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MICROSTRUCTURE ANALYSES OF TMT REBAR

Anjani Kumar Singh, Faculty, Dept. of Mechanical Engineering YBN University, Ranchi-834010, India. anjani232@gmail.com
Deependra Kumar Sinha, Faculty, Vocational and Management Dept. St. Xavier's College, Ranchi-834001, India

Abstract
The present work aims to study the evaluation of the microstructure of the various types of rebars. The microstructures of all rebar samples comprise an outer tempered martensite ring with an inner core of ferrite-pearlite in between a narrow bainitic transition zone. Maximum hardness is achieved at the periphery which gradually decreases towards the center.
Keywords: TMT, microstructure, bainitic, martensite

I. Introduction
The use of steel rebars was started in construction in 18th century. Cast iron was used in the earlier age. Cast iron rebars were of high quality, and there was no corrosion. The technique was refined by embedding the steel rebars in concrete. Square twisted steel bars (deformed bars) were introduced in 1960s but these were phased out due to their inherent poor strength. Later on, the steel rebars of high yield strength were produced by raising carbon (>0.5 and <1.0 wt %) as well as manganese contents in steels. Carbon was added to steels in order to achieve strength and later on it was realized that higher content of carbon created problem of brittleness and accelerated rate of corrosion [1]. This problem was partially overcome by reducing carbon content to less than 0.3 wt. % and twisting rebars in which cold working hardens the steels and improves their yield strength. Such treatment however was quite expensive and also distorted the crystal structures of iron resulting in increased susceptibility to uniform and localized corrosion. Steel rebar strength can be increased by adding carbon but some problem related to corrosion may also occur due to formation of galvanic cells. Therefore, the practices of twisting and cold working of rebars were adopted to increase their strength. However, the twisting and cold working is the mechanical process which led to internal deformation of crystal structures of steel. Through the twisting and cold working of steel rebar it increases the mechanical strength up to many folds and it was introduced in 1960s and from that period, the demand of such rebar is increased. Later on, another process was introduced in 1970s known as quenched and self-tempered steel rebar. Such steel rebar called as thermo mechanically treated (TMT) bars as shown in figure 1 [2]. In this process the outer diameter of steel rebars possess the microstructure of tempered martensite whereas the core consists of pearlite – ferrite as shown in figure 2 [3]. During this process about 5 - 10% of outer diameters of steel bars are transformed into hard tempered martensite structure [4]. This dual composite microstructure of TMT rebar is imparted through ductility and strength but the drawbacks of such production process of steel rebars are capital intensive. Therefore, such process of production of rebar is replaced by adding some micro alloying elements to get desired properties of steel.

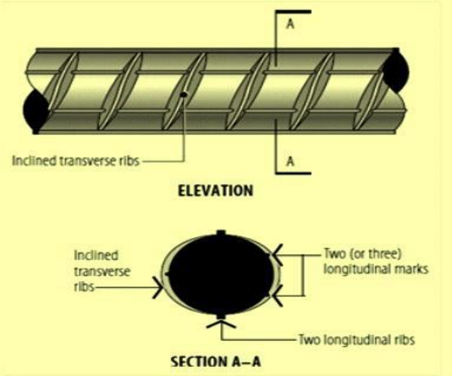

Figure 1: Typical cross section of steel rebar produced by quenching and self-tempering [2]

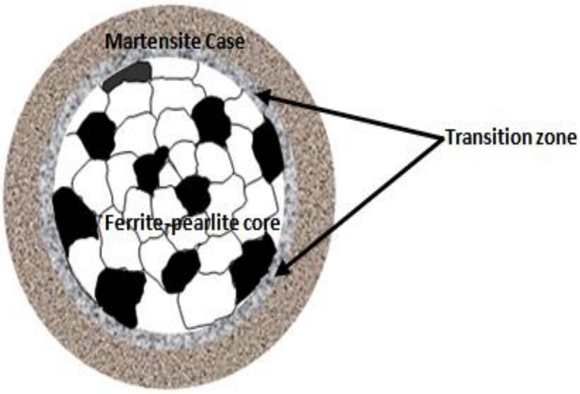

Figure 2: Cross-section of multi-layered microstructures of TMT steel rebars [3]

