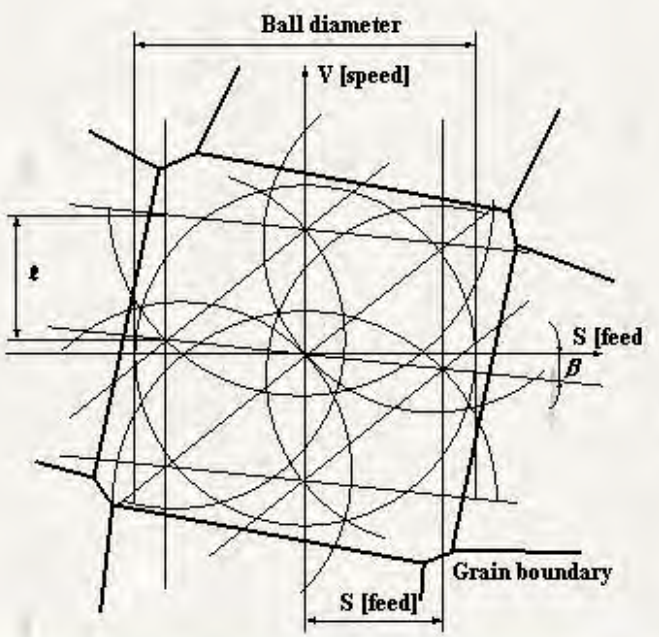
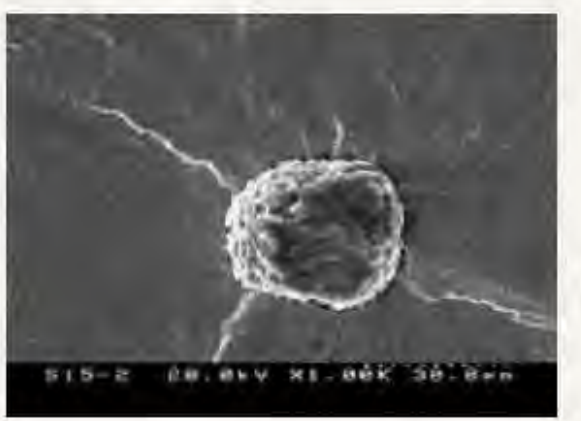
A Technology for the Improvement of Fuel Efficiency and CO2 Emmission in Vehicles

A Technology which integrates the effects of Double Shot Peening, Micro Dimples Surface and Nano Structured Surface in a Single Operation





Introduction about Proposing Technology

- Nano-structure surface modification, known as Ultrasonic Nano-Crystal Surface Modification (UNSM) is an emerging and very promising technology that can be used to solve fatigue and wear/friction related problems.

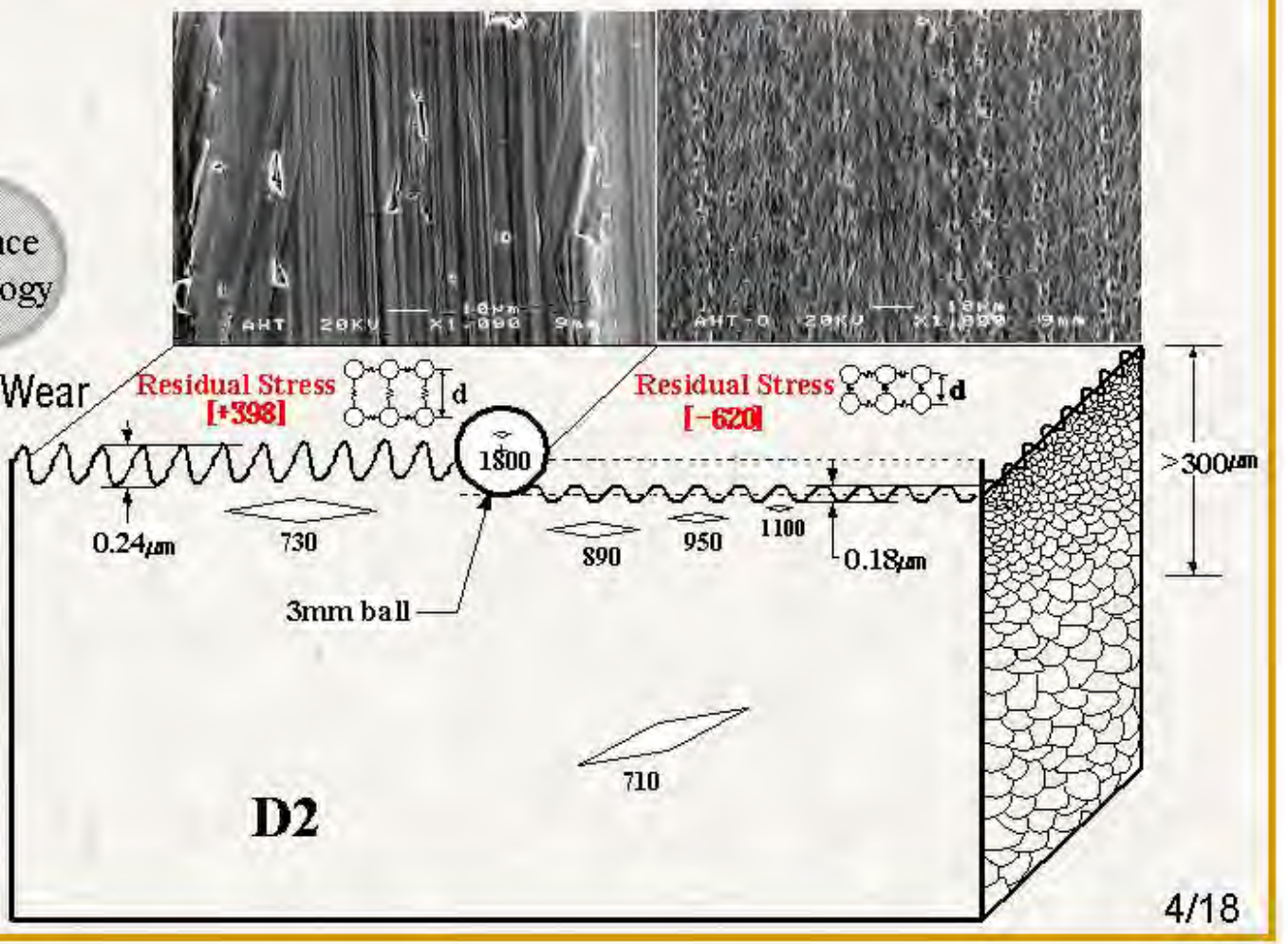
- Unlike other technologies, nano-structured surface modification directly improves the fatigue-strength of the surface by simultaneously inducing relatively large and deep compressive residual stresses, increasing the surface hardness, reducing surface roughness, eliminating micro-cracks and white layers on the surface, while also significantly reducing the coefficient of friction. Given these benefits, the same technology can also be applied gears, bearings, crankshafts, cylinder, and etc. In fact, this technology has already been successfully applied to the knives, rollers, and bearings extensively used by steel industry.

