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MAGNETIC FIELD INFLUENCE ON SUBSTRUCTURE FORMED BY ELECTRIC SPARK TREATMENT

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Abstract :The substructure of surface layer (about 10 microns thick) has been studied by x-ray line broadening technique in the samples of plain Carbon steel (0.45%C) after electric spark doping with and without magnetic field (MF). The applied spark pulse energy was 0.12 J and MF induction varied from 0 to 0.08 T. The electrode material was the same as that of the treated sample. It has been observed that the MF reduces the tensile residual surface stresses from 660±15MPa (no MF) to 260±15MPa (B=0.053 T). The analysis of x-ray line broadening has revealed only the existence of microstrains , which are dependent of the MF magnitude.The microstrains have been related to the randomly distributed dislocations with the density of about 3×10^{11} cm^{-2}.

INTRODUCTION

The first study of the influence of magnetic field (MF) on steel strengthening by aging was performed about 70 years ago . Since then the effect of MF on martensetic transformation, tempering , aging and recrystallization was investigated and its favorable influence on some properties has been reported [1] .

In the present paper the MF influence on fine structure and residual stresses of samples treated by the electric spark doping (ESD)has been investigated.

EXPERIMENTAL PROCEDURES

Samples of plain Carbon steel with 0.45%C were treated by ESD using the anode from the same steel . The spark pulse energy was W=0.12 J and the MF induction varied from 0 to 0.08 T. The treated samples of approximately 1×1×0.5 cm in size were used to obtain the profile of 110 and 211 reflections by step scanning method (FeKα rad.).

The calculation of the reflection broadening due to microstrains and small particle size (β) was performed by approximation technique [2] :

$$\beta = 0.5\, B(1- b/B + (1-b/B)^{1/2}) \qquad (1)$$

Where B and b are the half peak breadth of a reflection for the sample and the annealed standard sample respectively.

The ESD is a surface treatment and hence it produces the nonuniform (in sample depth) defect distribution.Therefore , it is very important to have the same penetration depth of x-ray beam when 110 ($\theta \cong 28.6°$) and 211 ($\theta \cong 56°$) lines are recorded.

It is known [3] that the x-ray penetration depth :

$$t = K \sin\alpha \sin\delta /(\sin\alpha + \sin\delta), \quad 2\theta = \alpha + \beta \qquad (2)$$

In the equation (2) K is a constant for all the lines of the same diffraction pattern ,α is the angle between an incident beam and irrediated sample surface ,and δ is the angle between the sample surface and the reflected beam.It is clear that for a symmetrical case ($\alpha = \delta = \theta$);the penetration depth $t = 0.5 K\sin\theta$ reaches maximal value .Thus 211 line was recorded for two δ–values:(a) $\delta \cong 18°$ which provides for 211 line the same penetration depth (t) as for 110 line at $\delta = \alpha = \theta(110)$,(b) $\delta = \alpha = \theta(211) = 56°$ (symmetrical case) which gave the penetration depth for 211 line 1.75 times more than for 110 .

The calculation of the residual surface stresses were made from the angular shift($\Delta 2\theta$) of 211 line with respect to the same line position of the annealed standard.The sum of principal surface stresses $\sigma1+\sigma2$ is given by [4]

$$\sigma1+\sigma2 = -(E/\nu)\mathrm{cotg}\theta . \Delta 2\theta \qquad (3)$$

Where E is Young's modulus in <112> direction and ν is Poison's ratio .

RESULTS AND DISCUSSION

The β' –values of 110 , 211 and 211* (the asterisk marks β'211-value when δ =18°)for the ESD treated samples at different magnitude of MF induction are given in the table .One can see that the ratio $\beta'211^*/\beta'110$ is equal (within the limit of an experimental error) to $\tan\theta211/\tan\theta110$. This fact may be related to a small fraction of particle size broadening .

Attributing the microstrains to randomly distributed dislocations one can find its density

$$\rho = A . (\beta'211)^2 \qquad (4)$$

where $A=6.4 \times 10\ cm^{-2}$ when β' is in degrees [5]. Thus the ESD (with and without MF)causes the formation of dislocations in a thin surface layer .Their density is independent (in the first approximation)of the applied MF .

Considering the difference in x-ray penetration depth discussed above ,the increase of $\beta'211/\beta'110$ from 1.67 (no MF) to 2.2 (with MF) possibly means the reducing of nonuniformity in defect distribution in the presence of MF. Meanwhile the residual stresses are remarkably reduced by the ESD in the presence of MF; though its sign remains positive.

CONCLUSION

1.The ESD causes the broadening of x-ray lines due to microstrains produced by dislocations with density of about $3 \times 10^{11}\ cm^{-2}$. The MF induction B= 0.08 T has no influence on the line broadening though it slightly reduces nonuniformity in distribution of defects .

2.The application of MF in ESD remarkably reduces the residual surface stresses .

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Table 1: Effect of magnetic induction on dislocation density and sum of biaxial residual stress.

	B_M = 0 .0T			B_M =0 .053 T			B_M = 0.08 T		
(hkl)	(110)	(211)	(211)*	(110)	(211)	(211)*	(110)	(211)	(211)*
β' (degree)	0.268 ±0.004	0.447 ±0.009	0.658 ±0.060	0.220 ±0.004	0.503 ±0.009	0.658 ±0.060	0.246 ±0.004	0.490 ±0.009	0.750 ±0.060
$\frac{\beta'211}{\beta'110}$		1.67 ±0.04	2.45 ±0.22		2.20 ±0.05	2.89 ±0.27		1.99 ±0.05	3.05 ±0.35
$\rho .10^{-11}$ (cm^{-2})			2.8±0.6			2.8±0.6			3.6±0.7
σ1+σ2 (MPa)	660±15			260±15			358±15		

BM = Magnetic Induction in Tesla

β' = Δ2θ