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THE EFFECT OF SANDBLASTING TIME ON PRODUCING NANOCRYSTALLINE SURFACE OF PO733 STEEL (DIN: 1.8509)

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Abstract. Techniques to produce nanostructured materials are severe plastic deformation (SPD) and surface severe plastic deformation (SSPD). This paper reports our study on severe plastic deformation that applied on samples surfaces with sandblasting by hard particles of silica and then annealing. The samples were made of nitriding steel PO733 (DIN: 1.8509).

The grain size of the nanocrystalline surface layer was in the range of 20 nm, determined by using scanning electron microscopy (SEM) and X-ray diffraction (XRD) analysis. Mechanical behavior of nanocrystalline surface was investigated using micro hardness test.

The result show grain size decreases to nanometer scale (even 15 nm), by increase time of sandblasting, but this decreasing is not linear. Thickness of nanocrystalline surface is independent by time of sandblasting and its stable. It was demonstrated that the mechanical behavior of samples surface was markedly improved when its grain size was reduced to nanoscale. The nanocrystalline surface caused by the sandblasting and annealing treatment exhibited considerably higher hardness.

1. Introduction

Nanocrystalline and submicrocrystalline materials have been the subject of extensive investigations during the past decades owing to their considerable scientific and practical interest [1].

Nanocrystalline (NC) materials have new physical and technical properties as compared to conventional materials [2]. The various synthesis techniques have been developed for producing bulk NC materials, i.e. the crystallization of amorphous precursors [3], electro-deposition [4], and severe plastic deformation (SPD) of bulk materials [5].

It has been recognized recently that severe plastic deformation, i.e. intense plastic straining under high imposed pressure performed at low temperatures (usually less than 0.4 T_m) can refine the microstructure of metals and alloys to the nanometer-sized range [6].

Materials with an ultrafine grain structure produced by severe plastic deformation techniques poses non-equilibrium grain boundaries that can play a significant role in mechanical behavior [5, 7]. Recent work has also demonstrated possible changes in phase compositions during processing by severe plastic deformation. For example, complete dissolution of cementite and formation of a supersaturated solid solution of carbon in a- Fe was demonstrated in a high carbon steel after severe torsion straining [7]. However, there appears to have been no systematic studies of changes of structure and phase compositions in

The samples put on sandblast machine that protect by wind compressor for create the pressure on silica sands. For best time to process on reducing the grain size of particles, sandblasting on fourth different time (15, 25, 35, and 45 min) is performed. After the treatment samples were perpetrated by abrasives and polishing and annealed at 650 ^{o}C for one hour to removed error caused by residual strain in the samples. The X-ray diffraction analysis was done on a Philips 1480 X-ray diffractometer with Cu Kα radiation by 1.54 wave length. Philips XL30 scanning electron microscope by 25 kW accelerating voltage was used to examine the microstructures of the surface layer. The micro-hardness test was done by SHIMADZU with 15 gr load for third time.

2. Experimental

The material used in this study was a nitriding steel grade (41CrAlMo7), couple-phase material (perlite-ferrite) with face-centered cubic (FCC) crystal structure and the chemical composition is given in Table 1. Disk-shape samples were processed, with a diameter of 20 mm and a thickness of 5 mm.

Table 1. Chemical composition of PO733 (1.8509).

C	Si	Mn	P	S	AI	Cr	Mo
0.40	≤0.40	0.50	≤0.025	≤0.035	0.90	1.60	0.25

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3. Results and discussion

3.1. Nanocrystalline surface. XRD analyses were carried out for determining the average grain (or cell) size and the microstrain in the surface layer. Figure 1 shows X-ray diffraction (XRD) profiles of the annealed and the sandblasted samples for different time of sandblasting. X-ray diffraction measurements have revealed the presence of a martensitic phase on the surface of the samples. This phase, which does not exist in the base material, is created during the treatment via the deformations supported by the material. The Bragg-diffraction peak broadening in the sandblasted sample may be attributed to grain refinement and/or an increase in the atomic level lattice strain. Quantitative XRD measurements indicate that the average grain size in the top surface layer of the treated sample is about 14 nm after 45 min sandblasting, and the microstrain is neglectable. Table 1 shows decreasing of grain size by sandblasting time.

