ACADEMIC STUDY
Professor Hitoshi Soyama | Tohoku University | soyama@mm.mech.tohoku.ac.jp

Cavitation S Peening®

"*I, along with staff members at Tohoku University and Babcock-Hitachi K.K., began developing a peening method for mitigating Stress Corrosion Cracking (SCC) in nuclear power plants about 25 years ago. We found that water-jet peening could mitigate SCC, and the cavitation impacts peened a surface. I got my PhD in cavitation erosion so I understood the complicated mechanisms of cavitation impacts. I then began to research 'cavitation peening' and received a trademark for a method that I named Cavitation S Peening®.*

Cavitation peening has many advantages: Its treated surfaces are smooth compared to conventional shot peened surfaces and there are no sparks during the process as there are no solid collisions. The strain speed during the process is very high because shock waves when the cavitation bubble collapses are used. The cost is very inexpensive compared with the laser shock process.

Cavitation peening can be applied in the automobile industries and chemical plants. Although we can peen hard materials in the same way as shot peening, I think soft materials such as aluminum alloy and magnesium alloy are better suited for this peening process. An additional benefit to using cavitation peening in chemical plants is that the water supply that is part of the fire-extinguishing system can be used for cavitation peening.

Unfortunately, many researchers and engineers do not understand the difference between cavitation peening and water-jet peening. Cavitating jet can treat a much wider area than normal water jet and when the cavitation is optimized, the impact intensity of cavitating jet is also bigger than that of normal water jet.

I am pleased to share some of my research on cavitation peening with the readers of The Shot Peener magazine. If you are interested in reading more of my research on Cavitation S Peening®, please send an email to soyama@mm.mech.tohoku.ac.jp."

—Professor Hitoshi Soyama
Tohoku University, Japan
Department of Nanomechanics, School of Engineering

CAVITATION S PEENING® is a peening method that uses cavitation impacts to improve fatigue strength and/or to introduce compressive residual stress. The peening method using cavitation impact is called "cavitation shotless peening (CSP)", as shots are not required (see Fig. 1). In the case of cavitation shotless peening, cavitation is generated by cavitating jet.

Cavitation is a phase change phenomena from liquid-phase to gas-phase. It is similar to boiling, but with cavitation the liquid-phase becomes gas-phase by decrease of static pressure until saturated vapor pressure due to increase of flow velocity (see Fig. 2). When the static pressure is increased by decrease of the flow velocity, the cavitation bubble is collapsed. When the cavitation bubble collapses, a part of the bubble is deformed and a micro-jet is produced (see Fig. 3). As the speed of the micro-jet is about 1,500 m/s, the micro-jet produces plastic deformation pit on the solid surface. After the cavitation bubble shrinks, the cavitation bubble rebounds. At the rebound, a shock wave is produced. The shock wave also produces plastic deformation (see Fig. 3 on page 18).

Cavitating jet is a jet with cavitation bubbles produced by injecting a high-speed water jet into normal water jet. (See Fig. 4 on page 18.)

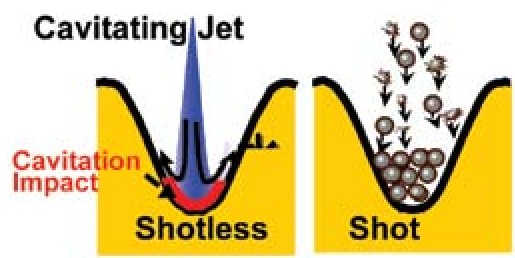

Figure 1. Shotless Peening and Shot Peening

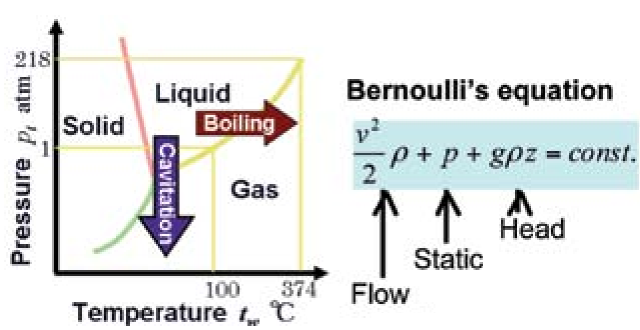

Figure 2. Phase diagram of water and Bernoulli's equation

The cavitation bubbles take place in the low pressure region of vortex core in the shear layer around the jet. The vortex cavitations combine and a big cavitation cloud is produced. When the cavitation cloud hits the surface, cavitation impacts are produced when the bubble collapses. Soyama successfully produced cavitating jet in air by injecting a high-speed water jet into a low-speed water jet.