The potential and significant benefits of the proposed UNSM treatment for power train elements

	Results of UNSM	Anticipated Benefits
1	Nanocrystal Microstructure (Grain Sizes of 50-200 nm)	1) Increased tensile strength, 2) Increased fatigue strength, 3) Increased hardness, 4) Increased wear resistance
2	Deep Compressive Residual Stresses (Greater than 1000MPa and at depths of at least 1000 μm)	Improved LCF and HCF fatigue endurance limit
3	Dimple Surface (Area: 1-2 μm^2, Depth : sub micron, Pattern pitch: few μm)	1) Reduced surface roughness 2) Decreased friction coefficient

A UNSM Technology which integrates the effects of Double Shot Peening, Micro Dimples Surface and Nano Structured Surface in a Single Operation

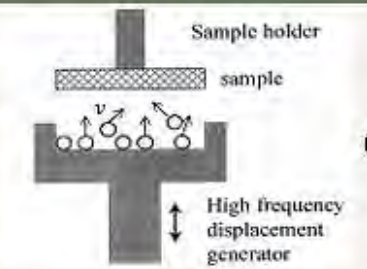
Ultrasonic Nano Crystal Surface Modification Technology



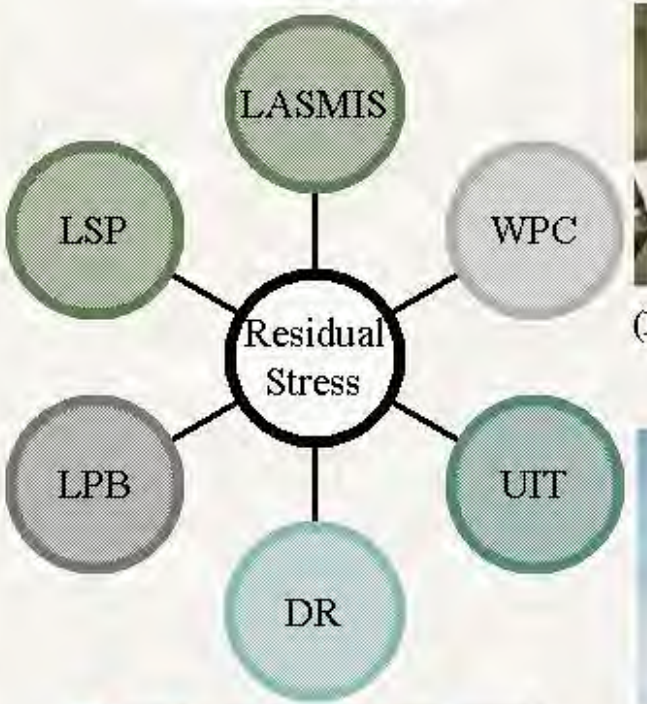
Schematic diagram of main effects

Related Technologies on Peenings for Compressive Residual Stress

(Laser Shot Peening)
[www.lspt.com]
[www.metalimprovement.com]



(Ultrasonic Micro Peening/SONATS)



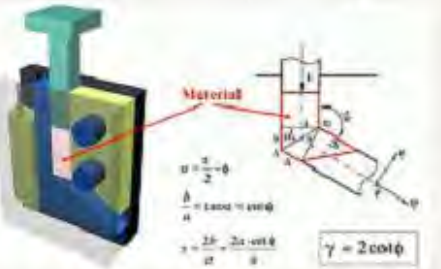
(Fine or Micro Shot Peening)

(Low Plasticity Burnishing)
[www.surfaceenhancement.com]

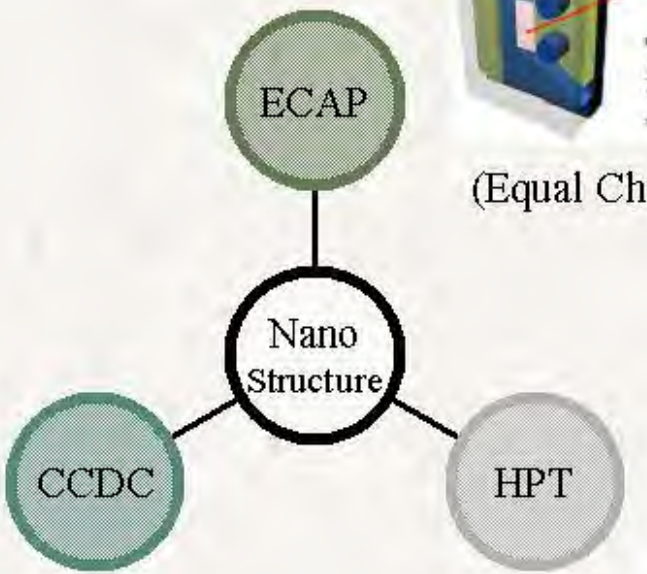
(Ultrasonic impact treatment)

(Deep Rolling)
[www.ecoroll.de]

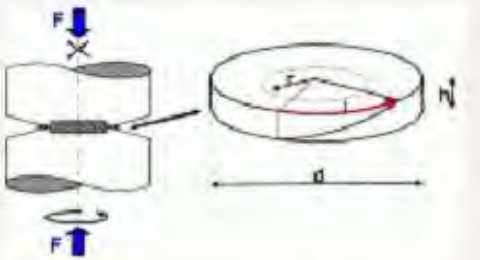
Related Technologies on Nano Structured Materials