II. Experiments

Optical metallography of TMT rebars

Transverse sections of the both types of rebar were polished and etched with 2% nital to observe macrostructure. A dark peripheral rim of the tempered martensite and a grey core corresponding to the ferrite-pearlite interior was observed in both rebars. Typical nital-etched macrographs of the transverse polished section of 20 mm diameter of both rebars are shown in figure 3.

Optical microscopic examinations were carried out in a Lieca model microscope on nital-etched transverse sections of both 20 mm diameter rebars. Both rebar essentially exhibited a composite microstructure comprising a ferrite-pearlite core and a tempered martensite rim [5, 6].

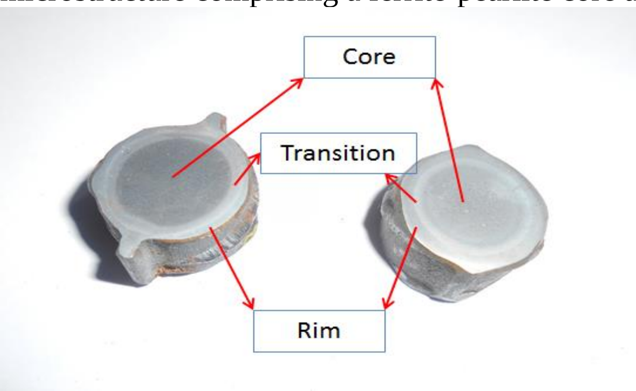

Figure 3: Nital-etched macrograph of the transverse polished section of 20 mm diameter rebar, showing a uniform and concentric outer dark etching rim and an inner light grey core.