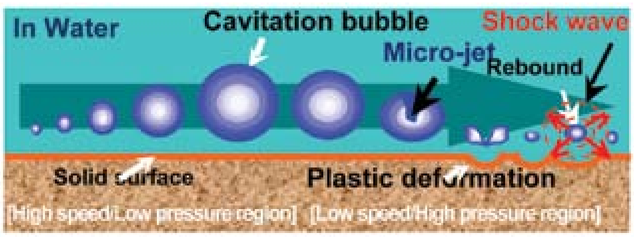

Figure 3. Schematic diagram of cavitation bubble

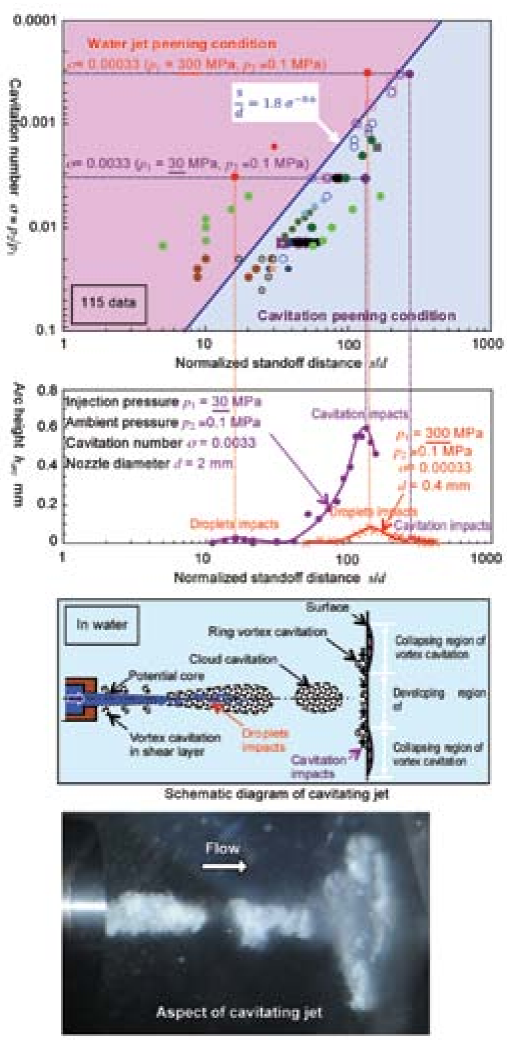

Figure 4. Schematic diagram and photo of cavitating jet

Improvement of Fatigue Strength

Cavitation S Peening® improves the fatigue strength of gears made of carburized chromium molybdenum steel SCM420H[1]. It also enhances the fatigue strength of carburized chromium molybdenum SCM420[2] and SCM415[3], aluminum alloy AC4CH-T6[4], Duralumin, magnesium alloy, stainless steel, silicon manganese steel and other materials. See Fig. 5 - 7.

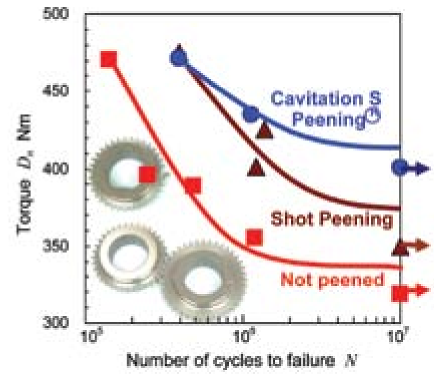

Figure 5. Improvement of fatigue strength of gear demonstrated using a power circulating type gear tester (Carburized SCM420H)[1]

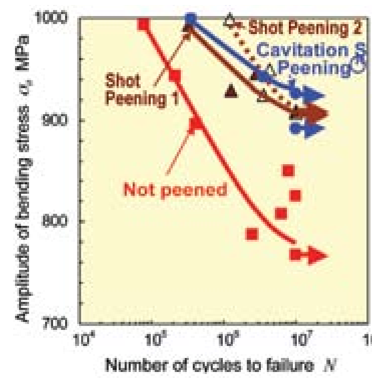

Figure 6. S-N curve of rotating bending fatigue test (Carburized SCM420)[2]

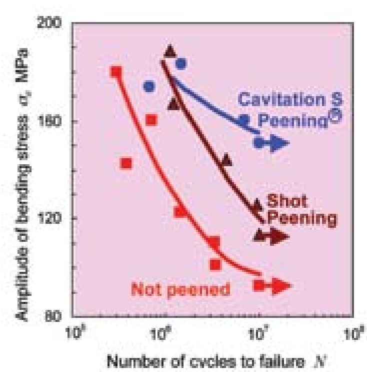

Figure 7. S-N curve of rotating bending fatigue test (AC4CH-T6)[3]

