The 56th International October Conference on Mining and Metallurgy
22-25 October 2025, Bor Lake, Bor, Serbia
www.ioc.tfbor.bg.ac.rs

DOI: 10.5937/IOC25546J Original scientific paper

DEVELOPMENT OF 12,0mm THICK HOT ROLLED STRIP OF S460MC GRADE STEEL IN HBIS SERBIA

Dragan Jeremić[1a], Željko Šutović[1b], Milić Ječmenica[1c], Dragomir Glišić[2a], Stefan Dikić[2b], Nenad Radović[2c]

[1] Quality Assurance, HBIS GROUP Serbia Iron & Steel d.o.o., Bulevar Mihajla Pupina 6, Belgrade, Serbia
[2] Faculty of Technology and Metallurgy, University of Belgrade, Karnegijeva 4, 11000 Belgrade, Serbia
[1a] draganjeremic@hbisserbia.rs, 0009-0009-0187-6577
[1b] ZSutovic@hbisserbia.rs, 0009-0002-3351-8212
[1c] MJecmenica@hbisserbia.rs, 0009-0002-9689-600X
[2a] gile@tmf.bg.ac.rs, 0000-0001-7132-0245
[2b] sdikic@tmf.bg.ac.rs, 0000-0003-2700-0628
[2c] nenrad@tmf.bg.ac.rs, 0000-0002-9521-6159

Abstract
The aim of this paper is to present development of hot rolled coils of microalloyed S460MC grade steel in 12.00x1500 mm dimension in HBIS Serbia hot strip mill, according to European Standard EN 10149-2:2013. The basis for this development was present experience in production of grade S460MC in dimension 6.00-8.00x1500 mm. In the first step, modification of chemical composition required the increase in the content of microalloying elements. Second step included modification of parameters of rolling technology (transfer bar thickness, reheating temperature/time etc.). Finally, after cooling and coiling, hot-rolled strips were tested by means of tensile testing and Charpy impact toughness. The results show that, in all cases, yield strength, ultimate tensile strength, elongation and Charpy impact toughness meet the requirements of EN 10149-2:2013.

Keywords: *microalloyed steel, control rolling, grade S460MC*

1. INTRODUCTION

Microalloyed steels are most commonly used group of structural steels, due to their good combination of strength and toughness, together with good weldability. Their microstructure is characterized by very small ferritic grains with or without a small presence of pearlite, with precipitates within grains. Due to low carbon content and low content of alloying elements, microalloyed steels are characterized by very good weldability. Since microalloyed steels are produced at hot strip mill, obtaining final microstructure does not require quenching and tempering, making them much cheaper in comparison to quenched and tempered steels. Main alloying elements in microalloyed steels are Ti, Nb and V. All these elements share the same feature, that they are prone to intensive precipitation below solubility product. The main task of conventional controlled rolling of microalloyed steels is to obtain the structure consisting of uniform small ferrite grains with fine second phase particles in order to provide good mechanical and technological properties [1-10].

The aim of this work was to produce hot rolled strip of grade S460MC (with guaranteed minimal yield strength of 460 MPa) on the existing equipment and process conditions of HBIS-Serbia, with a target thickness of 12.00 mm and a target width of 1500 mm.

2. EXPERIMENTAL

Chemical composition and mechanical properties must comply with European standard EN10149-2:2013 [11] – selected data are extracted and given in Tables 1 and 2. The basis for this development was present experience in production of grade S460MC 6.00-8.00 mm thick hot strip.

Table 1. Chemical composition of the ladle analysis for thermomechanically rolled S460MC steel

Grade	C max	Si max*	Mn max	P max	S max	Al min	Nb max	V max	Ti max	(Nb+V+T)max
S460MC	0.12	0.50	1.60	0.025	0.015	0.015	0.09	0.20	0.15	0.22

* Suitability for hot-deep zinc-coating: Category A: Si≤0.03% and Si+2,5P≤0.090; Category B: 0.14%≤ Si ≤0.25% and; Category D: 0.25%< Si ≤0.35%.

