Cavitation S Peening®

S : Shotless, Shockwave, Smooth, Soyama

Cavitation S Peening® is a peening method using **cavitation** impacts in the same way as shot peening 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**.

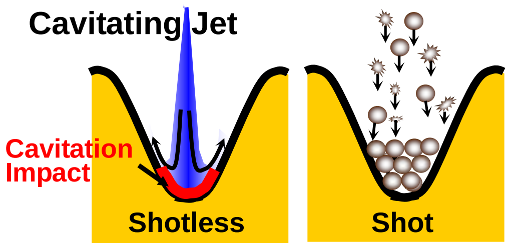
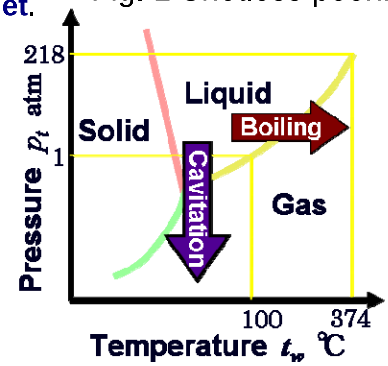


Fig. 1 Shotless peening and shot peening

Cavitation is phase change phenomena from liquid-phase to gas-phase. It is similar to boiling, but, in the case of cavitation, 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. At the cavitation bubble collapse, 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 shrink, the cavitation bubble rebounds. At the rebound, shock wave is produced. The shock wave also produces plastic deformation (see Fig. 3).



Bernoulli's equation

$$\frac{v^2}{2}\rho + p + g\rho z = const.$$

Flow velocity ↑ Static pressure ↑ Head ↑

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

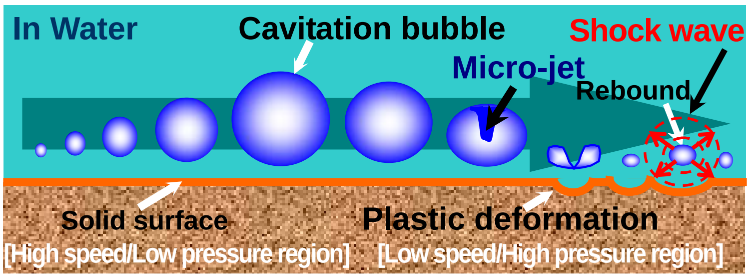
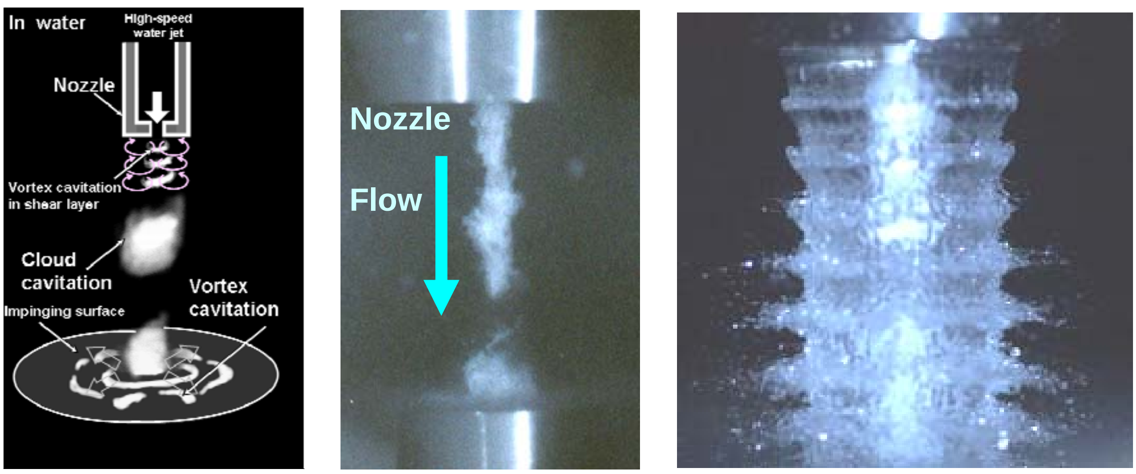


Fig. 3 Schematic diagram of cavitation bubble

Cavitating jet is a jet with cavitation bubbles produced by injecting a high-speed water jet into water (see Fig. 4). 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 big cavitation cloud is produced. When the cavitation cloud hit the surface, cavitation impacts are produced at bubble collapses. Soyama successfully produced cavitating jet in air by injecting a high-speed water jet into a low-speed water jet.