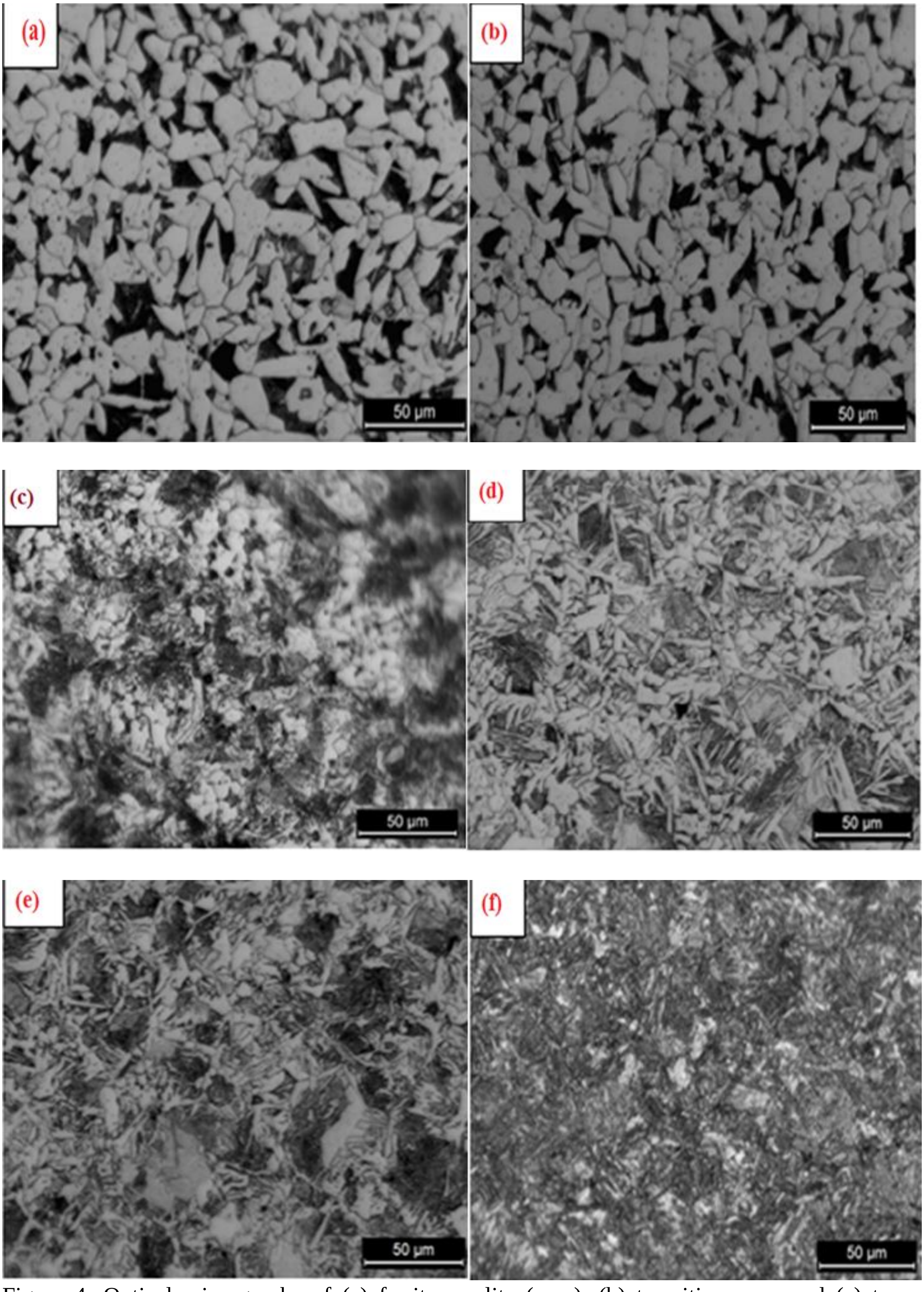

Figure 4: Optical micrographs of (a) ferrite-pearlite (core), (b) transition zone and (c) tempered martensite (edge) of the Steel rebar S; and (d-f) are corresponding micrographs for the Steel rebar T [5,6].

