A. DI SCHINO, M. CORRADI

ISSN 0543-5846
METABK 57(4) 307-309 (2018)
UDC – UDK 669.15.621.78:620.18:620.17=111

QUENCHING AND TEMPERING (Q&T) EFFECT ON A STEEL FOR FORGING WITH Cr AND Mo ADDITION

Received – Primljeno: 2018-03-21
Accepted – Prihvaćeno: 2018-06-10
Original Scientific Paper – Izvorni znanstveni rad

The effect of heat treatment on the mechanical behavior of a 0,20 % steel with Cr and Mo addition is here reported. Such steel can just target the mechanical properties achievable by its intrinsic hardenability. Aim of this paper is to evaluate the mechanical behavior dependence as a function of different quenching and tempering (Q&T) treatments. Results show that, after Q&T, the material can target a - 20°C fracture appearance transition temperature (50 % FATT) measured by a Charpy-V impact test making this steel suitable for low temperature application.

Key words: steel, Q&T process, microstructure, mechanical properties

INTRODUCTION

Alloying elements such as chromium, molybdenum, tungsten, etc. are added to carbon steel to improve properties such as hardness, strength and toughness. The standard methods of strengthening low alloy steels are:

- solution hardening;
- quenching and tempering;
- precipitation hardening;

This paper will focus mainly on the second method [1-2]. To obtain high strength and hardness values, heat treatment could be performed after forging. By tempering and quenching, the forged component becomes less brittle and its ductility is enhanced without sacrificing too much hardness. It is the combination of these two processes that produces a harder, tougher part that's also more than ordinary has forged material. Unfortunately, however, producing forgings using the Q&T is inefficient and deleterious to the environment and alternative routes to high strength forgings have been studied for decades [1]. For the flat rolled product of C-Mn steels small addition of elements such as niobium or vanadium could increase the strength when the steel was rolled and cooled correctly [2]. In the medium carbon steel for forgings applications vanadium is preferred over niobium because the dissolution of vanadium carbo- nitrides (VCN) particles occur at lower reheat temperature so niobium level is very limited, while vanadium additions can be more substantial [3-5].

Thus, vanadium micro alloying is predominant in these steels, although growing importance is being placed on dual additions of vanadium with lower levels of niobium. Nitrogen additions are useful to enhance precipitation strengthening in the vanadium applications [6]. Moreover, increased yield strength can be achieved by improving hardenability and Mo or Cr are usually added with increasing material costs [7].

These micro alloying strategies are progressively more employed to increase strength and performance, or to reduce the number of heat-treating steps while maintaining adequate mechanical performance.

A. Di Schino (e-mail: andrea.dischino@unipg.it, M. Corradi, University of Perugia, Dipartimento di Ingegneria, Perugia, Italy

EXPERIMENTAL

The chemical composition of the considered steel is reported in Table 1.

Table 1 **Chemical composition of the considered steel / wt. / %**

C	0,20
Mn	0,95
Cr	0,20
Ni	0,25

Steel was manufactured by electroslag remelting (process used to remelt and refine steels resulting in high-quality ingots). Starting from the ingot, specimens have been cut and heat treated by quenching and tempering (Q&T). The austenitizaion stage of the heat treatment was performed at two different temperatures: 980 °C and 1 050 °C. Tempering was performed in a wide range of temperature ranging 540-680 °C. Microstructure analysis and hardness of heat treated specimens have been carried out by means of light microscopy (LM) after 4 % Nital etching and 2 kg Vickers indenter (HV_2). Tensile test and Charpy test have been performed on the most promising cases.

RESULTS AND DISCUSSION

Continuous Cooling Temperature (CCT) of the considered steel is reported in Figure 1.

