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journal or publication title	Proceedings of the International Offshore and Polar Engineering Conference
volume	2007
page range	3338-3342
year	2007-01-01
URL	http://hdl.handle.net/2297/19679

Proceedings of the Seventeenth (2007) International Offshore and Polar Engineering Conference
Lisbon, Portugal, July 1-6, 2007

ISBN 978-1-880653-68-5; ISBN 1-880653-68-0(Set); ISSN 1098-6189 (Set)

Influences of Shot-Peening on Fine Grain Steels

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ABSTRACT

Recently, fine grain steel has been actively researched. However, as we know, the influence concerning the shot peening processing to fine grain steels has been few reported up to now. Therefore residual stress distribution near the surface of fine grain steel after shot-peening was measured by X-ray diffraction technology. Moreover, the hardening effect the distributed near the shot-peened surface was also estimated. The relationships between the effects of shot-peening and the grain size of material were discussed.

KEY WORDS: Fine grain steel; Shot-peening; Residual stress; Vickers hardness; X-ray; FWHM

INTRODUCTION

Recently, the study of fine grain steels that aims to achieve to high strength is active. Fine grain steel can highten the yield stress as expected from the Hall-Petch relation. Therefore, the ecomical design is expected to be realized. usually, Fine grain steel is made by the strong distortion processing. As specimens for this paper, The ratio of extending by rolling is 90% or more. And, the made metal doesn't add the alloy element. Therefore, material is an excellent material in various characteristics and recyclabilities. And material is expected to be used in various fields in the future.

For instance, it is considered to use for the structure material. Welding is one of the most useful method to connect the structure components. For that case, the negative influence of residual tensile stress that occurred in the welding processing must be considered. It has been proved that the shot peening processing can solve this problem effectively. However, the influence concerning the shot peening processing to fine grain steels has been few reported up to now. In this study, JIS-SM490 and NGF600 were used, and three kinds of specimens were obtained after heat treatment. Residual stress distribution near the surface of fine grain steel after shot-peening was measured by X-ray diffraction technology. Moreover, the hardening effect the distributed near the shot-peened surface was also estimated. The relationships between the effects of shot-peening and the grain size of material are discussion.

Experimental

Annealing processing

SM490 and the minute making the crystal grain equivalent material NFG600 in the rolled steel plate for the welding structure as the specimen are used this paper. However, it should know what influence a average grain size of fine grain steel and initial hardness gives to the shot peening processing. For that reason, We clarified the relation between grain size and Vickers hardness beforehand for that. Fig. 3 shows the experiment result. This experiment is a result of annealing by 523-1173K, making NFG600 of various grain sizes, and measuring Vickers hardness.

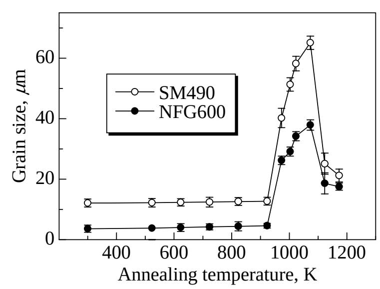


Fig. 1. Relation between annealing temperature and grain size

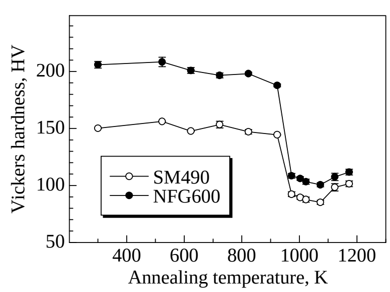


Fig. 2. Relation between annealing temperatureand Vickers hardness.

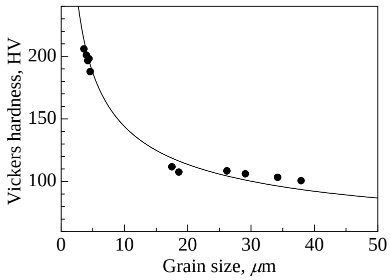


Fig. 3. Relation between grain size and Vickers hardness.