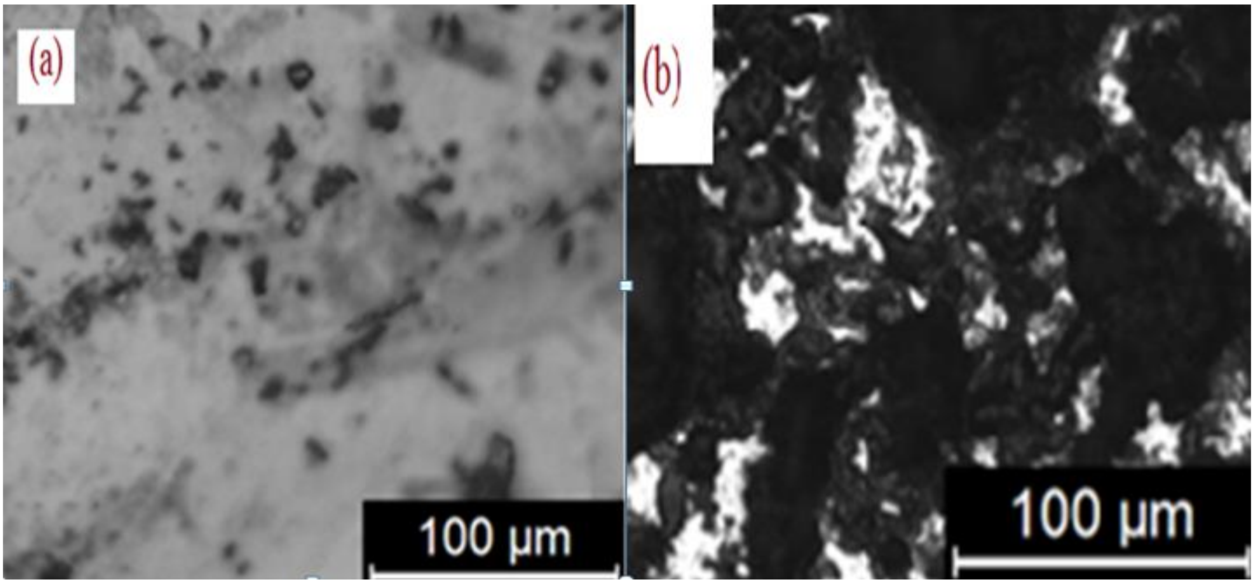

Figure 5: Optical image of a rebar S (Fig.a) and T (Fig.b) surface immersed in the SPS solution

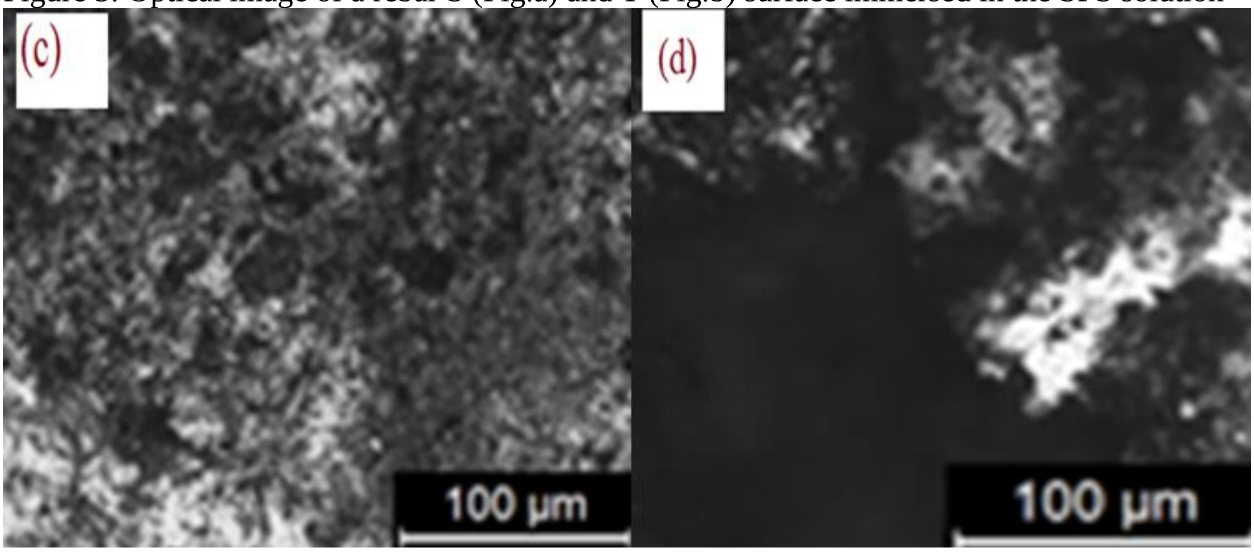

Figure 6: Optical image of a rebar S (Fig.c) and T (Fig.d) surface immersed in the SPS solution contaminated with 3.5 % NaCl.

III. Conclusion

Microstructure evolution figure 2 and 3 shows the visual images of these TMT rebar samples (cross-section) which clearly exhibit three distinctly separate regions. Figure 2 illustrates the schematic diagram of the cross-section and its different zones of TMT rebar. The dark peripheral ring (edge) consists of tempered martensite [7] with an intermediate narrow bainitic transition zone [8] along with a comparably grey core corresponding to the ferrite-pearlite interior [9]. Hot rolled bars when subjected to water quenching result in the formation of martensite at the surface layers of the rebars. During cooling the residual heat flow across the rebar section results in tempering of the initially formed martensite rim and also produces ferrite-pearlite mixed microstructure in the core region. Due to intermediate cooling the microstructure of the core region of TMT rebar which reveals equiaxed ferrite and pearlite along the grain boundaries of ferrite.

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