Table 2. Mechanical properties for thermomechanically rolled S460MC steel

Grade	ReH min, [MPa]	Rm min, [MPa]	Rm max, [MPa]	A min (H≥3,0 mm), %	Bending at 180° min	KV_2 at -20°C min
S460MC	460	520	670	14	1 x t	40

Tensile Test - Longitudinal test specimen; Bending Test - Transversal test specimen; Impact Test - Longitudinal test specimen

In order to provide strength of 460MPa, it is necessary to increase the content of alloying elements, i.e Nb, V and Mn, due to slower cooling of thick cross-sections. Also, in order to obtain homogenous solid solution before roughing rolling, increased content of alloying elements requires higher slab soaking temperature and longer total slab reheating time. Therefore, starting Manufacturing Procedure Specification (MPS) for 6.00-8.00 mm thick S460MC hot-rolled strips (KW39), was modified, for 12.00 mm (KW54) thicknesses, and given in Table 3.

Table 3. MPS for S460MC hot-rolled strips with different thickness

PARAMETER	UNIT	KW39		KW54	
		min.	max.	min.	max.
H_{ST}	[wt.%]	6.00	8.00	10.01	12.00
C	[wt.%]	0.066	0.094	0.075	0.095
Mn	[wt.%]	1.195	1.405	1.346	1.505
Si	[wt.%]	-	0.030	0.146	0.254
Al	[wt.%]	0.020	0.050	0.020	0.045
N	[wt.%]	0.0066	0.0094	0.0070	0.0095
Nb	[wt.%]	0.040	0.050	0.045	0.055
Ti	[wt.%]	0.010	0.015	0.010	0.015
V	[wt.%]	0.045	0.055	0.060	0.070
T_{SS}	[°C]	1230	1240	1230	1250
t_{RH}	[min]	210		230	
T_{TB}	[°C]	1040	1060	1040	1060
H_{TB}	[mm]	32	37	37	39
T_{FRT}	[°C]	830	850	830	850
T_{CT}	[°C]	580	620	580	620

Where:
H_S, B_S are : specified thickness and width of hot-rolled strip, respectively
T_{SS} : slab soaking temperature
t_{RH}: total slab reheating time
T_{TB}: transfer bar temperature, measured at the end of roughing mill
H_{TB} : transfer bar thickness, measured at the end of roughing mill
T_{FRT} : finish rolling temperature, measured at 12.5 m from the last finishing mill stand
T_{CT} :coiling temperature, measured at a distance of 28 m in front the downcoiler
Mechanical properties of Hot strip were tested by means of uniaxial testing and Charpy impact testing.

3. RESULTS AND DISCUSSION

Actual chemical composition of steel and actual parameters of hot rolling are given in Tables 4 and 5, respectively.

Table 4. Actual chemical composition of casted KW54 slabs

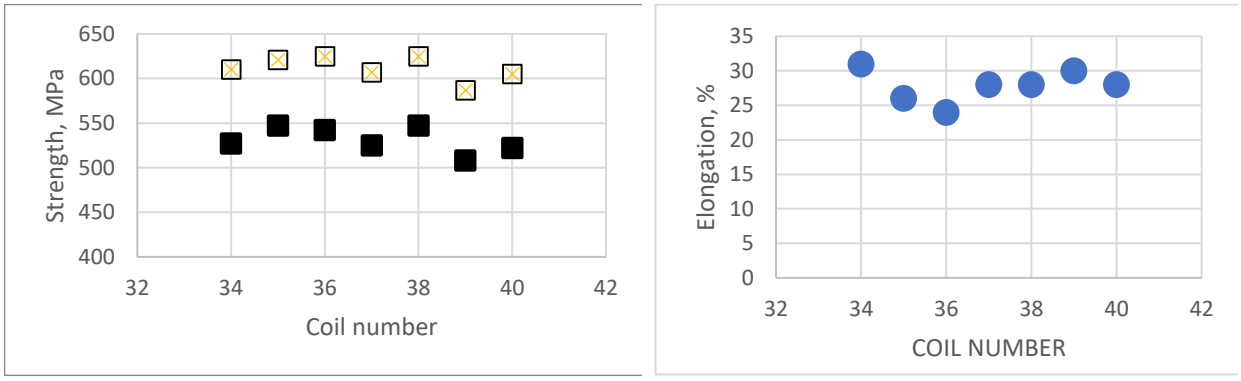
	C	Si	Mn	P	S	Al	Nb	Ti	V	N	Ca
avg.	0,086	0,191	1,465	0,012	0,0044	0,038	0,047	0,013	0,066	0,0076	0,0028

