EVALUATION OF THE FRACTURE SURFACE MICROSTRUCTURES OF SOME STAINLESS STEEL REINFORCING BARS USED FOR CONCRETE STRUCTURES

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Using a scanning electronic microscope it was possible to observe and evaluate the cavities which are situated on the fracture surface. The materials we selected for this purpose included Enduramet 32 rebar, 316LN rebar, and 2205 Duplex and MMFX II. Coarse areas at the top demonstrate that those were the places where the specimens finally fractured. A certain amount of fracture sections of the low-cycle fatigue test specimens were almost perpendicular to the longitudinal direction of the specimens, while the others were slanted, which shows that the shear lips do affect the growth of the crack.

Keywords: stainless steels, reinforcing, concrete structures

1. Introduction

The use of stainless steel reinforcing bars has recently attracted much attention in the civil engineering community due to its superior material properties, including high corrosion resistance and high specific strength. However, as with all new materials, a number of shortcomings are unavoidable, such as high initial costs, unknown low-cycle fatigue behaviour, uncertain ductility properties and unidentified bond-slip behaviour between the embedded bar and grouted duct in precast concrete element [1]. In recent years there has been an increasing interest in applying stainless steel reinforcement in concrete structures to combat the durability problems associated with chloride ingress. However, the use of stainless steel reinforcement has so far been limited mainly due to high costs and lack of design guides and standards. The study of fractures has been approached in several ways [2]. One procedure is to categorize fractures on the basis of macro- or microscopic features, that is, by macro- or microfractography. The fracture path may be classified as transgranular or intergranular. Another approach is to classify all fractures as either ductile or brittle, with all others, such as fatigue, being special cases of one or the other. In general, all fractures can be grouped into four categories: ductile, brittle, fatigue, or creep [3].

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2. Theoretical and Experimental descripsion

In order to perform the desired fracture on the steel bars we used MTS (Strain-Controlled Method and Test Equipment) fabricated load frame assembly. Fatigue failure led to fracture under repeated or fluctuating stresses that are less than the tensile strength of the material. Fatigue fractures are progressive, beginning as minute cracks that grow under the action of fluctuating stress [4]. There are three stages of fatigue failure: initiation, propagation, and final fracture. The initiation site is minute, never extending for more than two to five grains around the origin. The location of the initiation is at a stress concentration and may be extremely small and difficult to distinguish from the succeeding stage of propagation, or crack growth. The crack initiation site is always parallel to the shear stress direction [5]. As repetitive loading continues, the direction of the crack changes perpendicular to the tensile stress direction.

After the original crack is formed, it becomes an extremely sharp stress concentration that tends to drive the crack ever deeper into the metal with each repeating of the stress. The local stress at the tip of the crack is extremely high because of the sharp "notch," and with each crack opening, the depth of the crack advances by one "striation" under many (but not all) circumstances [6]. Striations are very tiny, closely spaced ridges that identify the tip of the crack at some point in time. Although striations are the most characteristic microscopic evidence of fatigue fracture, they are not always present on fatigue fracture surfaces. As the propagation of the fatigue crack continues, gradually reducing the cross-sectional area, it eventually weakens the material so greatly that final, complete fracture occurs. The final fracture may be either ductile (with a dimpled surface) or brittle (with a cleavage surface), or a combination of the two [7, 8].

Detailed observation of the fracture surface was best accomplished by use of the scanning electron microscope (SEM). The materials we selected for this purpose included Enduramet 32 rebar, 316LN rebar, and 2205 Duplex, and MMFX II (a high strength steel which has recently been introduced on the market).

3. Results and Discussions

The electron microscope pictures of stainless steel rebar: Enduramet 32 rebar (figure 2), 316LN rebar (figure 3), and 2205 Duplex were analyse in order to evaluete their microstructure. In figure 1 is shown Carbon steel rebar (2205 Duplex), which is typical for seismic design, and in figure 4 it is given MMFX II, a high strength steel were tested for comparison.

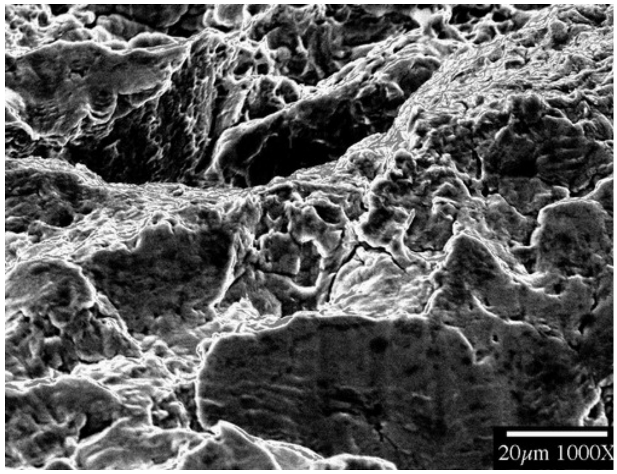

Fig. 1. SEM image for Fracture Section of sample 2205 Duplex at Strain Amplitude 1.837%