(Equal Channel Angular Pressing)



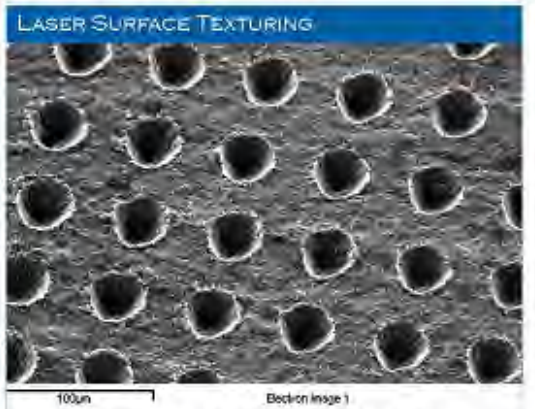
(Cyclic Channel Die Compression)



(High Pressure Torsion)

Related Technologies on Wear and Friction

Surface Topology : Improvements of Wear Resistance and Friction Loss



Laser Surface Textured Titanium with 0.050 mm Diameter Divots

[www.mlpc.com]
[www.fricso.com]
[www.surface-tech.com]

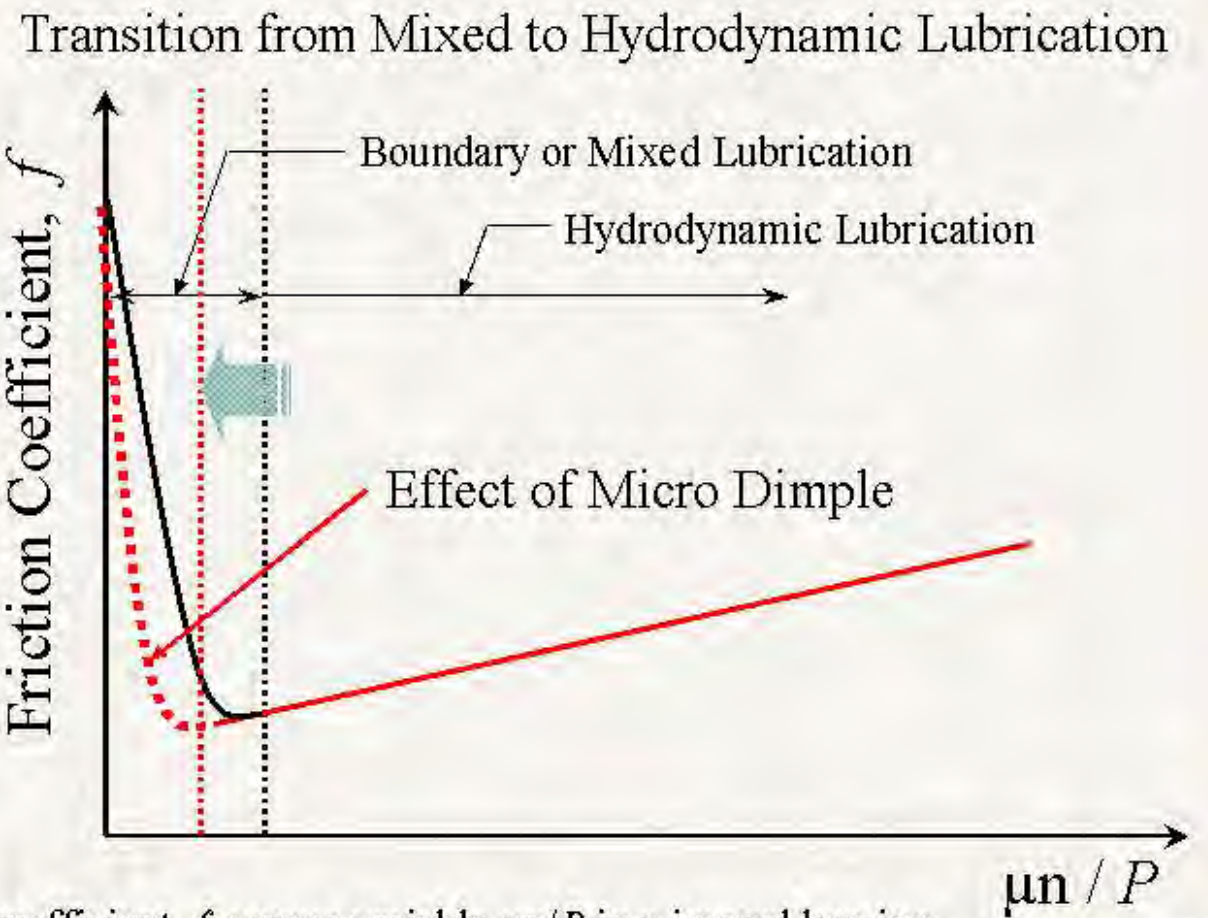
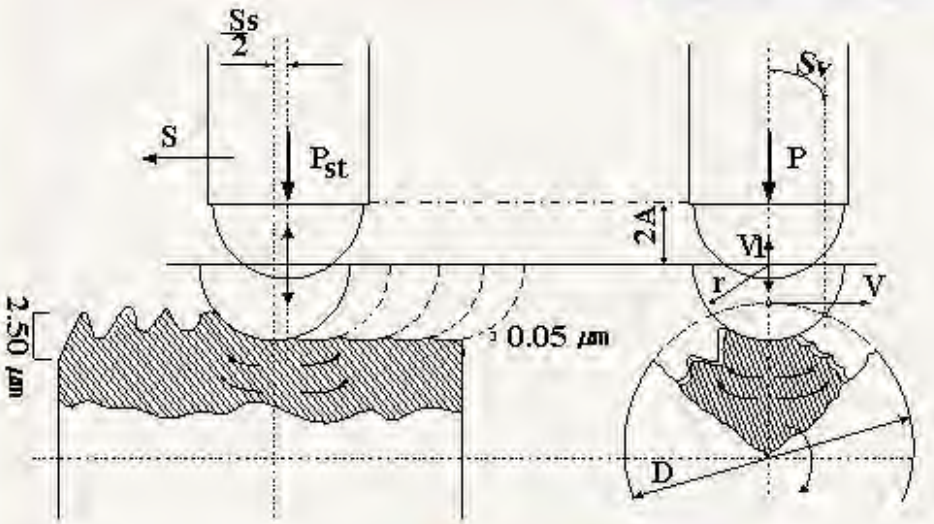
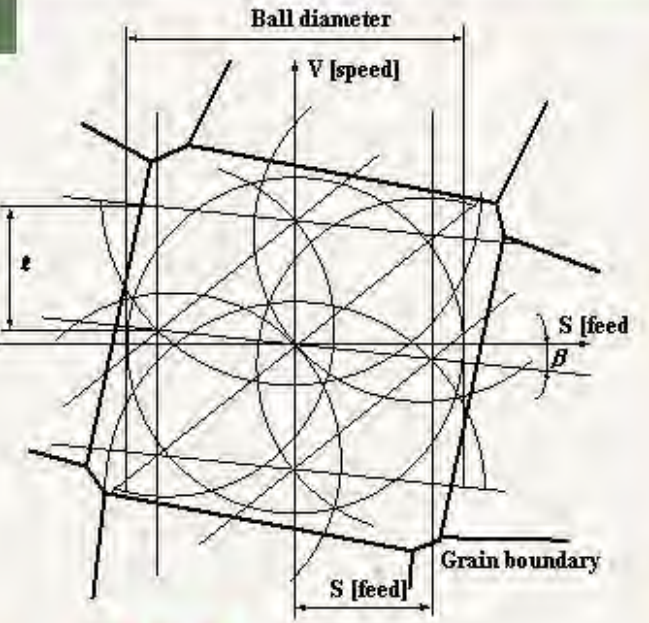


