EFFECT OF COILING TEMPERATURE ON THE MECHANICAL PROPERTIES OF HOT ROLLED MULTI PHASE 800 MPA STEEL *

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Abstract

The influence of the coiling temperature after hot strip rolling on the microstructure and on the tensile and hole expansion properties of a 800 MPa multiphase steel was investigated. For the temperatures between 150°C and 600°C the microstructure consisted of a ferritic matrix with a dispersion of fine martensite-austenite (MA) and regions of degenerated upper bainite. In all cases the ferrite presented a heterogeneous mixture of polygonal, quasi-polygonal and acicular grains. The yield and tensile strengths showed a tendency of decreasing with the increasing coiling temperature, probably because of the larger fraction of MA particles at lower temperatures and higher fraction of quasi-polygonal ferrite at higher temperatures. The elongation was not significantly affected by the variation of coiling temperature. The average hole expansion ratio showed a maximum of 80% for the material coiled at 400°C and fell below 50% only for the coiling temperature of 150°C, probably due to the larger hardness difference between the ferrite matrix and the MA particles.

Keywords: *Complex Phase*; *Hole Expansion Ratio*; *Hot Rolled*.

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1 INTRODUCTION

Automotive sector has been demanding steels of increasing resistance aiming to reduce fuel consumption and pollutants emissions, without compromising passenger safety. The steel industry has been spending resources to study and develop Advanced High Strength Steel (AHSS). One of these is multiphase steel, also known as Complex Phase [1].

Multiphase steels microstructure contains a ferritic matrix with islands of bainite, and martensite in small amounts, in some cases perlite, ensuring the high mechanical resistance to the material. As consequence of small Ti and Nb additions, fine and stable carbides are founded as well [2].

Multiphase steels can be produced either by hot rolling or by cold rolling process followed by annealing. The studied steel in this paper was obtained by hot rolling, varying the cooling profile after the last rolling pass and coiling temperature.

The coiling temperature effect on the microstructure and mechanical properties by tensile test and hole expansion test was evaluated in a multiphase 800 MPa steel in industrial scale, having as reference the grade 780 of the standard JFS A 1001.

2 MATERIAL AND METHODS

Slabs from the same heat, with 252 mm thickness, were rolled by hot rolling mill, on USIMINAS, Ipatinga site. Table 1 shows the steel chemical composition. Coils of 3.60 mm thickness were produced and sampled at skin pass equipment.

Table 1. Chemical Composition

C	Mn	Si	Al	Nb+Ti
	1.00	0.60	0.015	0.100
≤	~	~	~	~
0.10	2.00	1.00	0.090	0.200

2.1 Microstructural Characterization

The coil samples metallographic analysis was performed by a Zeiss Axio Image Optical Microscope (OM) and a Zeiss EVO 50 Scanning Electron Microscope (SEM). The samples were etched with Nital 4% after conventional metallographic preparation. The analysis was performed in thickness cross-sections, parallel aligned (longitudinal) and at 90º (cross) to the rolling direction. Qualitative micro-constituents identification was performed.

2.2 Tensile Tests

Tensile tests were performed in a Zwick Roell test machine, with 25 t of capacity, at Usiminas Mechanical Test Laboratory, according to JIS Z 2201 [3]. Rectangular specimens measuring 50 mm (JIS n° 5) were taken in the strip width center, aligned at 90° (cross) to the rolling direction. The mechanical characterization was performed using yield strength (YS) at 0.2% deformation, tensile strength (TS) and total elongation.

2.3 Hole Expansion Test

The Hole Expansion Tests were carried out at Usiminas Development Research Center using an Erichsen universal press model 145-60, with conical punch (60°) in accordance with ISO 16630 [4]. Square samples measuring 100 mm were taken in the center of the strip width. A center hole with 10 mm diameter was made by punching.

2.4 Thermomechanical Processing

Table 2 shows Coiling temperatures (CT) in coils' sampled positions. Slabs Reheating Temperatures (SRT) and Finish Temperatures (FT) were within the ranges shown in Table 2. Others process parameters were controlled and can be considered constant to all rolled slabs.