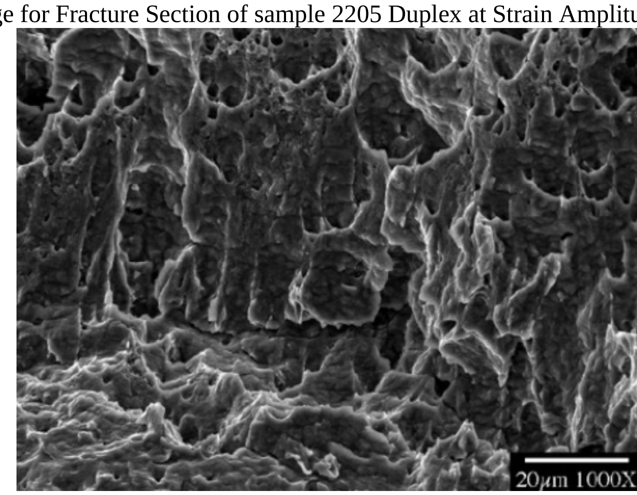

Fig. 2. SEM image for Fracture Section of sample Enduramet 32 at Strain Amplitude 2.238%

The beach mark of the three types of stainless steel is more obvious compared to MMFX II. The Fracture surface of MMFX II is smoother than the rest of the steels investigated. Among the three types of stainless steel, fracture surfaces of Enduramet 32 and 316LN are typical and the fatigue characteristics are distinct, while those of 2205 duplex are different. Taking the lower parts of the surfaces for example, the beach mark for Enduramet 32 and 316LN is finer compared to 2205 duplex; and that of 2205 duplex is flatter than Enduramet 32 as well as 316LN stainless.

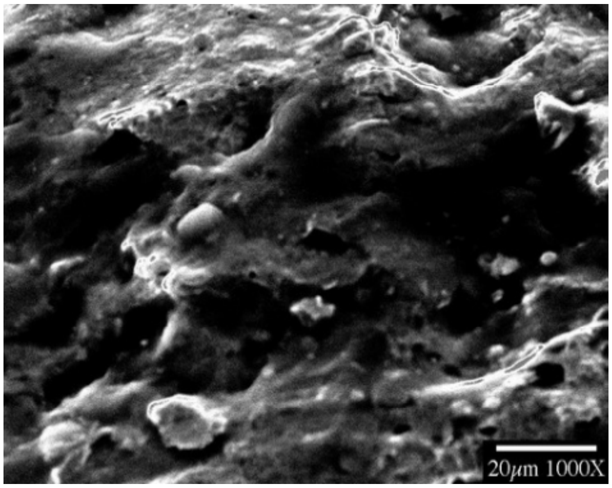

Fig. 3. SEM image for Fracture Section of sample 316LN at Strain Amplitude 2.008%

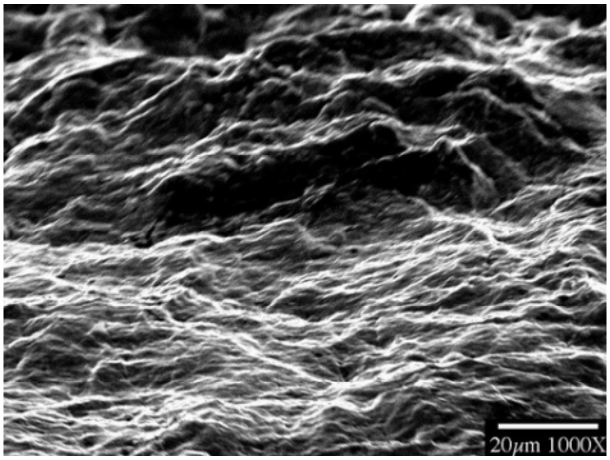

Fig. 4. SEM image for Fracture Section of sample MMFX II at Strain Amplitude *1.114%*

6. Conclusions

Metal fatigue first happened at the bottom of the sections with smooth surfaces and small radial beach marks. As the cyclic reverse loading continues, micro cracks occur, propagate and nucleate to form major cracks, and then the major cracks propagate across the section from bottom to the top. Coarse areas at the top demonstrate that those were the places where the specimens finally fractured. A certain amount of fracture sections of the low-cycle fatigue test specimens are almost perpendicular to the longitudinal direction of the specimens, while the others are slanted, which shows that the shear lips do affect the growth of the crack, and further study about the influence of the shear lips on the crack growth should be carried out in the future research work. With the increase of the strain amplitude, the beach marks on the fatigue specimens fracture section tend to be more visible with naked eye observation.

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REFERENCES

[1] *ASM Handbook*, Vol. 9, Metallography and Microstructures, ASM International, Materials Park, OH, 2004.

[2] *Troeger, L.P. and E.A. Starke*, Microstructural and mechanical characterization of a superplastic 6xxx aluminum alloy. Materials Science and Engineering A. 277(1-2): 2000, p. 102-113

[3] *Brandon, D., W. D. Kaplan,* Microstructural Characterization of Materials,Wiley, New York, 1999.

[4] *Ashby, M. F., D. R. H. Jones,* Engineering Materials 2, An Introduction to Microstructures, Processing and Design, 3rd edition, Butterworth-Heinemann,Woburn, UK, 2005.

[6] *Prof. Dr. Ing. Angel Aloman*. Structura Materialelor Microstructura si Imperfectiunile Structurale PRINTECH Bucuresti 1999

[7] *Prof. Dr. Ing. Angel Aloman*. Structura Materialelor Structura cristalina si cristalizaeza Editura AGIR Bucuresti 2000

[8] *Chen, Y.C. and K. Nakata*, Microstructural characterization and mechanical properties in friction stir welding of aluminum and titanium dissimilar alloys. Materials & Design, 2009. 30(3): p. 469-474.