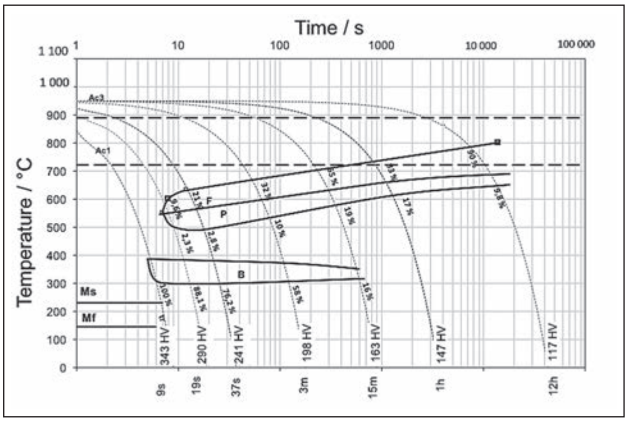


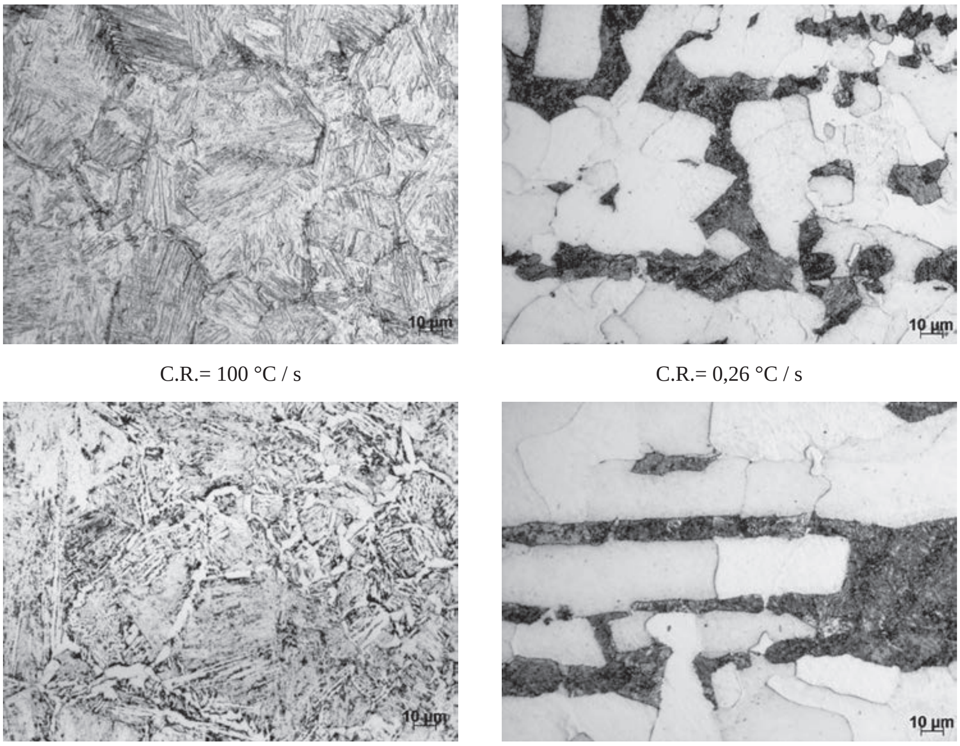
Figure 1 CCT of the considered steel (austenitization temperature: 980 °C)

Some of the most indicative microstructure referring to different cooling rates (C.R.) are reported in Figure 2.

Based on the results reported in Figure 1, specimens were austenitised at 980 °C and 1 050 °C in order to exploit also the prior austenitic grain size effect. Specimens were cooled in air to avoid any bainite formation and to obtain a fully ferritic-pearlitic microstructure (Figure 3). Specimens were tempered in the range 540–660 °C for 30 minutes holding. Results of hardness measurements on heat treated materials are reported in Figure 4.

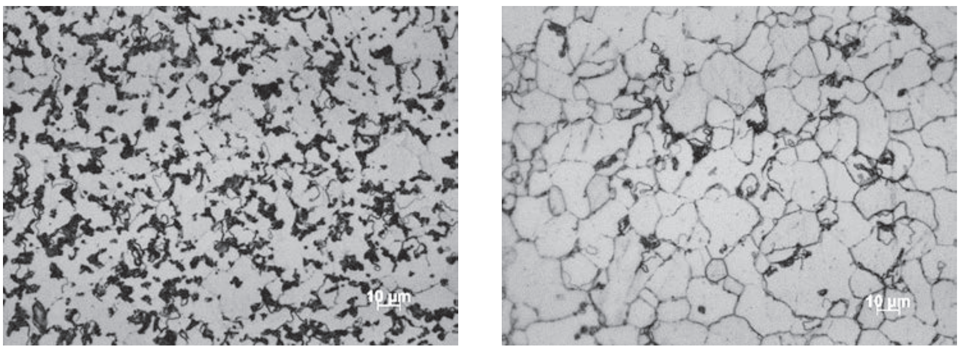
Results show that hardness behavior is not significantly affected by heat treatment in the considered range of the processing temperature.

Further, some effect is detected following different austenitisation conditions: in particular, the higher the



C.R.= 100 °C / s
C.R.= 0,26 °C / s
C.R.= 25 °C / s
C.R.= 0,02 °C / s

Figure 2 Microstructures of cooled specimens according to different cooling rates (C.R.)



a
b

Figure 3 Microstructure after austenitization and cooling: (a) austenitization temperature = 980 °C and (b) austenitization temperature = 1 050 °C.