The relational expression of Hall-Petch was used for the relation. As a result, NFG600 was made same of hardness as SM490. This is called NFGAn in this paper. The condition of annealing NFGAn is to keep for one hour by 1073K in an atmospheric furnace. Incidentally, the Eq.1 can show the relation of Hall-Petch.

$$\sigma_Y = \sigma_0 + kd^{-\frac{1}{2}} \qquad (1)$$

σ_Y is a yield stress.

σ_0 , k are a constant.

d is average grain size.

Specimen

Preprocessing

The chemical composition of SM490 and NFG600 are shown in Table 1. And, mechanical properties before it processes it to Table 2 are shown.

Table 1. Chemical compositions (wt.%).

	C	Si	Mn	P	S
SM490	0.16	0.25	1.60	0.018	0.005
NFG600	0.17	0.36	1.30	0.011	0.007

Table 2. Mechanical properties.

	Yield stress, MPa	Tensile strength, MPa	Elongation, %
SM490	358	543	25
NFG600	461	602	30

First of all, these specimens were cut out to the size of 30×30×10. Next, the influence of extending by rolling was removed by grinding the surface of the test piece by 2mm. The electrolytic polishing was done until the residual stress became 0MPa at the end. Moreover, the average of grain size and Vickers hardness in each specimen are shown in Table 3.

Table 3. Grain size and Vickers hardness

	Grain size,μm	Vickers hardness(Hv)
SM490	16	155
NFG600	3	185
NFG600An	6	163

Shot-peening condition

The shot-peening was processed to three kinds of specimens of SM490, NFG600, and NFGAn. There are two kinds a low stress condition and a high stress condition of conditions of the shot peening processing. The shot peening condition is shown in Table 4. Moreover, it is assumed that each test piece is called after this as shown in Table 5.

Table 4. Conditions of shot-peening process.

Stress-type	Low stress	High stress
Peening machine	Air type	Air type
Shot peened material	RCW06AC (0.06%Carbon Steel beads)	BPS150 (Stainless steel beads)
Beads size, mm	ϕ 0.6	ϕ 0.1
Pressure, MPa	0.15	0.3
Peening time, sec	20	15
Distance, mm	100	100
Nozzle diameter, mm	ϕ 9.0	ϕ 9.0
Arc height, mmA	0.02	0.025

Table 5. Name of each specimen

	High stress	Low stress
SM490	SM1	SM2
NFG600An	NFGH1	NFGH2
NFG600	NFGN1	NFGN2

Vickers hardness test

The change in hardness takes place in the vicinity of the surface because of the shot-peening. Therefore, Vickers hardness distribution measured by micro-vickers hardness tester. As for the specimen, it measured the section, cutting a specimen after shot-peening processing to the size of 10×10×30. Vickers hardness distribution was obtained on the perpendicular section of shot-peened surface. As for experimental conditions, examination power were 0.05N and hold time were 30 sec.

Measured by X-ray diffraction

The residual stress that had been given by the shot-peening was measured. X-ray diffraction technology was used to measure the residual stress. We measured it by using $\sin^2\psi$ method. The measurement condition is shown in Table 6. However The X-ray stress measurement is a method of obtaining surface stresses. Therefore the measurement was one by one ground from the surface of the shot peening processing by the electrolytic polishing by about 5μm. The residual stress was measured for each newborn surface. The electro polishing processing used phosphoric acid solution. The processing was done until the stress became an initial state. The expression of a method are shown from Eq. (2) by Eq. (5).

$$\sigma_{11} - \sigma_{33} = -\frac{1}{S_2} \cdot \cot\theta_0 \cdot \frac{\partial(2\theta_0)}{\partial(\sin^2\psi)} \cdot \frac{\pi}{180} \quad \text{(MPa)} \qquad (2)$$

We name S_1 and S_2 as X-ray elastic constants (XEC) and they can be described as follows, E_x and ν_x are X-ray Young's modulus and Poisson's ratio.