Table 5. Actual parameters of hot rolling of KW54 slabs

	T_{SL}	t_{RH}	T_{TB}	H_{TB}	T_{FRT}	STD $_{FRT}$	T_{CT}	STD T_{CT}
avg.	1219	261	1039	37	846	14	602	30

The chemical composition is in general agreement with designed values. Contents of Nb and V were targeted to middle of the interval between minimum and maximum values. Hot rolling parameters were also within designed range.

Tensile properties. Values of Yield Strength (YS), Ultimate tensile strength (UTS) are shown in Figure 1a while elongation values are presented in Figure 1b.



(a) (b)

Figure 1.Mechanical properties of hot strip: (a) Strength - YS-closed symbols: UTS – open symbols; (b) Elongation

In all hot strips, obtained values for Yield Strength, Ultimate tensile strength and elongation for 12.0 mm are in agreement with values required by EN10149-2:2013 [11].

Impact toughness. Measured values are presented in Figure 2. Results of impact toughness are much higher than required 40 J at -20 °C, showing small scatter.

It should be pointed out that a different thickness of hot strip requires mandatory modification of chemical composition. The cooling from F_{RT} to T_{CT} of 6 mm strip is much faster than cooling of 12 mm strip, leading to a higher driving force for ferrite nucleation and smaller ferritic grain. On the other hand, slower cooling in 12.00 mm strip can't produce grain size as small as in 6.00 mm thick strip. One of the limitations is the capacity of the cooling section in Hot strip mill, i.e. present cooling rate is considered to be ultimate cooling rate [13]. Therefore, it is necessary to compensate driving force by additional increase in content of alloying elements to more efficiently suppress recrystallization [1-3,9,10]. Consequently, increased presence of alloying elements, requires increase both of soaking temperature in reheating furnace and time for soaking, in order to provide dissolution of all particles that contains V and Nb [1-3,9]. Detailed results with all measured and monitored values are available in [12]. The parameters that are to be optimized are related to rolling forces in all stands (temperature and thickness of transfer bar etc).

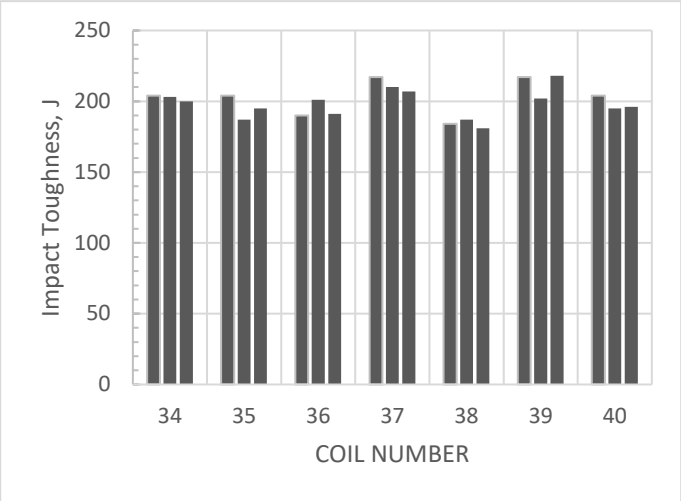


Figure 2. Impact toughness of hot strips

4. CONCLUSIONS

- S460MC grade microalloyed steel was developed successfully in HBIS Serbia Hot Strip Mill, in 12.00 mm thickness.
- All mechanical properties are above required level.
- In future work, rolling forces are to be optimized.

ACKNOWLEDGEMENT

This work was funded by HBIS Co, Shijiazhuang, China through Contract No 449-2025. Authors greatly acknowledge the cooperation with colleagues from HBIS Serbia Hot Strip Mill.

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