تأثير أشعة كاما و بيتا على تصليد السطح في فولاذ القطع السريع

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الخلاصة

لقد تمت دراسة تأثير التشعيع باشعة كاما واشعة بيتا على صلادة سطح الفولاذ المعامل حرارياً وغير المعامل حرارياً. وقد وجد ان : الصلادة تزداد بصورة لوغارتيمية مع زمن التشعيع، وان التشعيع باشعة بيتا اكثر فاعلية من التشعيع باشعة كاما في تصليد سطح الفولاذ ولكن الطبقة المصلدة في الحالة الاولى اقل سمكاً مما هي عليه في الحالة الثانية بشكل ملحوظ، وان الفولاذ غير المعامل حرارياً اكثر تأثراً لتصليد السطح من الفولاذ المعامل حرارياً. وقد أعزي تصليد السطح الى التغير في التركيب المجهري الناجم عن تحول المارتنسايت والذي تتحدد كميته ونوعه بالحرارة الداخلة خلال التشعيع.

Effect of Gamma and Beta Rays on Surface Hardening in High-Speed Steel

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Abstract

The influence of gamma rays and beta rays irradiation on the surface hardness of heat-treated and non heat-treated steel has been investigated. It was found that; the surface hardness increases logarithmically with the time of irradiation, beta rays irradiation is more efficient than gamma rays irradiation for hardening the steel surface but the hardened layer in the former case is markedly thinner than that in the latter case, and non heated steel is more sensitive to the surface hardening than the pre-heated steel. The surface hardening is attributed to the microstructural modification due to transformation of martensite whose amount and type are determined by heat input during irradiation.

KEYWORDS: hardening; high-speed steel; irradiation

I- Introduction

Hardness is the most important property which determine the use of steel in specific industry applications and tools, so it is still a subject of interest. Lin [1] has studied the effect of titanium content on the hardening behaviour of medium carbon steel alloyed with chromium and molybdenum. He found that the optimum titanium content for superhardening is between 0.03-0.05 wt%. Pan et al. [2] have investigated the effects of silicon additions up to 3.5 wt% on the mechanical properties of high speed steels. They showed that silicon additions can increase the temper hardness of steels Fe-16 Mo-0.9C, 6W3Mo2Cr4V and W3Mo2Cr4V, but yield an opposite influence on the temper hardness in W9Mo3Cr4V steel. Dimitrov et al. [3] have studied the effect of high speed electron beam on the hardness of conventional ion nitriding steel with nominal composition (wt%) of 0.42% C, 0.96% Cr, 0.6% Mn, 0.37% Si balance Fe. They found that the hardness of the electron beam hardened layers varies in the range 800-850 HV. Park et al. [4] have investigated the effect of alloying elements on the hardness of four high-speed steel. De Andres et al. [5] have investigated the effect of carbide-forming elements on the response to thermal treatment of the X45Cr13 martensitic stainless steel. Robertson et al.[6] have found that the hardness as measured on the ion-irradiated zone of 316L stainless steel is modified by postirradiation thermal annealing and that the amplitude of this modification is important at 600 degrees C. Choo et al. [7] have found that high-energy electron beam irradiation can be effectively applied to the surface hardening process of an AISI steel used for automotive crankshaft. In the present work, the effects of gamma and beta rays on the surface hardness of high-speed steel have been investigated.

II- Experimental

In order to investigate the influence of gamma and beta rays on the surface hardness in high speed steel, two identical sets of hardened drills were prepared. Set No.(I) contains 8 samples, each of them was irradiated with gamma rays emitted from Co^{60} source for times range between 24-580 hr. The Co^{60} source emits two characteristic energies of 1.17 MeV and 1.33 MeV, the source activity was 200 Ci, and the distance between the source and the irradiated sample was 10 cm. Set No.(II) also contains 8 identical samples of hardened drills. They were subjected to beta rays irradiation for times ranging from 24 hr to 624 hr. The beta source was Sr^{90} with a maximum energy of 2.3 MeV and an activity of 250 mCi. The distance between the source and sample was 4 cm.

Two identical sets of unhardened steel disks were also prepared to be irradiated with gamma and beta rays. Set No.(III) of unhardened disks were subjected to gamma irradiation with the same conditions of set No.(I). Whereas set No.(IV) of samples were irradiated with beta rays with conditions similar to those of set No.(II). The time intervals of irradiation for set No.(III) and set No.(IV) were 26-720 hr and 26-672 hr respectively. For each set of samples, the hardness was measured before and after the irradiation process.