Fig. Friction coefficient, f, versus variable $\mu n/P$ in a journal bearing

Ultrasonic Nano Crystal Surface Modification Technology

Basic mechanism of UNSM





$$P_t = P_{st} + P_{dy}$$

P_t : total contact load
P_{st} : static load
P_{dy} : dynamic load (psin2ft)

$$N = \frac{60 \cdot f}{V \cdot S}$$

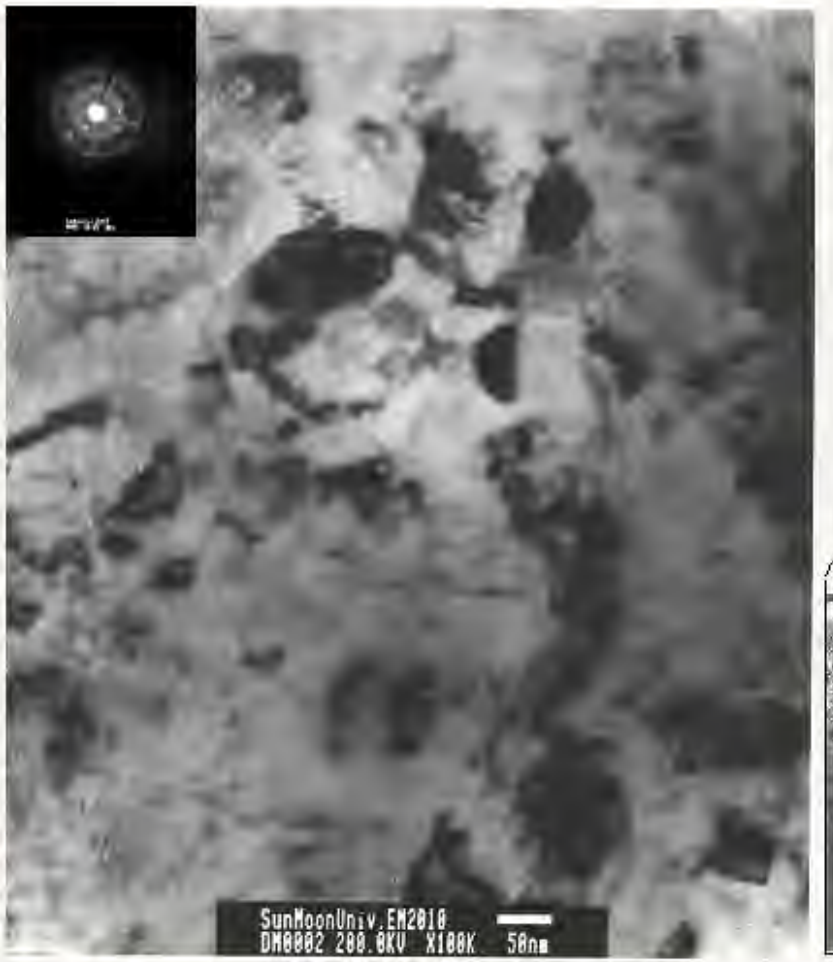
Pst : static load
V : speed [m/min]
D : Specimen diameter
A : amplitude
S : feed [mm/rev]
r : ball radius

N : Contact count per unit area [mm^2]
f : Frequency [kHz]
V : Speed [mm/min]
S : Feed [mm/rev]

UNSM operate in the Ultrasonic frequency range, 20,000 to 40,000 impacts per second.