Based on observations and other investigations it was found that the grain refinement process is developed of dislocation in original grains and in the refined cells under further straining in first level. Transformation of these dislocations into subboundaries with small misorientations of separating cells and evolution of subboundaries to highly misoriented grain boundaries are followed in during of treatment. The grain refinement mechanism can be schematically illustrated in Fig. 3 that adopted from Tao and Wang investigation [11].

Various dislocation activities were done during treatment, including sliding, accumulation, interaction, tangling, and spatial rearrangement. Development of dislocation gradually results in subdivision of original grains by forming individual dislocation cells primarily separated as can be clearly seen in the literature as well [14, 15]. The spacing of dislocation depends on cell dimensions (L) formed in the coarse-grains, which showed by function of the acting shear stress (τ) by $L = 10\ Gb/\tau$ with G being the shear modulus and b the Burgers vector [16]. It is clear by increasing of shear stress, dislocation density increases, and leads to smaller cell sizes.

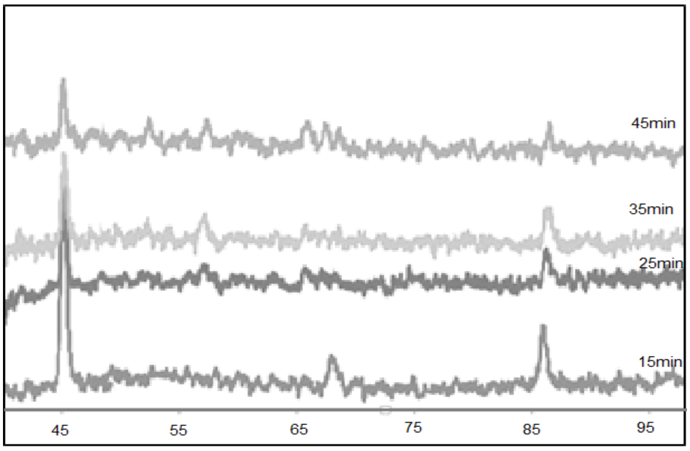

Fig. 1. X-ray diffraction performed on PO733 steel after sandblasting.

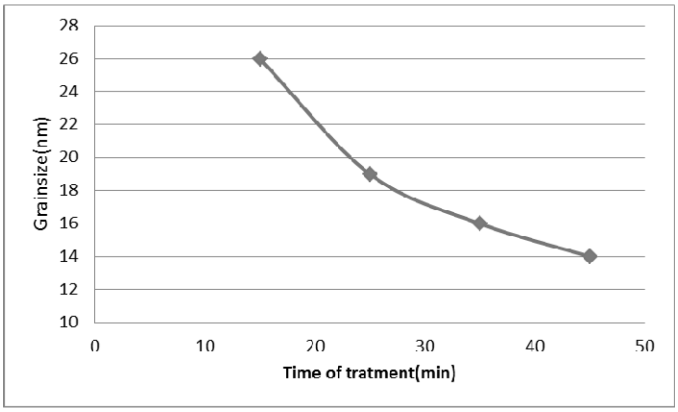

Fig. 2. The grain size on surface of PO733 after different time of sand blasting.

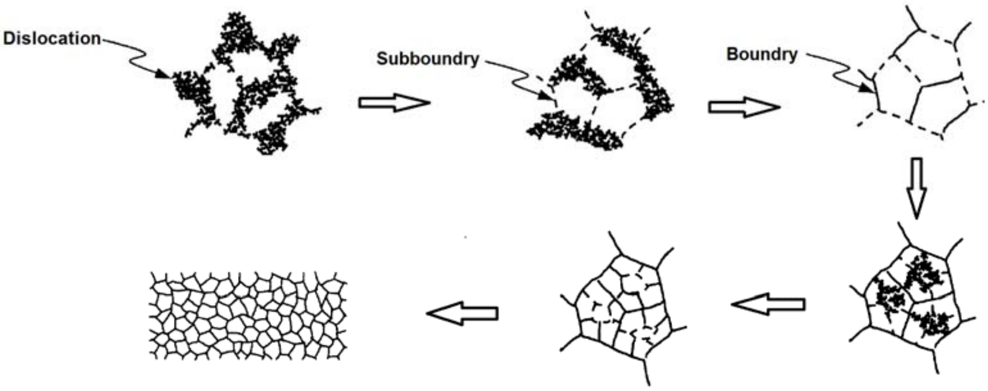

Fig. 3. Schematic of grain refinement mechanism.