III- Results and Discussion

The hardness of each samples of set No.(I) and set No.(II) was measured before irradiation process. The average value for these measurements was 62.5 HRC. After gamma rays irradiation for set No.(I) samples and beta rays irradiation for set No.(II) samples, the surface hardness was found to be influenced as displayed in Fig.1. This figure reveals that the percentage change in hardness ($\Delta H / Ho$) is a logarithmic function of irradiation time (t_{irr}) i.e.

$$\Delta H / Ho = a + b \log t_{irr} \text{ ....(1)}$$

Where a and b are constants depend on the ray type and energy, and on the target material. To determine these constants, the data were plotted in semi-log graph as shown in Fig.2. The least-squares analysis yield the following values

a=1.55	and	b= 0.82	for gamma rays irradiation
a=0.52	and	b= 1.12	for beta rays irradiation

The same analysis were performed on the non heat-treated samples of set No.(III) and set No.(IV) which have an average intial value of hardness of 17 HRC. The results are plotted in Fig.3 and Fig.4. The relation between the percentage change in hardness and the irradiation time is also logarithmic one for both gamma and beta irradiation. The a and b values in this case are as follows:

a= -0.35	and	b= 12.44	for gamma irradiation
a= 2.83	and	b= 13.83	for beta irradiation

It is obvious from the results of the present work that the percentage changes in hardness of non heat-treated samples are significantly larger than that of the corresponding ones of the prehardened samples. This can be attributted to the fact that the prehardened samples reach nearly the saturation value of hardness. Also, it is inferred that beta rays irradiation is more effective than gamma ray irradiation, but the hardened layer in the case of beta irradiation is markedly thinner than the corresponding layer in the case of gamma irradiation. The thickness of hardened layer in the former case does not exceed 0.1 mm, whereas it is in the range of cm in the latter case. This is in agreement with the data published by Cember [8]. The increase in hardness can be interpretated as follows; upon irradiation, the unirradiated microstructure containing band structure was changed to martensite and bainite in the carbon-rich zone or ferrite, bainite, and martensite in the carbon-depleted zone. This microstructural modification improved greatly surface hardness due to transformation of martensite whose amount and type were determined by heat input during irradiation. Thus, high-energy beta and gamma rays irradiation can be effectively applied to the surface hardening process of steel.

IV- Conclusions

From the data of the present work it can be concluded that:

1- Irradiation of high-speed steel by gamma rays or beta rays increases its surface hardness, and the surface hardness is a logarithmic function of irradiation time in both case of irradiation.

2- Beta rays irradiation is more efficient than gamma rays irradiation for hardening the steel, however, the depth of hardened layer in the former case is much thinner than that of the latter case.

3- None heated steel samples are more sensitive to the surface hardening than the pre-heated samples.

4- The improvement of surface hardness is due to transformation of martensite whose amount and type are determined by heat input during irradiation.

5- High-energy beta and gamma rays irradiation can be effectively applied to the surface hardening process of steel.

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Figure Captions

Figure.1. Percentage change in hardness as a function of irradiation time of gamma and beta rays for pre-heated samples.

Figure.2. Semi-log graph of percentage change in hardness versus irradiation time of gamma and beta rays for pre-heated samples.

Figure.3. Percentage change in hardness as a function of irradiation time of gamma and beta rays for non heated samples.

Figure.4. Semi-log graph of percentage change in hardness versus irradiation time of gamma and beta rays for non heated samples.

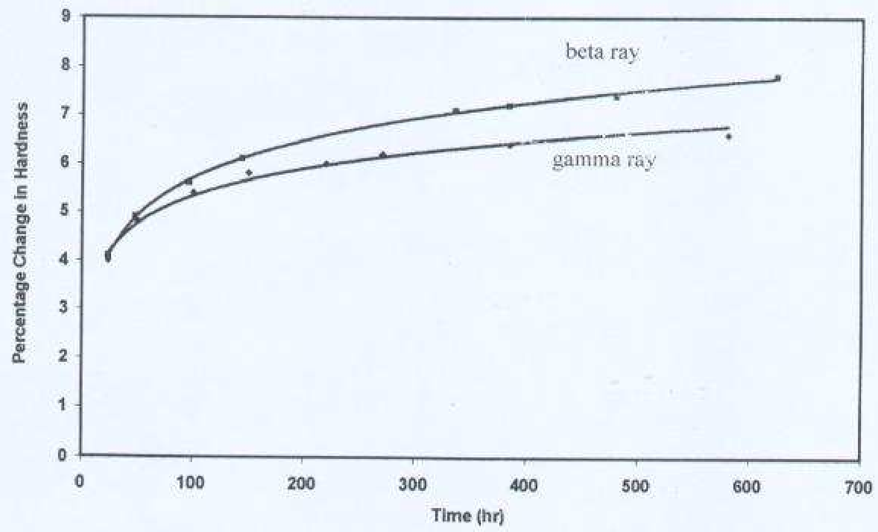

Figure.1. Percentage change in hardness as a function of irradiation time of gamma