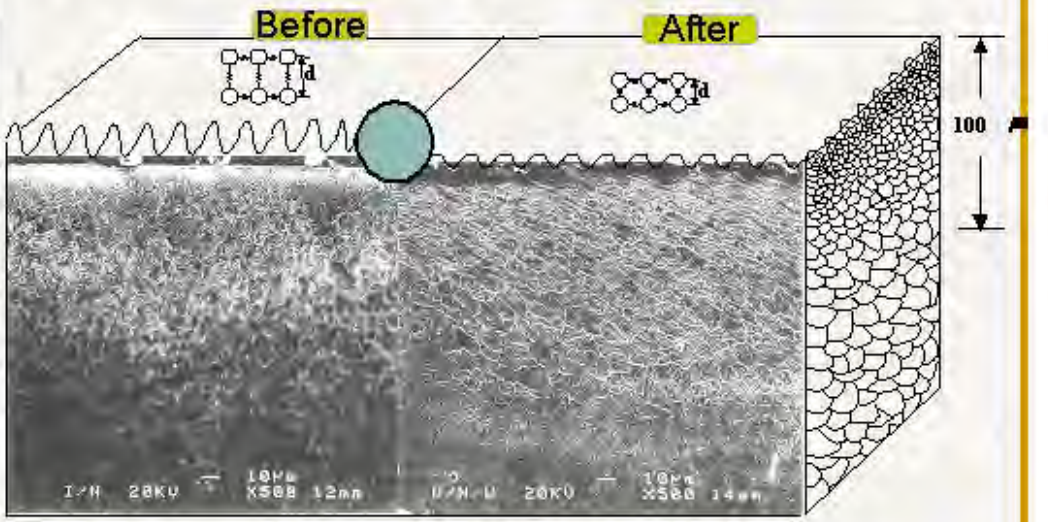
Generally, our device makes 1000 to 10,000 shots per square millimeter on the work surface.

Grain Size Miniaturization (Nano Crystal Structure) Test Example - SKD61



This picture shows that after UNSM the grain size miniaturized is on the Nano level.

There are no comparable studies about this topic for materials treated with LSP and LPB. One of the outstanding points of UNSM compared with other surface technologies is nano grain sized semi-crystal structure. FE SEM or TEM is using for this evaluation. A test result of UNSM treatment on Tool steel SKD61 is shown in the figure at left.

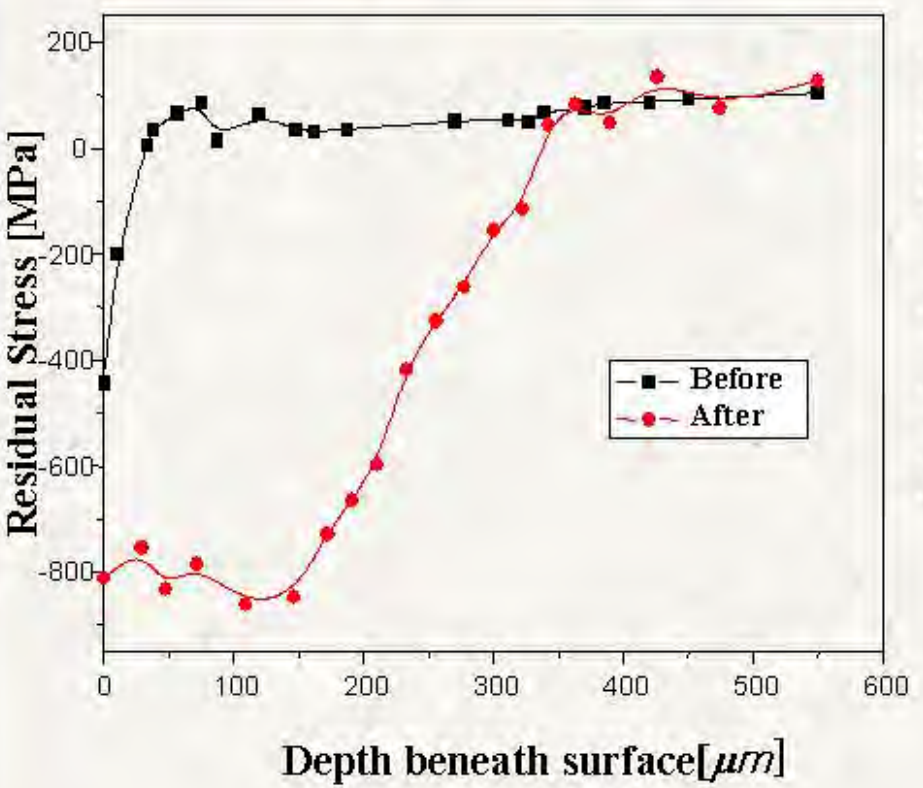


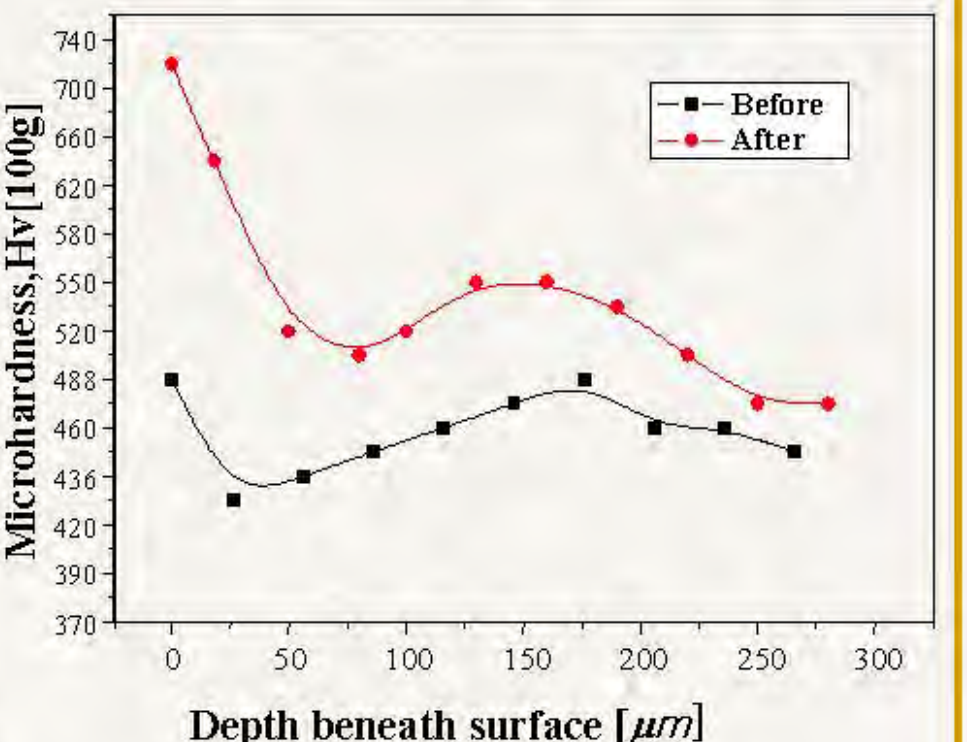
Grain size becomes nano size (about 50nm) and residual stress is compressed by a vibrating ball striking the surface

Nano grain structure retards crack initiation, decrease wear rate, and increase toughness.