Based on the grain refinement mechanism, one note finds that strain and strain rate play important role in final grain size. In certain strain rate, increasing of strain leads to a high density of dislocations and accordingly to finer grains, which was observed in various deformed metals and alloys [17, 18].

The SEM picture in Fig. 4 shows samples surface that verification to XRD analyze to forms nanograin structures. There are also show to the presence of the martensite phase, at the surface of the treated sample that caused by high rate strain.

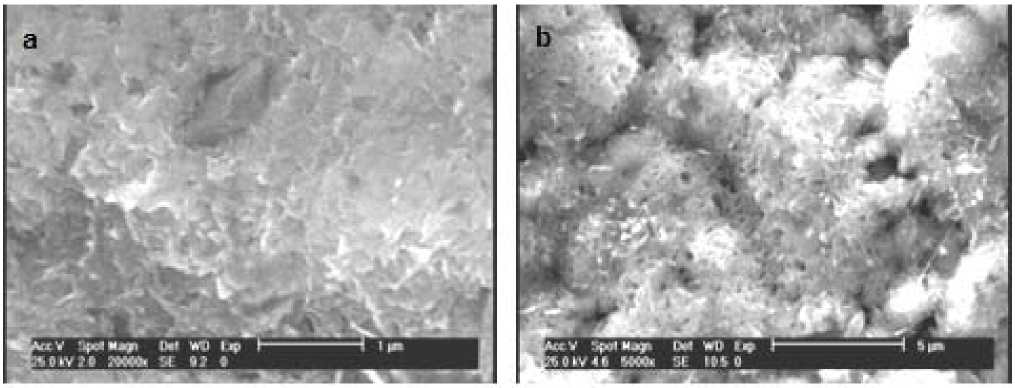

Fig. 4. SEM images of PO733 nanostructure surface
(a) after 25 min sandblasting, (b) after 45 min sandblasting.

3.2. Mechanical properties of nanostructure surface. For determining mechanical properties of nanostructure surface, the micro-hardness test done for third time on samples surface, it was showed in Fig. 6. The effect of the nanostructured layer on the hardness was done at room temperature.

By the micro-hardness test, it was observed that the hardness near the surface attains approximately 300–320 Hv, which is a high value that cannot be obtained by conventional surface treatments. This high hardness is mainly due to the presence of the nanostructured layer that follows the Hall–Petch relationship [19].

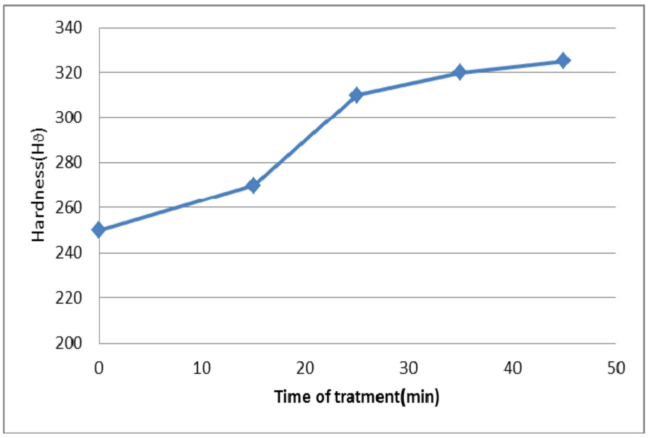

Fig. 5. Hardness of PO733 steel surface after different time of treatment.

Hall–Petch relationship: $H_g = H_0 + K_y / \sqrt{d}$, where H_0 and K_y are constants. The high values of microhardness are also due to the presence of a hard phase, the martensite, at the surface of the treated sample as observed from the SEM observations.

4. Summary

On surface steel samples, grain size decreased to nanometer range(less than 100 nm) by sandblasting. Based on investigation and microstructure observation, this decreasing is induced by plastic deformation during sandblast treatment. It caused by formation of dislocation in original grains and in the refined cells after further straining, transformation of this dislocation into subboundaries and formation of randomly oriented crystallites lead to nanograined surface. For formation of nanocrystalline in metals surface by plastic deformation, the high strain by high rate is necessary.

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