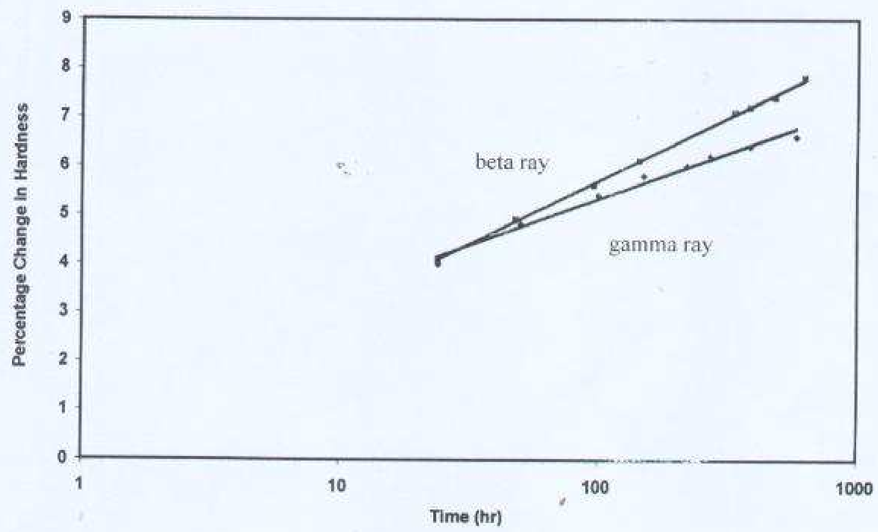

Figure.2. Semi-log graph of percentage change in hardness versus irradiation time

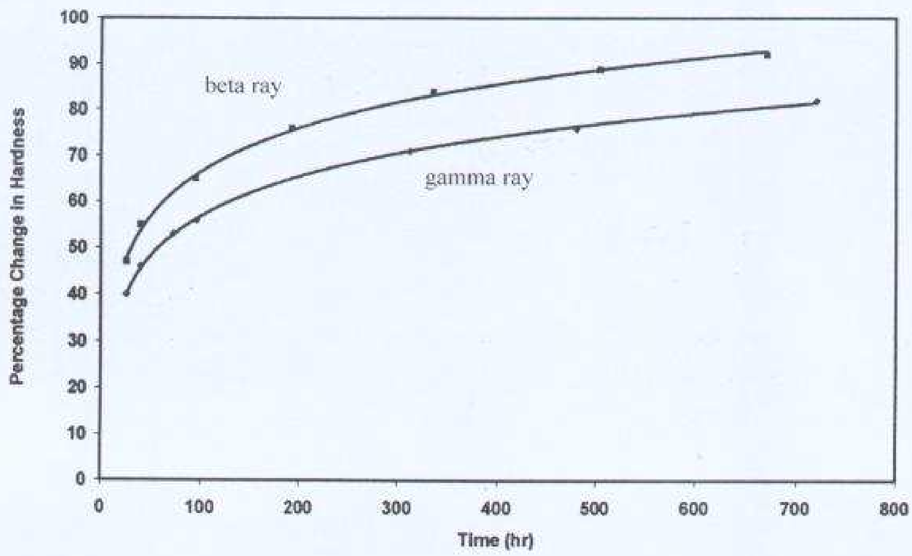

Figure.3. Percentage change in hardness as a function of irradiation time of gamma

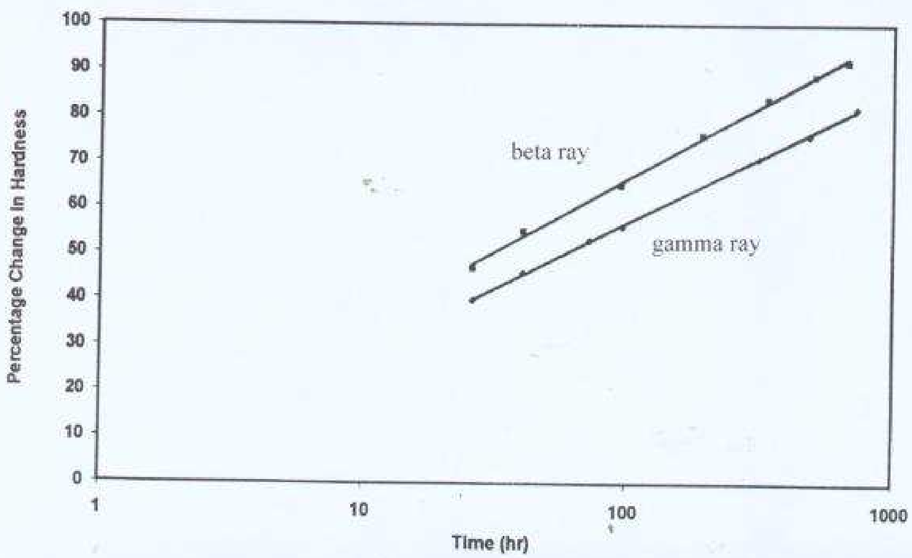

Figure.4. Semi-log graph of percentage change in hardness versus irradiation time