Evaluation of Known Residual Stress Using Instrumented Indentation Test

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1. Introduction

Residual stress measurement techniques such as saw cutting and contour method are limited by being destructive methods. Scanning methods such as XRD and neutron diffraction methods are non-destructive but extremely sensitive to the test environment. To overcome these limitations, a technique is needed that is non-destructive, simple and evaluates residual stress quantitatively by measuring deformation directly. Recently, an instrumented indentation test has been developed from hardness testing. Instrumented indentation testing (IIT) measures the indenting load and penetration depth in real time and displays it as a continuous curve. Recent researchers have analyzed this curve and developed it to evaluate hardness, strength, impact toughness, fracture toughness and residual stress.

2. Basic Concept

Residual stress is not a mechanical property but a stress state. Figure 1 shows schematically how residual stress can influence the load/indentation depth curve. If compressive residual stress exists, the material around the indenter is squeezed by this stress and hence a greater load is needed to reach to the same indentation depth than in the stress-free state (top, Figure 1). On the other hand, if tensile residual stress exists, the material is released by tension and a smaller load is necessary to keep the same indentation depth than in the stress-free state (bottom, Figure 1). Therefore, to evaluate the residual stress, two load/indentation depth curves are required, in the stressed state and in stress-free state. And the load difference between two curves can be determined at a given indentation depth (usually the maximum depth of stressed state) from the stressed and stress-free load/indentation depth curves, as shown on the figure 2. The residual stress of the material can be quantitatively evaluated using this load difference.

3. Joint research

A stress-free disk specimen as shown figure 3 was fabricated at the Los Alamos National Lab. The material is SUS316L and the disk size is 60 x 60 x 12.7 mm^3. The stress-free specimen was indented with a 15-mm diameter flat indenter and residual stress was applied by causing plastic deformation. At Los Alamos National Laboratory residual stress evaluation was performed on the specimens through neutron diffraction, contour method, and finite element analysis. The residual stress values evaluated for the outermost surface are FEA data, not actual test results, so IIT was used to evaluate the results of the outermost surface residual stress. The test locations were set on stressed and stress-free specimens as figure 4, and testing was performed. The results of the residual stress evaluation are as figure 5. They agree well with the FEA data obtained at the Los Alamos National Laboratory.