$$S_1 = -\frac{\nu_x}{E_x}, \qquad S_2 = \frac{2(1+\nu_x)}{E_x} \qquad (3)$$

Defining K and M as

$$K = -\frac{1}{S_2} \cdot \cot\theta_0 \cdot \frac{\pi}{180} \quad \text{(MPa/deg)} \qquad (4)$$

$$M = \frac{\partial(2\theta_\psi)}{\partial(\sin^2\psi)} \qquad (5)$$

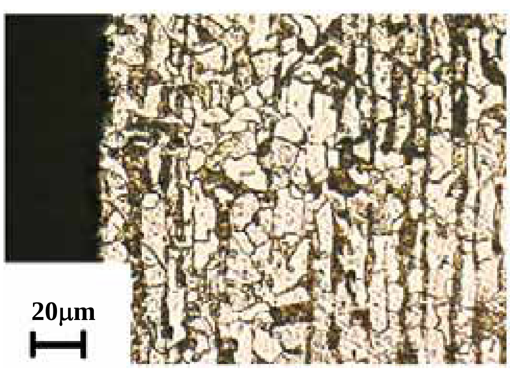
where K is called stress constant and M is the slope of a linear line in the 2θ-$\sin^2\psi$ diagram.

Table 6. Conditions of stress measurement.

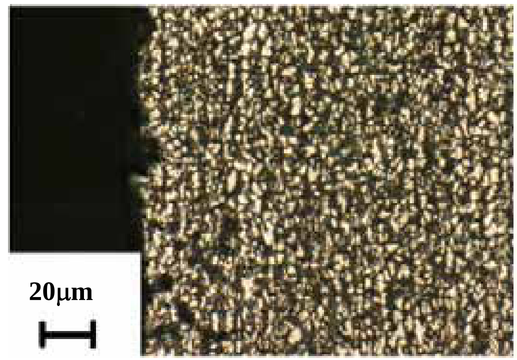
Characteristic X-ray	Cr-Kα
Tube voltage, kV	30
Tube Current, mA	10
Kβ filter	V
Diffraction plane	211
Diffraction angle 2θ, deg	156.41

Experimental Results

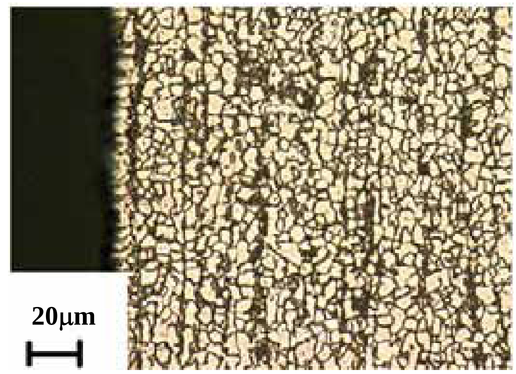
The influence layer by the shot peening that was called nanocrystalline surface layer could not be observed. The influence layer by the shot peening could not be observed from the organization photograph (Fig.4).



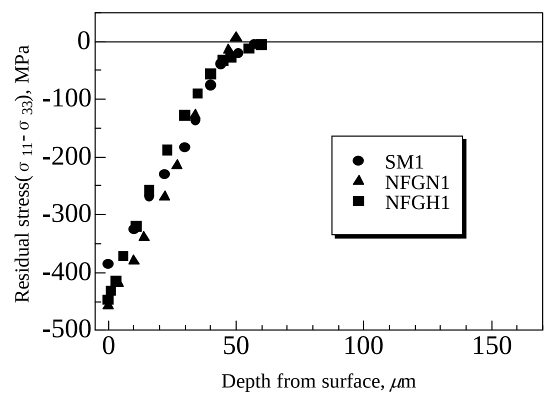
(a) SM490.