Compressive Residual stress and Surface hardness

Now, Greater than 1000MPa
at depths of at least 1000 μm





Test Example - SKD61

Surface topology (Micro Dimple Structure)

Test Example - SKD61

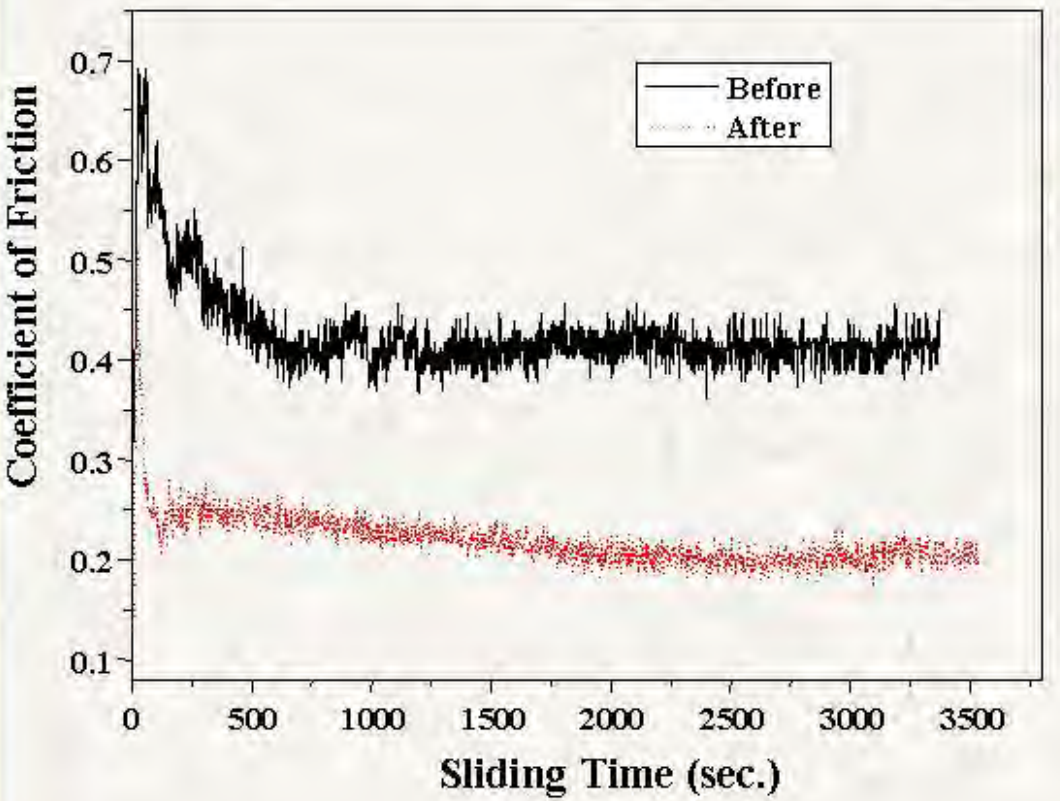
UNSM creates microscopic embossing on the surface of the workpiece.
The embossed surface reduces the coefficient of friction.

Surface treatment by UNSM not only improves surface finish but also REMOVES micro hair CRACKS on the surface, thus retarding crack initiation and wear initiation.

Before After (Micro Dimples)

Wear Failure/Friction Loss

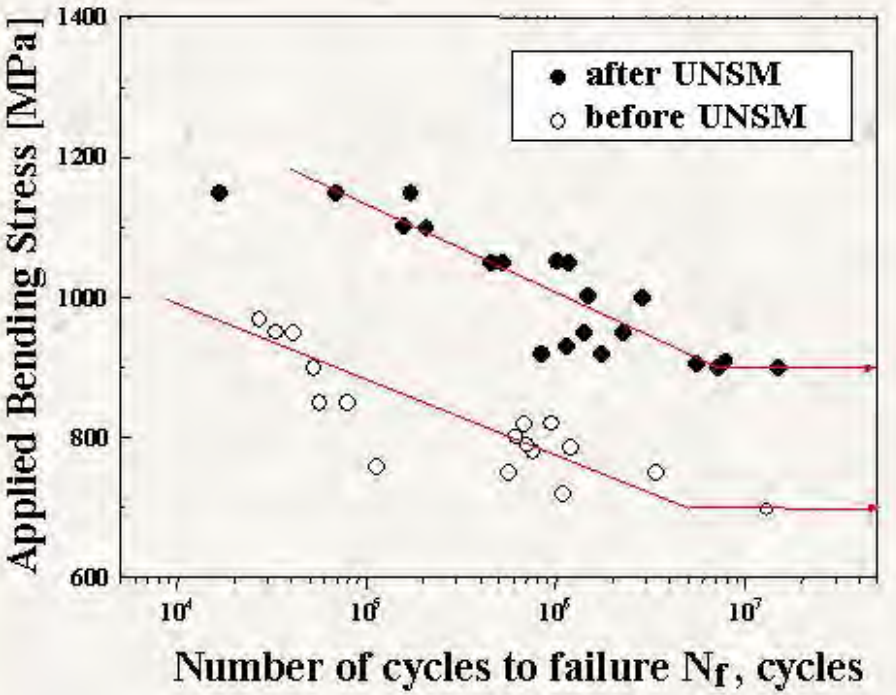
The surface treatment by UNSM is shown to decrease the friction coefficient. That means the surface wears smoothly and slowly. Micro dimples on the surface give main effect to decrease the friction coefficient