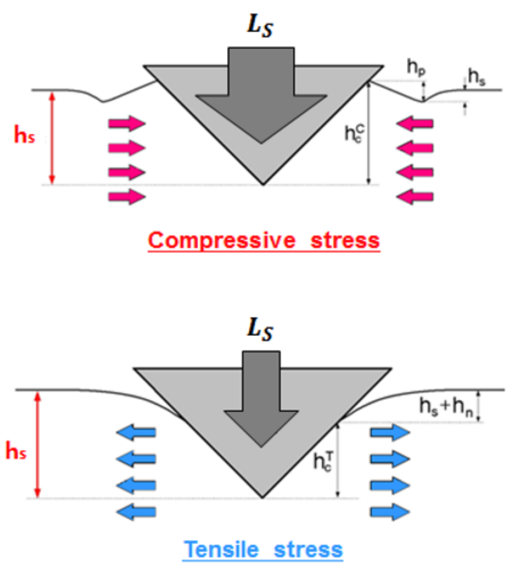

Figure 1. Residual stress affecting the indentation load

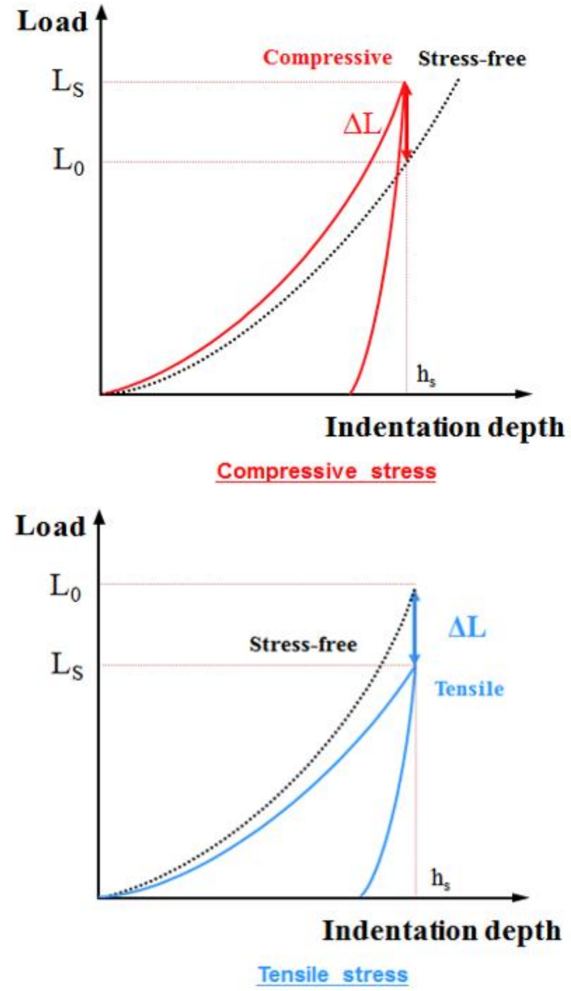

Figure 2. Load difference on the curve according residual stress

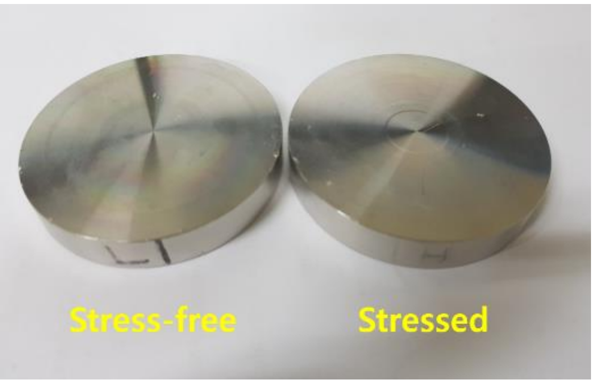

Figure 3. Disk specimens

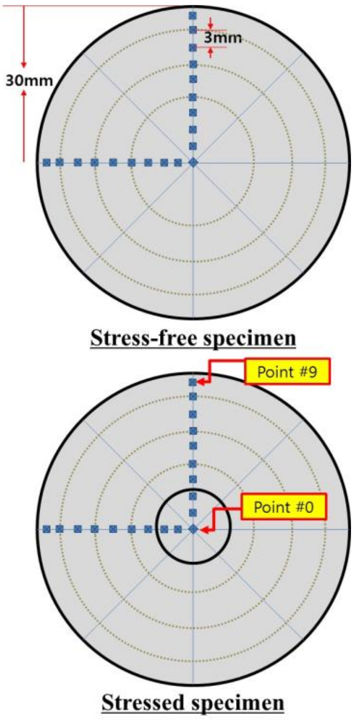

Figure 4. Test location

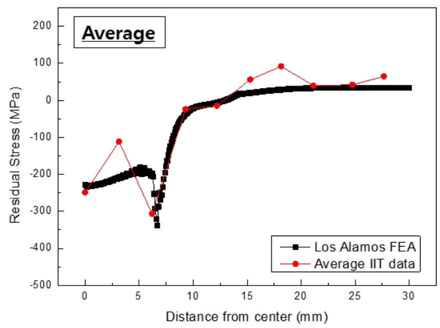

Figure 5. Test result

Acknowledgment

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References

[1] Y.-H Lee, D. Kwon, *Measurement of residual-stress effect by nanoindentation on elastically strained (100) W*, Scripta Materialia 49(5) (2003) 459-465.

[2] Pagliaro P, Prime MB, Clausen B, Lovato ML, Zuccarello B, *Known Residual Stress Specimens Using Opposed Indentation,* J Eng Mater Technol (2009) 131:031002