over-peening or increases slightly.
- UNSM produces the most significant impact on the microstructure, showing a heavily plastically deformed layer reaching a depth of ~300 μm. Based on KAM map results, ULP shows the affected layer with the depth of ~200 μm, and WJP shows only 20~30 μm of the affected layer.
- As the time of ULP increases, the depth of the microstructurally affected layer also seems to increase, while the depths of affected layers for UNSM and WJP specimens do not change significantly. The number of dislocations and small-size crystals in the regions near the surface of UNSM and ULP specimens increase significantly.

Thank you !

ACKNOWLEDGEMENT
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