Schematic diagram　Cavitating jet in water　Cavitating jet in air

Fig. 4 Schematic diagram and photo of cavitating jet

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— Improvement of Fatigue Strength —

Cavitation S Peening® improves the fatigue strength of gear 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.

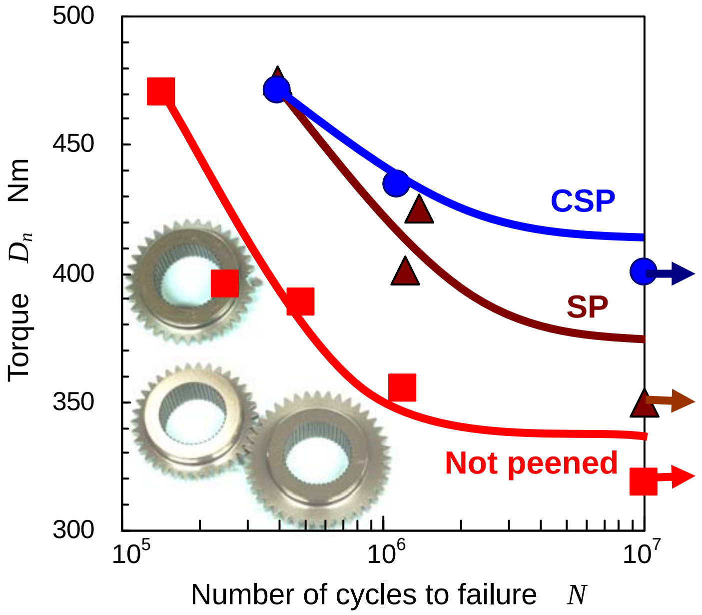

Fig. 5 Improvement of fatigue strength of gear demonstrated using a power circulating type gear tester (Carburized SCM420H)*[1]

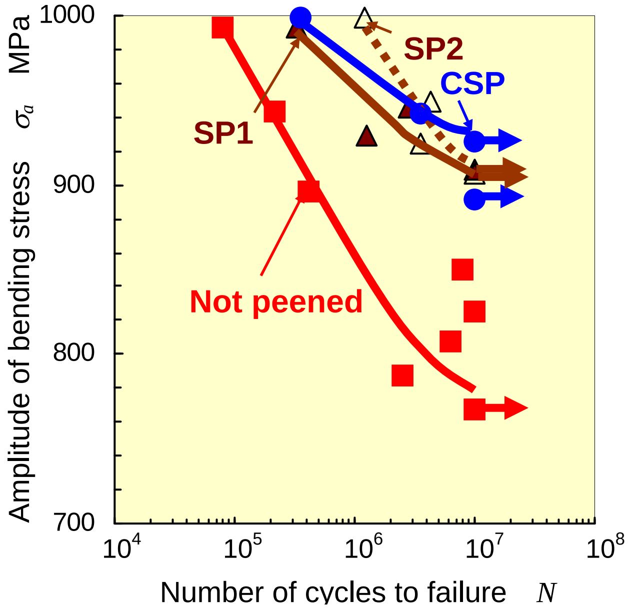

Fig. 6 *S-N* curve of rotating bending fatigue test (Carburized SCM420)*[2]