Table 2 Coiling Temperatures measures in coils´ sampled positions

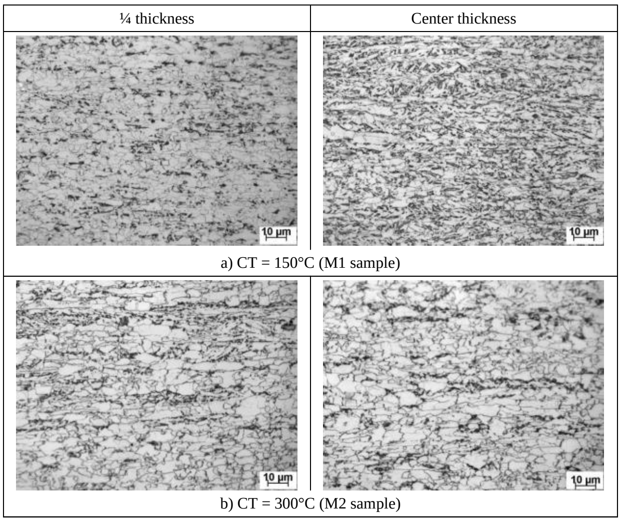
Sample	SRT (°C)	FT (°C)	CT (°C)
M1	1220 ~ 1260	890 ~ 930	150
M2			300
M3			400
M4			525
M5			600

A sample in the center of strip width, considered a stable temperature region, was used for each produced coil. This sampling position was chosen to minimize the interference of other variables.

3 RESULTS AND DISCUSSION

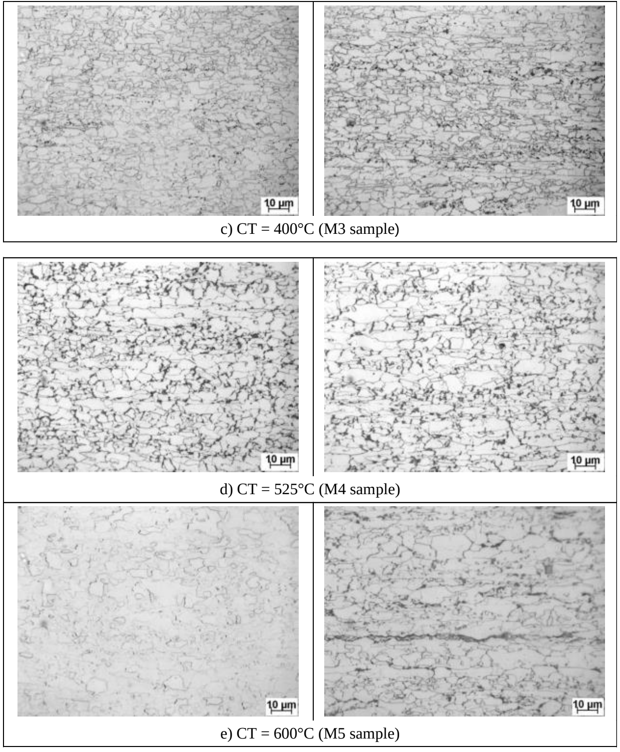
3.1. Microstructure

The evaluated microstructure in OM is formed by a second phase dispersion on ferritic matrix, as shown in Figure 1. A slight microstructural difference is observed at the center and ¼ samples thickness. At ¼ thickness the ferritic matrix has heterogeneous grain size and shape, while the second phase is formed by dispersed particles or concentrated particles in some defined areas. At the center, the second phase has a higher fraction compared to ¼, probably due to chemical segregation, common in materials produced by continuous casting.



a) CT = 150°C (M1 sample)

b) CT = 300°C (M2 sample)



c) CT = 400°C (M3 sample)

d) CT = 525°C (M4 sample)

e) CT = 600°C (M5 sample)

Figure 1. Evaluated samples microstructure in OM. Nital 4% etched samples (1000X magnification).

The microstructure of all the samples observed by SEM has fine carbides dispersion and particles of martensite-austenite (MA) constituent in ferritic matrix, as shown in Figure 2. The matrix presents a mixture of variable ferrite grain sizes and types: polygonal (PF), with regular contours and approximately equiaxial format; quasi-polygonal (QF), with irregular contours and more elongated shape; and bainitic ferrite (BF), with acicular appearance and defined laths presence. For the second phase, it is possible to identify two distinct morphologies: martensite-austenite (MA) fine particles constituent and regions with degenerate upper bainite (DUB) formed by laths of bainitic ferrite separated by alignments of MA or retained austenite [5]. For 600° C, the SEM shows some perlite alignments.

