Advanced High-Strength Steels as Workhorse of Our Society: Contribution and Importance of Martensite and Martensitic Transformation

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Steel is the workhorse of our infrastructure. Stronger steels are always needed to reduce weight and improve safety in transportation, enhance architectural flexibility in construction, and improve performance in heavy machinery[1]. Steel is frequently the 'gold-standard' against which emerging structural materials are compared. What is often not realized is that this is a moving standard, with notoriously regular and exciting discoveries being made in the context of iron and its alloys. This is the reason why steel remains the most successful of all materials, with more than a billion tons being consumed annually in improving the quality of life[2].

The world steel production was over 1800 million tons in 2020, while it was lower than 800 million tons when the author learned steel science in his graduate school classes around 1980 (Fig. 1). During the last 40 years, many types of advanced steels have been developed. One of the most important development is of high-strength steel (HSS) sheets for automotive. The first HSS sheet have been developed in mid-1970s by Japanese steel makers in collaboration with the Japanese automotive industry[3]. But the tensile strength of the HSS sheet was still lower than 0.5 GPa. Now, several strength grades of HSS sheets more than five are used in a modern automotive, and the highest strength grade among them is 1.5 GPa or over, where '*martensite*' is utilized.

Martensite is the structure name of the product phase of martensitic transformation, solid-solid diffusion-less phase transformation. Martensitic transformation appears in the metals and their alloys, where allotropic transformation takes place like iron (Fig. 2). Compared with that obtained by slow cooling, iron-carbon steel quenched from a high temperature in FCC region of Fig.2 has a very fine and sharp microstructure and is much harder/stronger. The mechanical properties and structure of quenched steels have long been studied because of their technology importance since 1920s. The structure of quenched steel is called '*martensite*' in honor of Professor A. Martens, the famous pioneer German metallographer who greatly extended Sorby's initial work[4].

Strong martensite is thus indispensable for advanced high-strength steels (AHSS) with the tensile strength higher than 1 GPa. In the present talk, I will emphasis contribution and importance of martensite and martensitic transformation in the AHSS by introducing examples of its application to 1) Japanese samurai sords, 2) aerospace landing gears, and 3) automotive bodies. Finally, I will try to make some comments on what is important in future research of steels when our society is approaching to the new steel era with the strength level of 2 GPa or over.

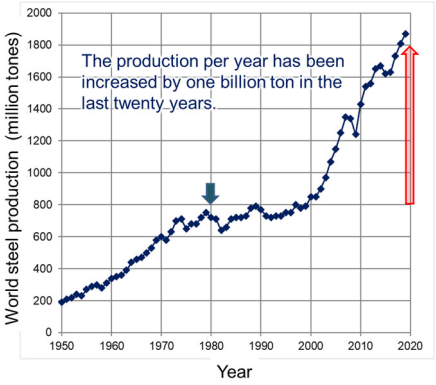

Fig. 1. Change in annual world steel production.

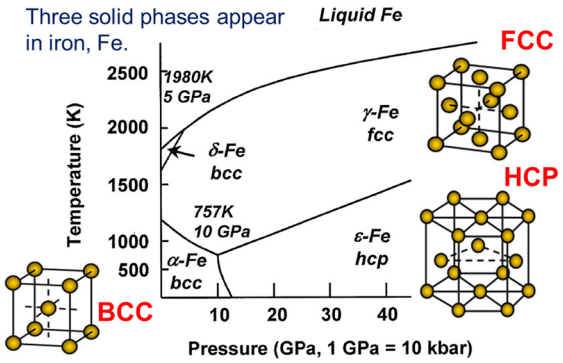

Fig. 2. Phase diagram of iron, Fe.

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