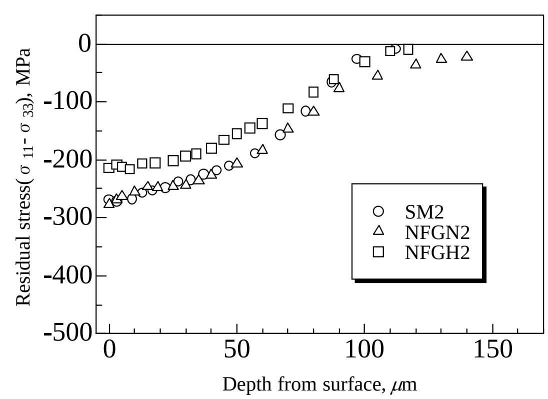
(b) NFG600.



(c) NFGAn.
Fig. 4. Microstructures of shot-peening section.



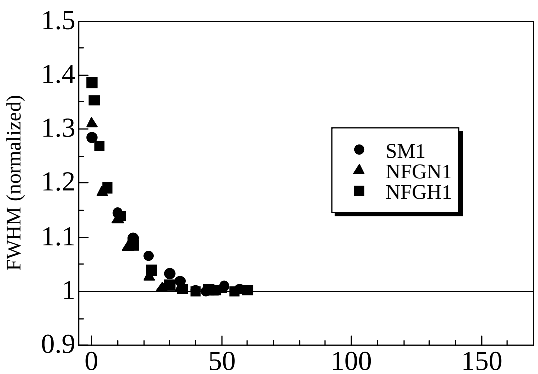
(a) High stress condition.



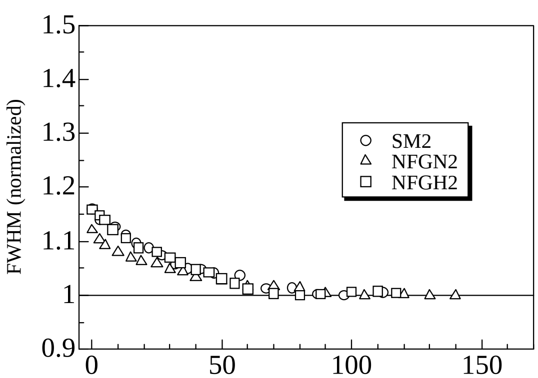
(b) Low stress condition.
Fig. 5. Residual stress distribution.

The residual stress distribution from the surface to the direction of depth is shown in Fig.5. In this study, measurement was one by one ground from the surface of the shot peening processing by the electrolytic polishing. However, that the change occurs to the residual stress distribution with the influence of the etching is known. Dr.Tousha clarified that the residual stress distribution depended on the direction of the etching. In this study, it did electrolytic polishing from specimens surface of the peening. Fig.5 shows the tendency which resembled the case to have done an electrolytic polishing on the surface which processed a shot-peening. As for the one of the high stress condition, NFG600 and NFGAn were about 450MPa on the surface. SM490 was about 60MPa low compressive residual stress compared with NFG600 and NFG600An. The compressive residual stress almost attenuated in the direction of depth because of proportion, and the influence of the shot-peening processing was lost in the depth of about 50μm. The influence of the shot-peening was lost in the depth of about 120μm in one of a low stress. Thus, the difference was at the position in which the influence of the processing was lost in a low stress condition and a high stress condition. However, two kinds and the compressive residual stresses can be given.

On the other hand, the result of X-ray profiles FWHM (Full width of half maximum intensity) is shown in Fig. 6. It is measured by the residual stress. However, it is normalized by the FWHM when no processing it. The FWHM settles by the depth of about 40μm in three specimens of a high stress conditions. The low stress condition specimens settled by the depth of about 90μm.