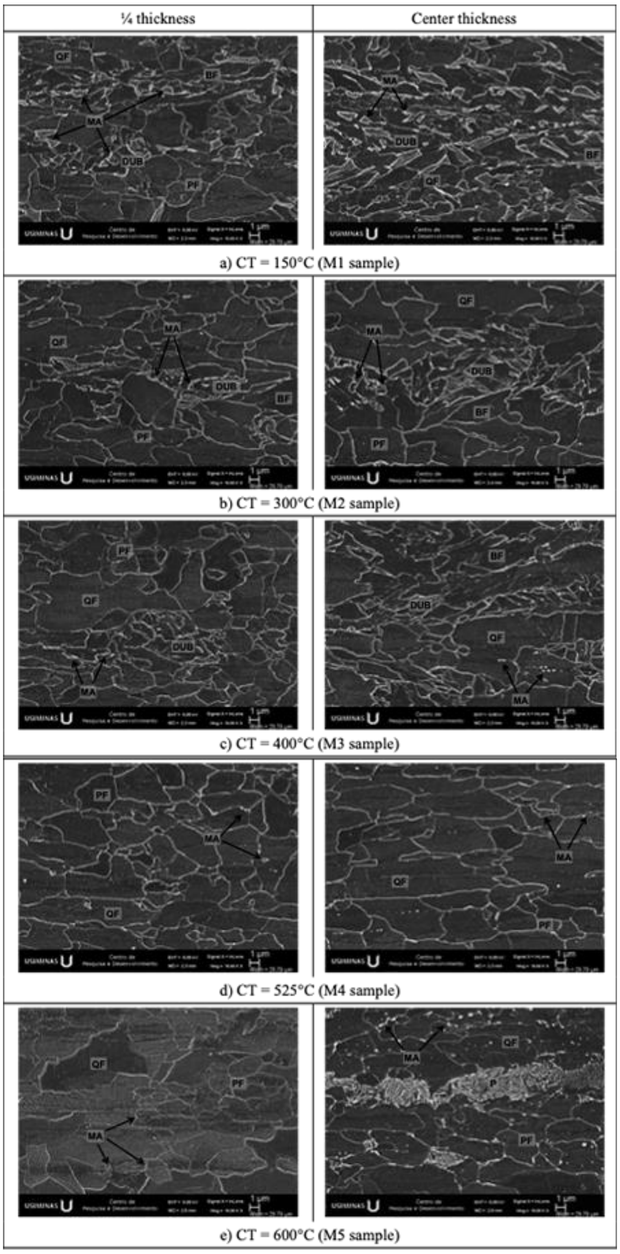
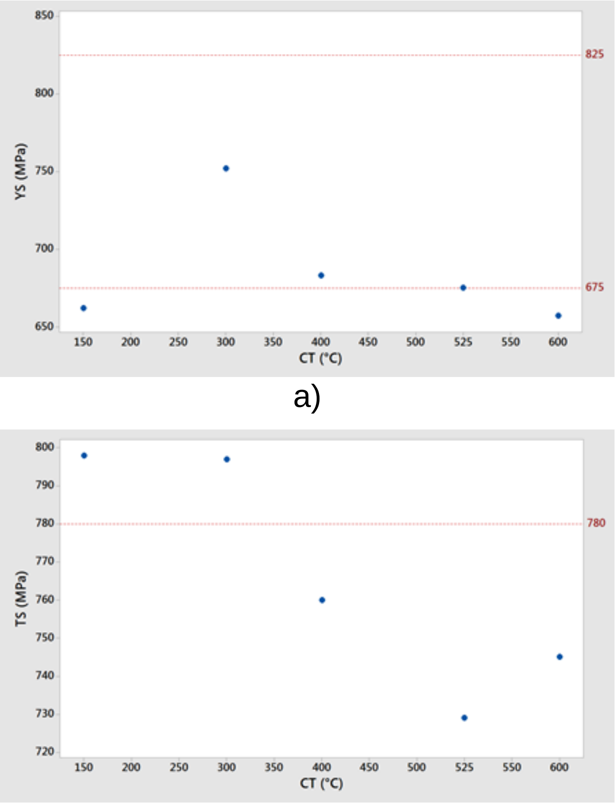


Figure 2. Evaluated samples microstructure in SEM. Nital 4% etched samples (10000X magnification). PF = poligonal ferrite; QF = quasi-polygonal ferrite; P = Perlite; BF = bainitic ferrite; MA = martensite/austenite; DUB = degenerate upper bainite.