1. H.Soyama and Y.Sekine, "Sustainable Surface Modification Using Cavitation Impact for Enhancing Fatigue Strength Demonstrated by a Power Circulating-Type Gear Tester," International Journal of Sustainable Engineering, Vol. 3, No. 1, 2010, pp. 25 - 32.
2. H. Soyama, "Improvement of Fatigue Strength of Metallic Materials by Cavitation Shotless Peening," Metal Finishing News, Vol. 7, March issue, 2006, pp. 48 - 50.
3. H.Soyama, K.Sasaki, K.Saito and M.Saka, "Cavitation Shotless Peening for Improvement of Fatigue Strength of Metallic Materials," Transaction of Society of Automotive Engineers of Japan, Vol. 34, No. 1, 2003, pp. 101 - 106.

Peened Surface

Cavitation S Peening® introduces compressive residual stress with considerably less surface roughness compared to that from shot peening (see Figs. 8 and 9). Individual pits induced by Cavitation S Peening® do not have a sharp tip up around the pit, compared to the pit induced by ball indentation at nearly constant volume and depth (see Fig. 10). It is very shallow compared to the pit at constant depth of plastic deformation area (see Fig. 11).

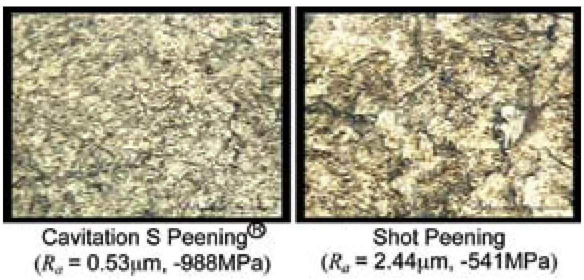

Figure 8. Peened surface and residual stress (Ti-6Al-4V)[4]

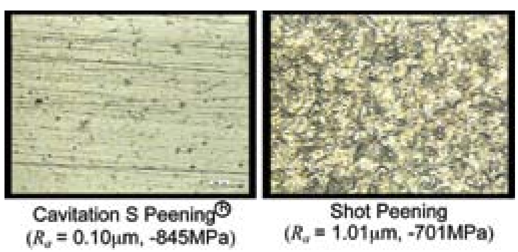

Figure 9. Peened surface and residual stress (SKD61)[5]

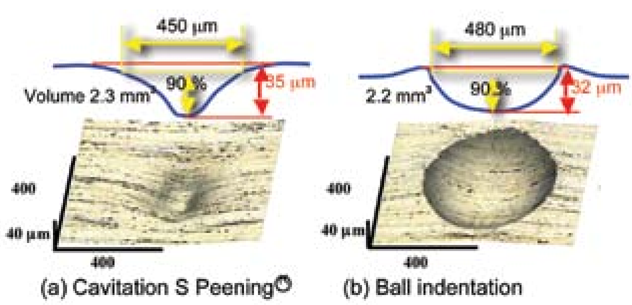

Figure 10. Aspect of pit[6]

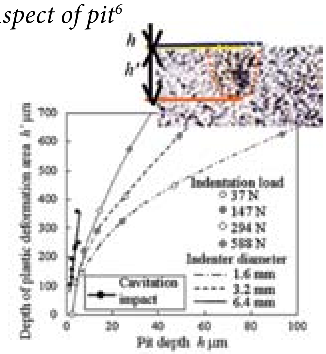

Figure 11. Depth and plastic deformation area[7]

4. H.Soyama, D.O.Macodiyo and S.Mall, "Compressive Residual Stress into Titanium Alloy Using Cavitation Shotless Peening Method," Tribology Letters, Vol. 17, No. 3, 2004, pp. 501 - 504.
5. H.Soyama, "Introduction of Compressive Residual Stress Using a Cavitating Jet in Air," Trans. ASME, Journal of Engineering Materials and Technology, Vol. 126, No. 1, 2004, pp. 123 - 128.
6. H.Soyama, "Distribution of Residual Stress around Plastic Deformation Pit Induced by Cavitation Shotless Peening," Proceedings of 2005 Annual Meeting of JSME/MMD, 2005, pp. 361 - 362.
7. A.Kai and H.Soyama, "Visualization of the Plastic Deformation Area beneath the Surface of Carbon Steel Induced by Cavitation Impact," Scripta Materialia, Vol. 59, No. 3, 2008, pp. 272 - 275. Intelligent Sensing of Materials Lab., Department of Nanomechanics, Tohoku