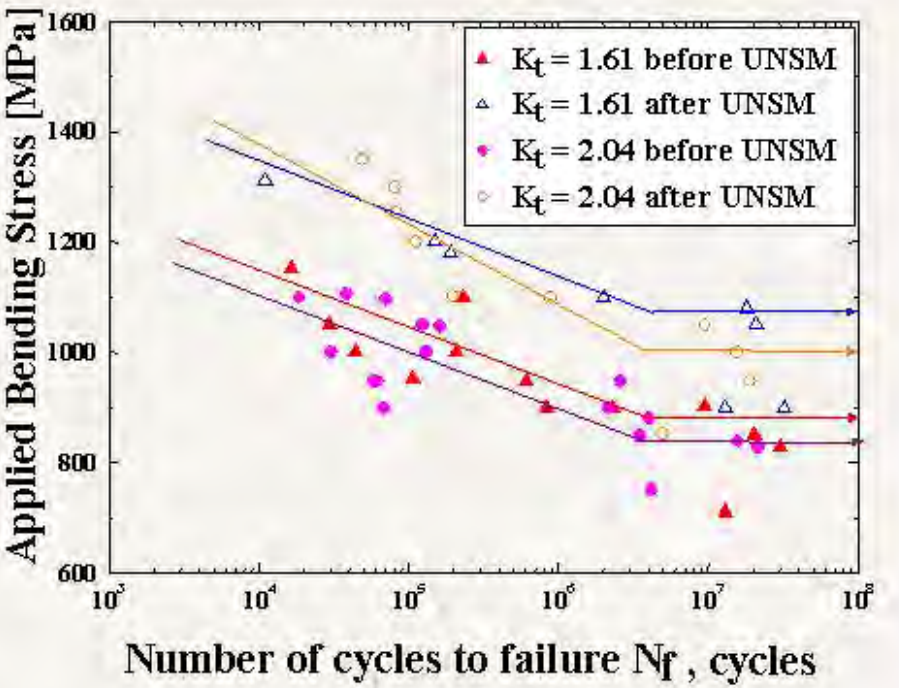
UNSM	Wear amount (mg)	Friction coefficient
Before	1.179	0.42
After	0.039	0.21~0.24

Fatigue Failure

Test Example - SKD61



S-N curves of smooth specimen
before and after UNSM
(25% increase in fatigue strength)

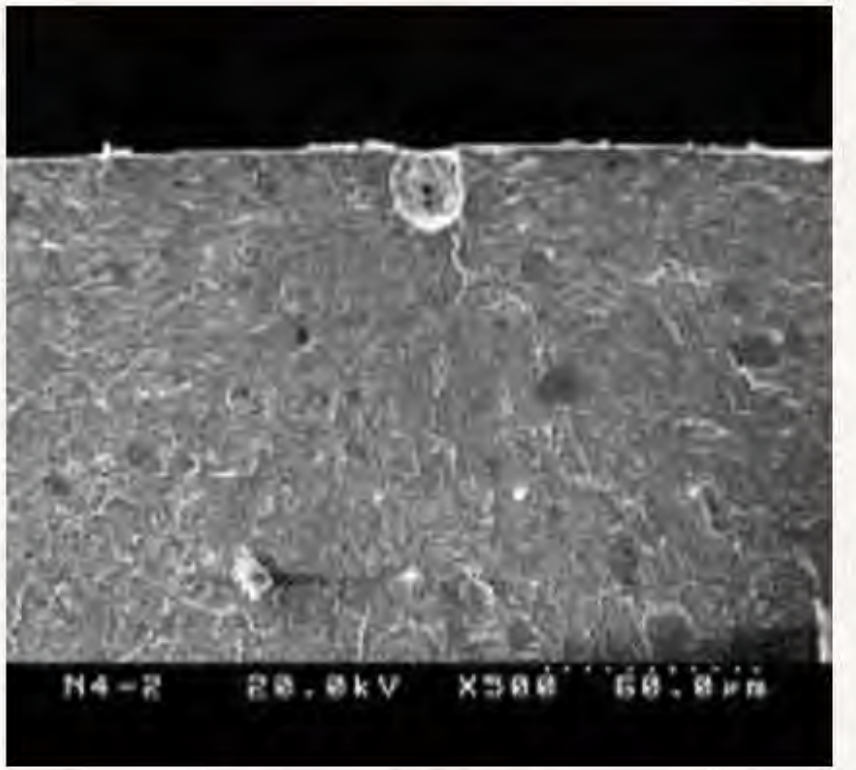


S-N curves of notched specimen
before and after UNSM
(20% increase in fatigue strength)