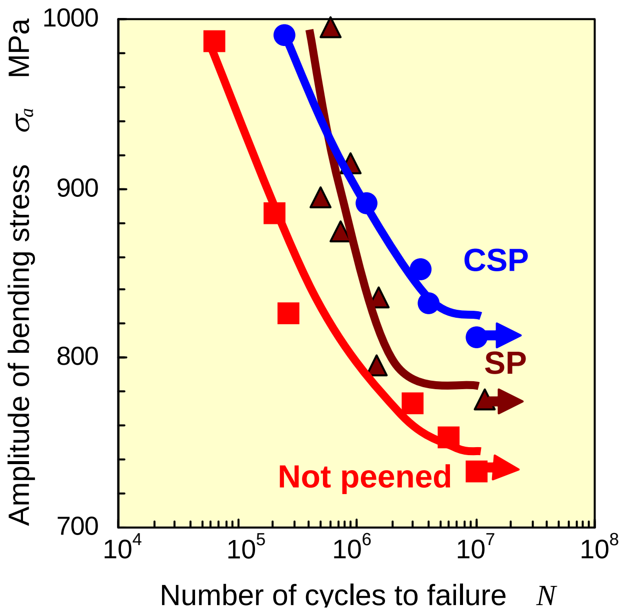

Fig. 7 *S-N* curve of rotating bending fatigue test (Carburized SCM415)*[3]

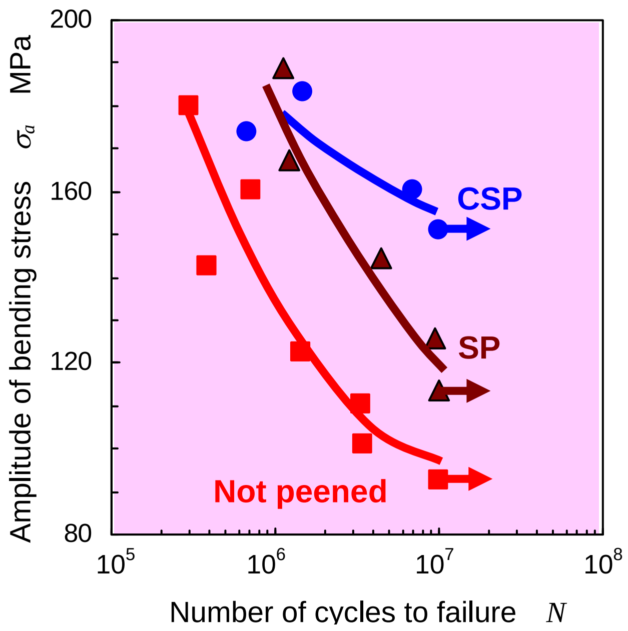

Fig. 8 *S-N* curve of rotating bending fatigue test (AC4CH-T6)*[4]

*[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] D.Odhiambo and H.Soyama, "Cavitation Shotless Peening for Improvement of Fatigue Strength of Carbonized Steel," *International Journal of Fatigue*, Vol. 25, Nos. 9-11, 2006, pp. 1217 - 1222.

*[4] 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 a considerable less surface roughness compared to that from shot peening (see Figs. 9 and 10). Individual pit induced by Cavitation S Peening® does not have sharp tip up around the pit, compared to a pit induced by ball indentation at nearly constant volume and depth (see Fig. 11). It is very shallow compared to the pit at constant depth of plastic deformation area (see Fig. 12).

