Establishment of Laser Peening Technology for Improving Surface Quality of Metallic Products

Optimization of laser irradiation conditions to enhance the effect of surface-quality improvement

Research method

Beamlines used at SPring-8: Engineering Science Research I (BL19B2), Engineering Science Research III (BL46XU)

Awards for this research: The 5th Hyogo SPring-8 Award (2007), The Science and Technology Award in the Development Category at the Awards from the Ministry of Education, Culture, Sports, Science and Technology (2008)

Achievements

- Establishment of optimal laser irradiation conditions for **laser peening*** to improve the surface quality by measuring the depth profiles of **residual stress**** on a metal surface nondestructively
- Confirming the suppression of the fatigue-crack growth on metals by laser peening through 3D imaging of the cracks
- Establishment of laser peening technology for suppressing the initiation and development of cracks in the nuclear-reactor structures

R&D facility: Toshiba Corporation

***Laser peening:** Peening is similar to the hammering process used by a swordsmith. Compressive residual stress is imparted to a metal surface by peening to cancel the tensile stress inside the metal, changing it into compressive stress. Hence, the prevention of fatigue and stress corrosion cracks from developing in welded parts is realized. In laser peening, a metal surface is compressed by the shock of plasma (high-pressure gas) that is generated by irradiating an intense pulsed laser onto the metal surface, and introduces compressive residual stress inside the metal. Laser peening technology has been used for nuclear reactors and is considered for application to the components of airplanes, automobiles, and bridges.

****Residual stress:** Stress retained inside an object even after the removal of the external forces such as tension, compression, bending, and heat treatment.

Role of SPring-8

Background

Shot peening with fine metallic balls being shot at materials is a well-known peening technology. However, this method is not suitable for peening in some cases, such as the inside of nuclear reactors, because of its large-scale setup and the difficulty in retrieving the metallic balls. There has been demand for a new peening technology with a compact setup.

With this background, laser peening using a high-intensity pulsed laser has come into the spotlight. However, it is difficult to observe the interior and fine regions of materials and measure the residual stress on sites very close to the surface using a conventional X-ray.

Results

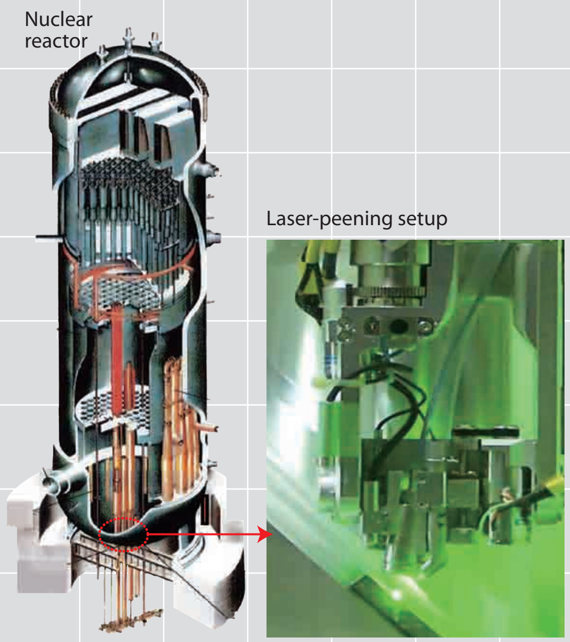
The synchrotron radiation X-ray of SPring-8 has a high transmittance, enabling us to nondestructively measure the states of materials processed by laser peening from their surface to their interior. We demonstrated that the residual tensile stress on the surface and interior is changed into compressive stress by laser irradiation. Moreover, the **depth profiles of residual stress** were compared between different laser irradiation conditions to determine the optimal conditions.

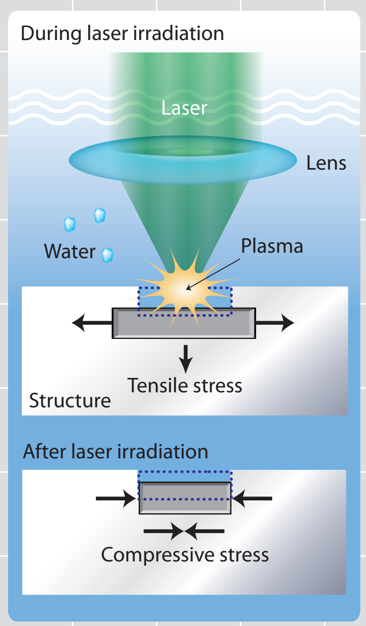
In addition, the images obtained from X-ray computerized tomography (CT) clearly revealed that the **growth of fatigue cracks** was markedly suppressed for materials processed by laser peening.

Publication: Y. Sano and K. Akita; SPring-8 Research Frontiers 2005, 127-128 (2006) Y. Sano and K. Masaki; SPring-8 Research Frontiers 2006, 151-152 (2007)
K. Masaki et al.; Journal of Solid Mechanics and Materials Engineering **2** (8), 1104-1113 (2008)

Principle of laser peening

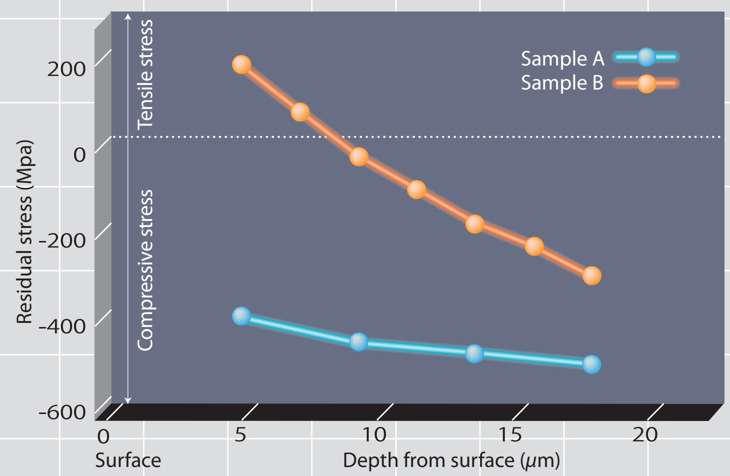
The surface layer of a metal in water changes into plasma upon the irradiation of a high-intensity pulsed laser. Because plasma expansion is prevented in water, the laser energy becomes locally concentrated on the metal surface, generating shock waves. The metal surface is slightly deformed by these shock waves; however, its further deformation is hampered by the surrounding parts. Thus, the material is strengthened by the compressive stress remaining on its surface.





Depth profile of residual stress

Tensile stress remains on the surface of sample B after the sparse laser irradiation to the target surface. Sufficient compressive stress is applied to the surface and inside of sample A after dense laser irradiation to the target surface.



X-ray CT image of fatigue crack generated on aluminum alloy

The growth of fatigue cracks (the white parts in the center) is suppressed on the specimen processed by laser peening.