Fatigue Failure

SEM micrographs of fracture surface of surface-originating fracture before UNSM

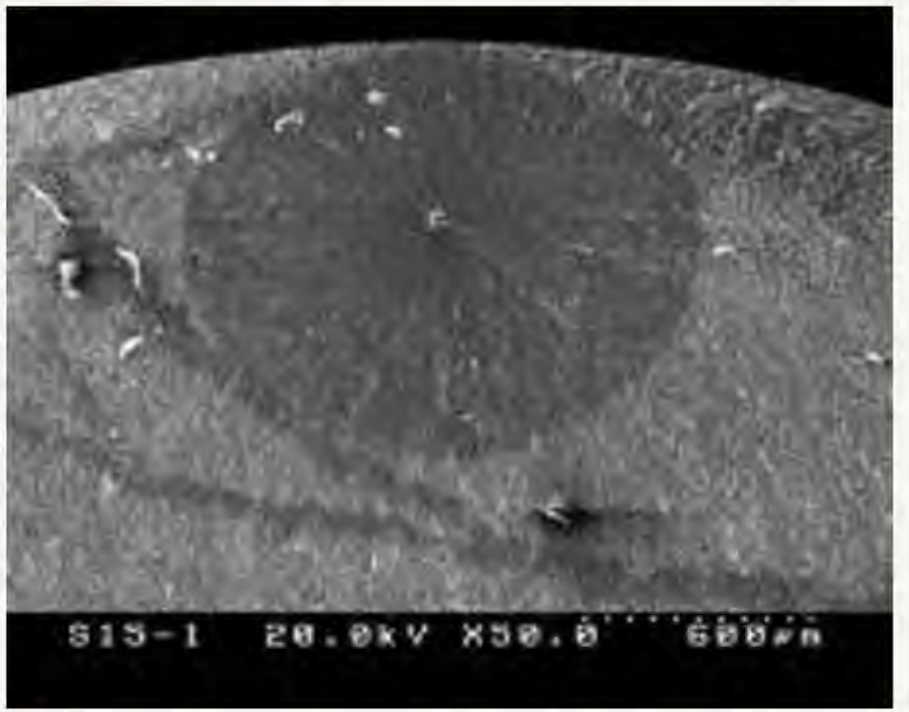
Low magnification view



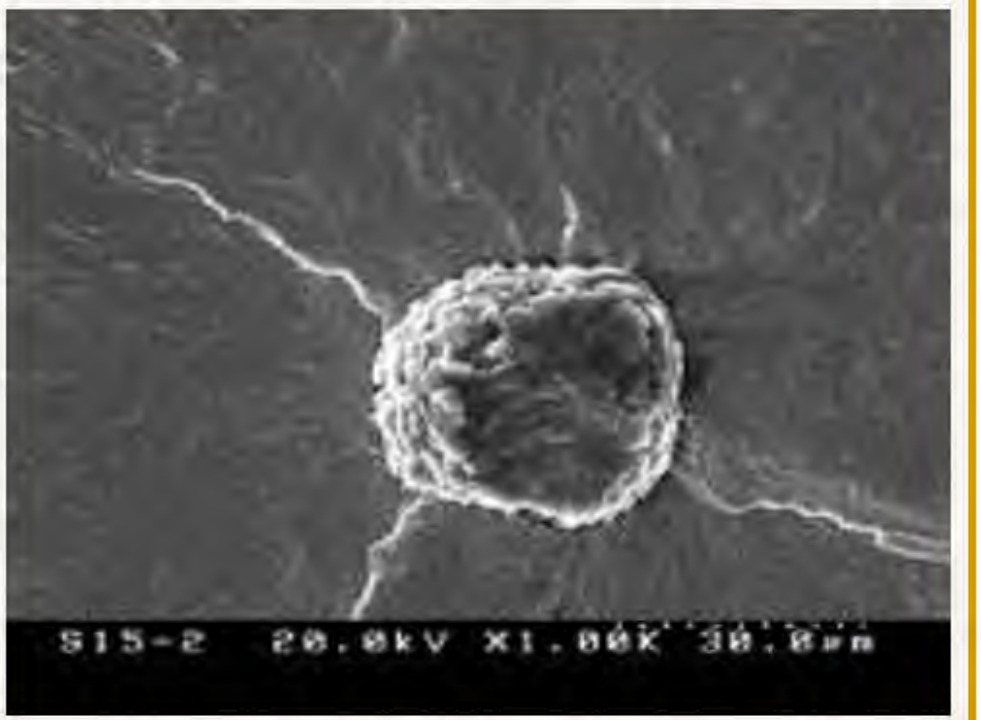
Enlargement of marked

Fatigue Failure

SEM micrographs of interior-originating fracture after UNSM



Low magnification view of fish-eye crack



Enlargement fish-eye

Device and Equipments in Industry

Successful Application in Industry

Industrial Knives

Bearings

Cases

Leveler Roll

Roll for Steel Industry

Plunger Tip

Forming Roll

Breaker piston & spool

Titanium Pin & Remer bolt

Grinding shaft

유압모터 Swash

cam Follower

<Some Published Papers about UNSM Technology

1. Pyoun Y. , H. S. Kim, K. G. Son, G. H. Song, M. K. Kim, J. H. Kang, B.U. Choi, Jin Park, I. H. Cho, C. S. Kim, J. H. Park, J. Kinney, " Development of D2 Tool Steel Trimming Knives with Nanoscale Microstructure" AISTech 2005 Proceedings – Vol. 2, pp. 465-473, May 2005.
2. Cho Inho, G.H. Song,C.S. Kim, Azuma Nobuhide, A. Combs, Jin Park, C. M. Suh, J.H Park, Y.S. Pyoun, "Nano structured Surface Modification of Tool Steel and It's Beneficial Effects in Mechanical Properties" Journal of Mechanical Science and Technology<KSME, I. J.>, Vol. 19, No. 11, pp.2151-2156, 2005.
3. Suh, C. M., G. H. Song, "Effect of ultrasonic vibration energy on mechanical characteristics and the trimming during cold rolling", Proceeding of 21st international symposium on reliability of materials and structure, JMSE, Dec. 2005.
4. Pyoun Y. , M. K. Kim, J. H. Kang, C. Lee, B.U. Choi, Jin Park, I. H. Cho, C. S. Kim, J.H. Lee, J. H. Park, J. Kinney, "Extending Service Life by Surface Modification of Local Area on Stretch Level Roll in PL-TCM Line, AISTech 2005 Proceedings Vol. 2, pp. 345-354, May 2005
5. Pyoun Y., B. K. Kim, K. J. Choi ,B.U. Choi ,Jin Park, I. H. Cho, C. S. Kim, J. H. Park, J. Kinney ,K. Zhang, N. Y. Tang, "Development of a Method of Nano Surface Structure Modification on a SUS 316L Pot Bearing and its Characteristics in a Test Rig and in Industry, AISTech 2005 Proceedings, Vol. 2, pp. 601-612, May 2005
6. Park Y. J, Y. S. Pyoun, "Development of Ultrasonic Nanocrystal Surface Modification (UNSM) Technology," Poster Presentation at the Defense Manufacturing Conference 2005, Nov. 28 - 30, 2005, Orlando, FL
7. Pyoun Y. J. Park, C.Park, I. Cho, J. Lee, A. Nobuhide, I.S. Cho, A. Combs, "A study on substituting pure titanium (grade 4) for implant Ti-6Al-4V utilizing nano urface technology" Proceeding of Biomechanics, spring, KSPE, pp.143-146, 2004.
8. Suh.C.M, Song G.H, Pyoun Y. S. "Fatigue and mechanical characteristics of nano-structured tool steel by ultrasonic cold forging technology" J Mat. Sci. Eng. A, Vol.443, pp. 101-106, 2007
9. Suh. C.M, Song G.H, Park H.D, Pyoun Y.S," A Study of the Mechanical Characteristics of Ultrasonic Cold Forged SKD 61", I.J. of Modern Physics B, Vo.2(27), pp. 4541-4546, 2006