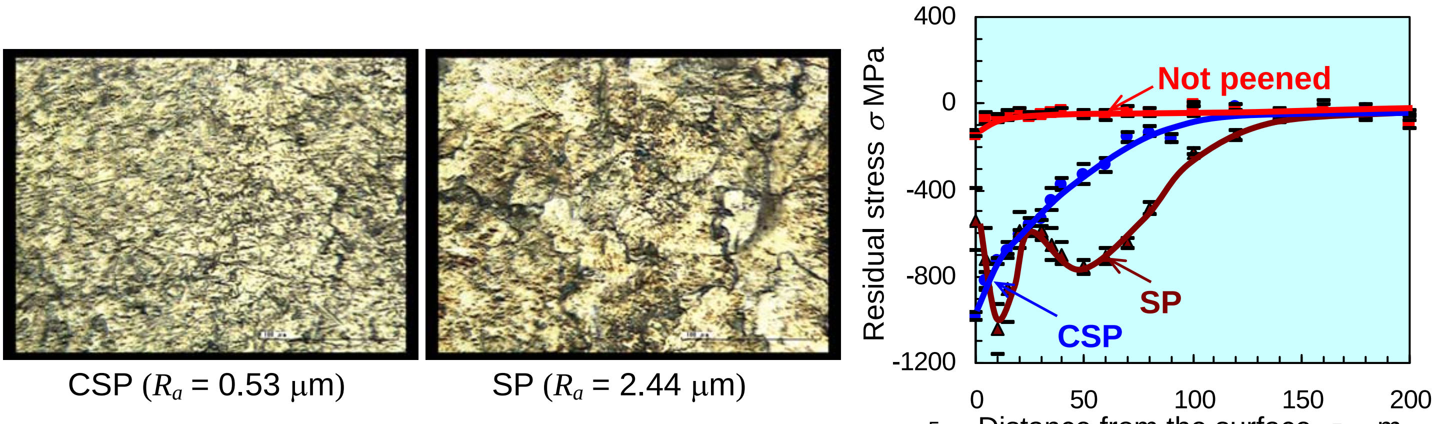

Fig. 9 Peened surface and residual stress (Ti-6Al-4V)*[5]

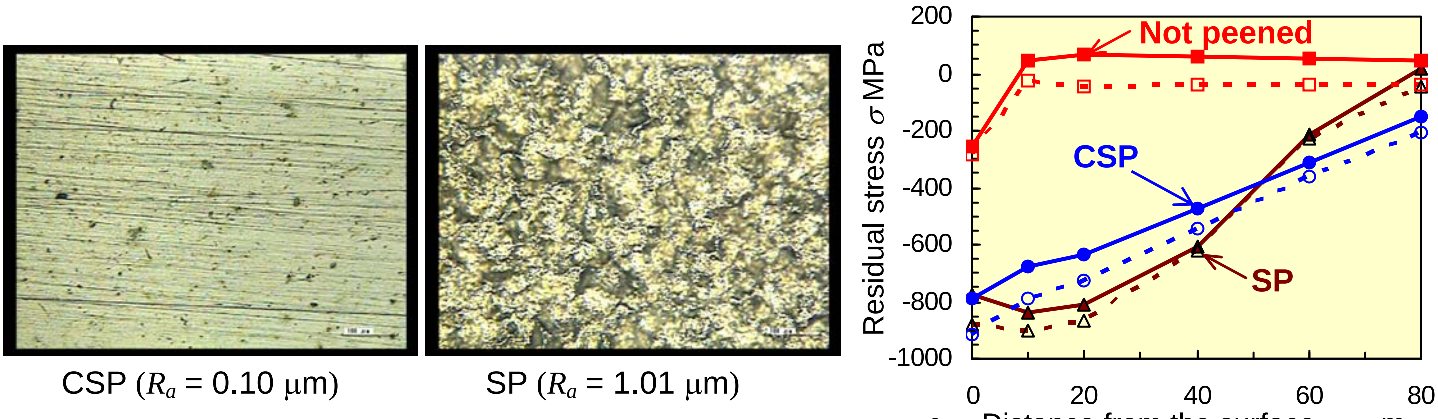

Fig. 10 Peened surface and residual stress (SKD61)*[6]

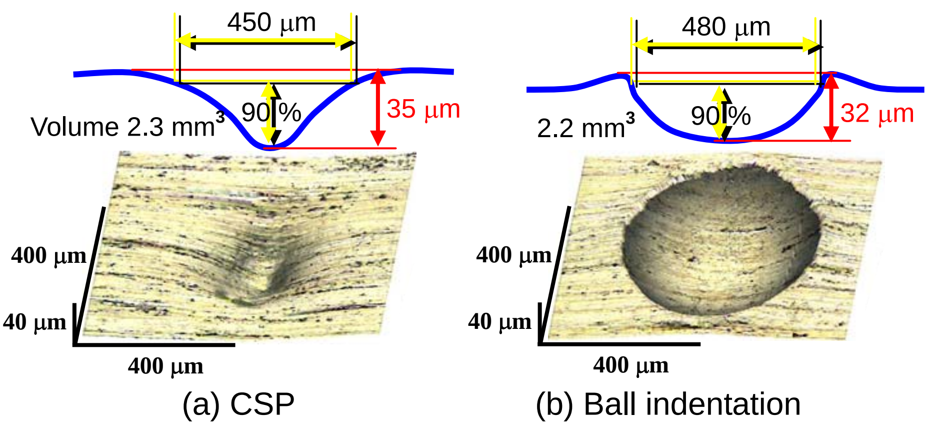

Fig. 11 Aspect of pit*[7]