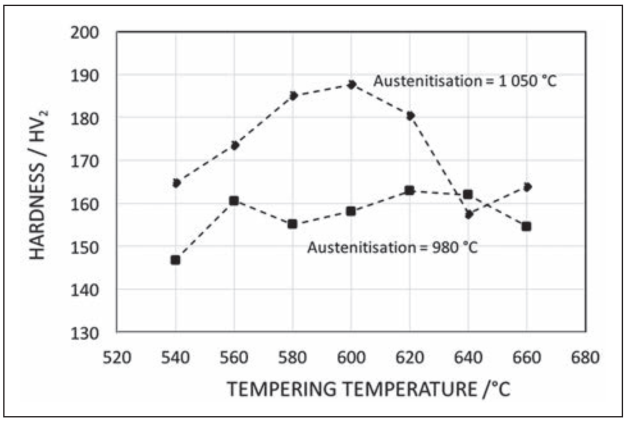


Figure 4 Effect of tempering on hardness

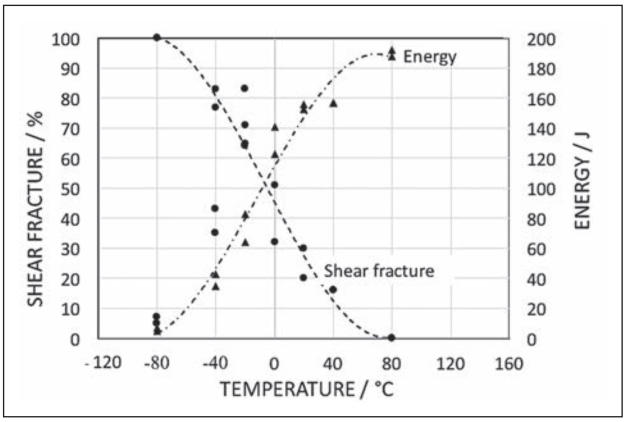


Figure 5 Percentage of shear fracture versus temperature of 0,20 % C – 1,00 % Mn – 0,20 % Cr – 0,25 % Ni

austenitisation temperature, the higher the hardness value, due to an increase of steel intrinsic hardenability.

Tensile tests have been carried out in the specimens after quenching and tempering at T = 980 °C & 640 °C. Results are reported in Table 2.

Table 2. **Tensile properties of material austenitized at 980°C and tempered at T = 640 °C**

$R_{p0,2}$ / MPa	332
R_m / MPa	534

Results of Chary-V impact test of Q&T materials after tempering at 640 °C are reported in Figure 5. Charpy tests show that a 50 % Fracture Appearance Transition Temperature (50 % FATT) of approximately - 20 ° C is found. This implies to possibility of use of such materials for low temperature applications. This is main difference with respect to such material and those obtained by adding micro-alloying elements (such as V). In fact, it is reported that precipitates formation n such steels lead to in increase of 50 % FATT [8-9].

CONCLUSIONS

In this work the effect of quenching and tempering (Q&T) thermal treatments on mechanical properties of a C-Mn steel (0,20 % Cr) for forged components has been exploited on a laboratory scale. Results show that the obtained hardness values are suitable for standard application of forged components (e.g. back up rolls) and the 50 % FATT temperature makes also it suitable for low temperature applications.

REFERENCES

[1] A. Di Schino, C. Guarnaschelli, Microstructure and cleavage resistance of high strength steels, Materials Science Forum 638-642 (2010), 3188-3193.

[2] P. Di Nunzio, A. Di Schino, Effect of Nb microalloying on the heat affected zone microstructure of girth welded joints, Materials Letters 186 (2017), 86-89.

[3] A.J De Ardo, C.I Garcia, M. Hua, Microalloyed steels for high-strength forgings, Metallurgia Italiana 119 (2010), 5-12.

[4] B. Zhao, T. Zhao, Effects of processing parameters on the grain refinement of vanadium nitrogen micro-alloyed steels, International Journal of Materials Research 109 (2018), 308-313

[5] S.F. Medina, Influence of Ti and N Contents on Austenite Grain Control and Precipitate Size in Structural Steels, ISIJ International 39 (1999), 930-937.

[6] M. Hamada Y. Fukada and Y. Komiz, Microstructure and Precipitation Behavior in Heat Affected Zone of C-Mn Microalloyed Steel Containing Nb, V and Ti, ISIJ International 35 (1995) 1196-1198.

[7] B. Hwang, Influence of Mo addition and austenitizing temperature on hardenability of low carbon steels, Korean Journal of Materials Research 25 (2015), 497-502.

[8] S. Pallaspuro, S. Kaijalainen, Effect of microstructure on the impact toughness transition temperature of direct-quenched steels, Materials Science and Engineering A 712 (2018), 671-680.

[9] S.W. Thomson, Interrelations between yield strength and impact toughness in low alloyed plate steels, Materials Science and Engineering A 711 (2015), 424-433.

Note: The responsible for English language is: Elisabetta Petricci, Italy