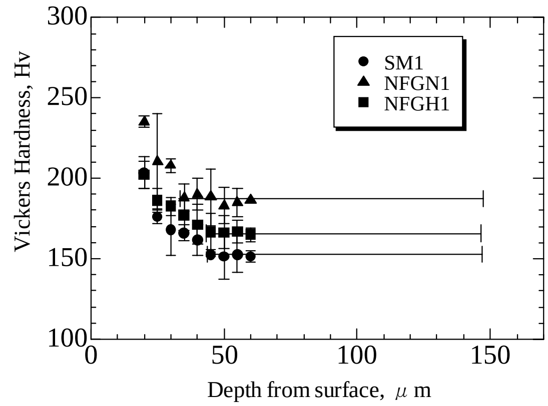


(a) High stress condition.

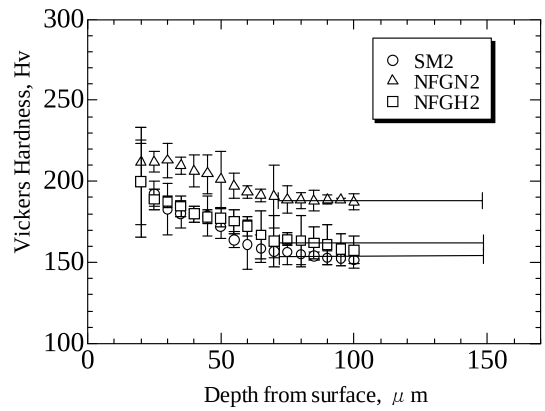


(b) Low stress condition.
Fig. 6. FWHM distribution (at ψ=0)

Fig.7 shows the Vickers hardness distribution. When this is seen, the high stress condition settled from the surface by the depth of 45μm. And, low stress condition is settled by about 90μm. The tendency similar to the residual stress and the FWHM is shown about hardness. Namely the low stress condition was influenced to a position that was deeper than the high stress condition by the shot-peening.



(a)High stress condition.



(b) Low stresscondition.
Fig. 7. Vickers hardness distribution.

Discussion

Both media size and media hardness are considered to be different on the condition of two shot peening condition. Hence the settled depth that the residual stress, the FWHM, and Vickers hardness were not agree with that in both the low stress condition and the high stress condition. The media size is ϕ0.6mm in the low stress condition. On the other hand, the media size is ϕ0.1mm in the high stress condition. The Vickers hardness of the projection material is 150HV in the low stress condition. On the other hand, the Vickers hardness of the high stress condition was 250HV. There are not so many differences for other parameters. It can be said that these two factors influenced from these. The change caused by hardness and the grain size of the specimen cannot be seen about the residual stress. However, the compressive residual stress can be given to each specimen. As a result, fine grain steel has understood that surface reforming can be done without deteriorating the characteristic even by the one of the average grain size about 3μm.

The FWHM is a parameter that shows the damage of the plastic deformation. Therefore, it usually agrees with the hardness distribution. Both the low stress condition and the high stress condition agreed with both the FWHM distribution and the hardness distribution of settling depth. However, the low stress condition and the high stress condition both understood settling depth of the residual stress is deeper than the settling depth of the FWHM and hardness. The difference of the NFG material was the greatest. This is considered that the residual stress influenced a deep position because of the restraint by the plastic deformation.

It was understood to approach that lost of the influence of initial hardness of NFGAn and NFG and to go about the hardness distribution in the vicinity of the surface. The influence of the processing error margin is considered from taking the correspondence of FWHM distribution and where as this reason. However, the tendency to shift the value as it is shown when NFG and NFGAn are seen, and it is understood that hardness influenced in other parts.

CONCLUSIONS

(1) It has been understood to be able to do the surface reforming without deteriorating the characteristic for the average grain size is about 3μm even if it is steel made from the plastic forming for the rate of rolling to exceed 90%.

(2) The residual stress for hardness and FWHM doesn't agree with the influence depth of the processing of the shot peening. There was a difference with the biggest NFG material about this.

(3) There is little influence by the grain size about the hardness distribution near the surface. However, the influence is caused at a deep position.

(4) As for the hardness distribution, the influence of original hardness is large. The tendency to shift as it is when the grain size is almost same is shown.

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