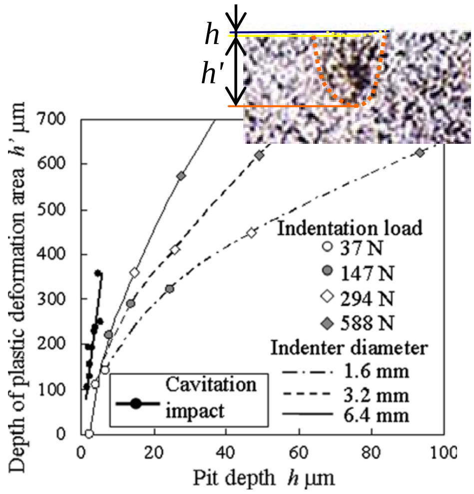

Fig. 12 Depth and plastic deformation area*[8]

*[5] 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.

*[6] 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.

*[7] 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.

*[8] 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.

— Singularity of CSP —

Full width at half maximum of diffracted X-ray profile from alloy tool steel peened by Cavitation S Peening® becomes narrower than that of not peened specimen (see Fig. 13). The ratio of arc height between N-gage and A-gage of Almen strip peened by Cavitation S Peening® is different from that of shot peening (see Fig. 14).

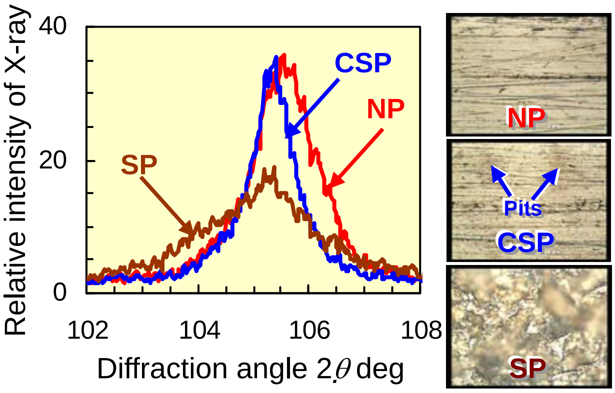

Fig. 13 Diffracted X-ray profile and peened surface of alloy tool steel SKD61*[9]

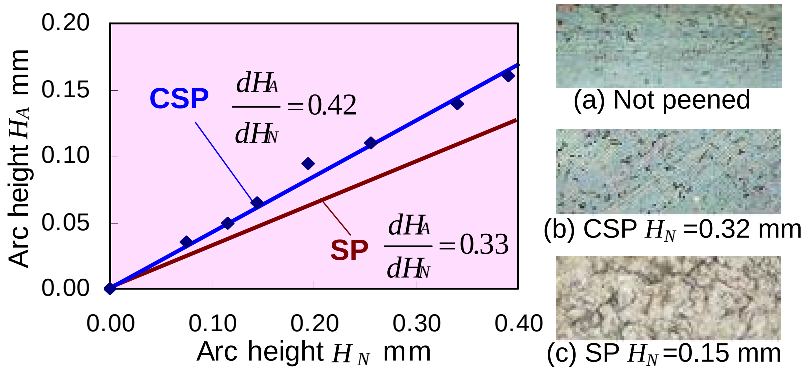

Fig. 14 Relation on arc height between N-and A-gauge, and surface of Almen strip*[10]

— Peening Effect —

Cavitation S Peening® can be applied for suppression of cracks induced by heat cycle (see Fig. 15), relief of micro strain (see Fig. 16), peen forming (see Fig. 17), and enhancement of CVT element (see Fig. 18).