3.2. Tensile Mechanical Properties

Figure 3 shows coil temperature influence on steel tensile strength. The yield strength (YS) decreased with coil temperature increase. This effect can be observed starting at 300°C. The low YS obtained for 150°C sample is probably associated to higher amount of MA particles in the microstructure. The tensile strength (TS) also had shown an overall decrease trend with increasing coil temperature, as expected. Coil temperature effect had no influence on total elongation. The values presented are the average of three results.

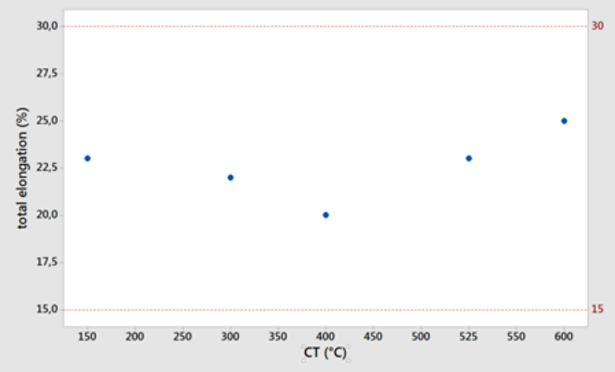
Figure 3 also shows the mechanical properties ranges specified for JFS A 1001 grade SPH780R [6]. The minimum value specified for the TS (780 MPa) was exceeded in lower temperature coils (300°C and 150°C), however the YS range was only reached by 300°C sample. All the samples evaluated presented total elongation values within the specified range.



a)

b)

Figure 3. Coil temperature effect average on a) yield strength, b) tensile strength and c) total elongation. Dashed lines show mechanical properties ranges specified for JFS A 1001 grade SPH780R [6].



c)

Figure 3. Continuation.

3.3. Hole Expansion Ratio

Figure 4 shows the conical hole expansion ratio average results. The reference value was of 50%. This value is the minimum specified by most of automotive assemblers for SPH780R grade. For 150°C coiling temperature, this requirement was not attended. It is probably associated to the greater hardness difference between ferrite and MA constituent [7].

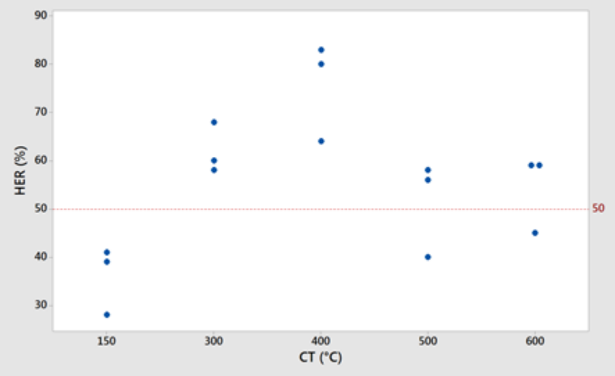


Figure 4. Coil Temperature (CT) effect on hole expansion ratio (HER). Dashed lines shown minimum specified HER value for SPH780R grade.

4 CONCLUSION

For the coiling temperatures evaluated, between 150°C and 600°C, the obtained microstructure was composed of a ferritic matrix with dispersion of fine particles of martensite-austenite constituents and regions with degenerated upper bainite. For the coiling temperature of 600°C, some perlite alignments were identified. For all cases, ferrite presents a heterogeneous mixture of polygonal, quasi polygonal and acicular form. Yield and tensile strengths showed a decreasing trend with coiling temperature increase, probably due to higher MA constituent fraction at lower temperatures and higher quasi polygonal ferrite fraction for higher temperatures. The temperature variation showed no influence in material elongation. The conical hole expansion presented values below the minimum specified for the 150 coiling temperature, probably due to the greater hardness difference between ferrite and MA constituent.

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