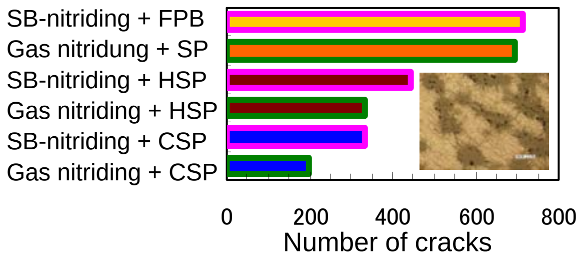

Fig. 15 Number of cracks after heat cycle test*[11]

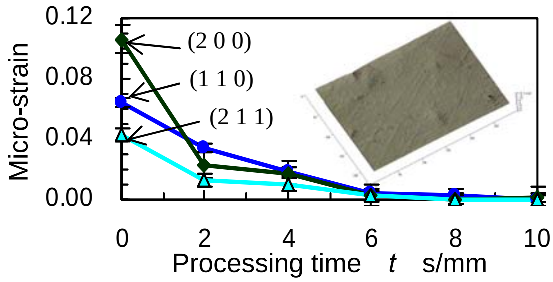

Fig. 16 Relief of micro strain by CSP*[12]

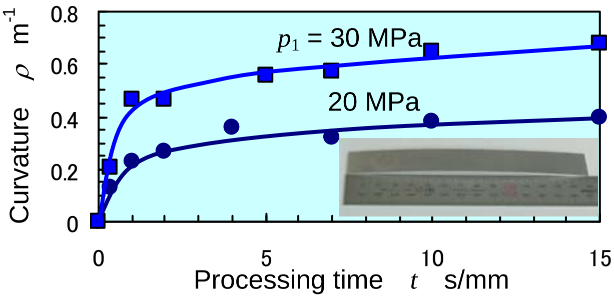

Fig. 17 Curvature induced by CSP*[13]

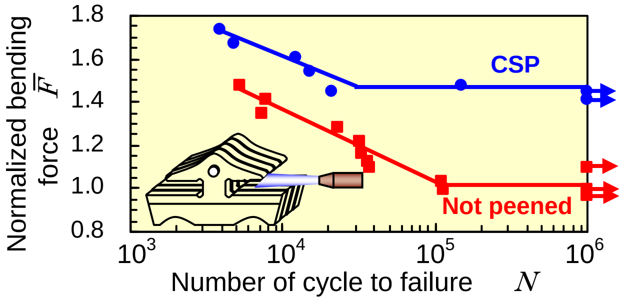

Fig. 18 *S-N* curve of CVT elements*[14]

*[9] H.Soyama, "Macro and Micro Strain in Polycrystalline Metal Controlled by Cavitation Shotless Peening," *Metal Finishing News*, Vol. 7, November issue, 2006, pp. 48 - 50.

*[10] H.Soyama, H. Kumano, K. Saito and M. Saka, "Evaluation of Peening Intensity of Cavitation Shotless Peening by Using Almen Strip," *Proceedings of APCFS & ATEM '01*, 2001, pp. 1047 - 1050.

*[11] H.Soyama, "Surface Modification of Metallic Materials by Using String Cavitation," *Journal of Japan Society for Heat Treatment*, Vol. 48, No. 2, 2008, pp. 74 - 78.

*[12] H.Soyama and N.Yamada, "Relieving Micro-Strain by Introducing Macro-Strain in a Polycrystalline Metal Surface by Cavitation Shotless Peening," *Materials Letters*, Vol. 62, No. 20, 2008, pp. 3564 - 3566.

*[13] H.Soyama and K. Saito, "Peen Forming Using a Cavitating Jet in Air," *Proceedings of Pacific Rim International Conference on Water Jetting Technology*, 2003, pp. 429 - 436.

*[14] H.Soyama, M.Shimizu, Y.Hattori and Y.Nagasawa, "Improving the Fatigue Strength of the Elements of a Steel Belt for CVT by Cavitation Shotless Peening," *Journal of Materials Science*, Vol. 43, No. 14, 2008, pp. 5028 - 5030.

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