IOP Conf. Series: Materials Science and Engineering **207** (2017) 012050 doi:10.1088/1757-899X/207/1/012050

Researching on Rolling Technology of Q460E Plate

Yanjun Meng, Bing Wang, Yanxia Liu, Ming Chen, Zhongqi Dong*

Material Engineering Department, Hebei College of Industry and Technology, Shijiazhuang 050000, China

*Corresponding author e-mail: dongzhongqi@126.com

Abstract. The production process of 3 kinds of Q460E medium and heavy plate produced was studied by controlled cooling rolling process. Results show: that were used in two stage preheating and two stage controlled rolling. The first stage is rolling in the austenite recrystallization zone, and the temperature of the billet is 1050 to 1100 ℃, and the reduction rate is more than 10%; The second stage is rolling in austenite non recrystallization, the rolling temperature is less than or equal to 950 ℃, the finishing temperature is 860 to 790 ℃, until the temperature after the cumulative reduction ratio is more than 50%, more than 12% times the rate of deformation; The laminar cooling is used, so that the steel has good toughness

1. Introduction

Engineering machinery steel with Nb, V, Ti and other micro alloying, using micro alloy elements to form carbon nitride in the steel plate on the dissolution and precipitation, on grain refinement and precipitation strengthening effect of [1~4] Q460E, which has high strength, good toughness and weldability, because of its good performance, widely used in various engineering machinery structure parts manufacturing [5~8]. Micro alloying and controlled rolling and controlled cooling based on the production of Q460E board, become the main way of steel plate during the rolling process of engineering machinery, take controlled rolling and controlled cooling and normalizing process, ensure the steel strength and toughness.

To this end, this paper combined with the characteristics of the equipment and process of the 3500mm rolling mill production line of a certain steel plant, through the reduction of carbon equivalent, using Nb, V microalloying and controlled rolling and controlled cooling technology, to explore the preparation of medium plate Q460E steel.

2. Experimental materials and methods

The thickness of Q460E continuous casting slab is 30~80 mm, the chemical composition is shown in Table 1, and the mechanical properties are shown in Table 2. The rolling is 20, 25 and the 32 mm of the steel strip of the three specifications, the heating system design is shown in Table 3, the rolling process parameters are shown in table 2 . The samples were cut at the strip 1/4, and the mechanical properties of the samples were tested by using BDCL 20mm 80 mm test machine.

Table 1 chemical composition of test steel (%)

Steel	C	Si	Mn	P	S	Nb	V	Als	CEV
Q460E	0.14-0.18	0.20-0.40	1.45-1.65	≤0.020	≤0.010	0.020-0.035	0.060-0.080	0.015-0.035	0.39-0.45

Table 2 mechanical properties of Q460E

Thickness /mm	σ_s /MPa	σ_b/ MPa	δ_5 %	V		180℃ bend test mm	
				℃	J	≤16	>16
≤16	≥ 460	550～720	≥17	-20	34	d=2a	d=3a
16～40	≥ 440	550～720	≥17	-20	34	d=2a	d=3a
40～63	≥ 420	550～720	≥16	-40	34	d=2a	d=3a
63～80	≥ 400	550～720	≥16	-40	34	d=2a	d=3a

Table 3 heating system

preform body	preheating ℃	Heating section ℃	Two heating section ℃	holding zone℃	heating time/ h
cold material	≤850	1040-1100	1230-1290	1180-1240	≥2.5h
Hot material	≤850	1000-1100	1230-1290	1180-1240	≥2h

Table 4 rolling parameters

Finished thickness / mm	Temperature thickness mm	End of temperature ℃	finishing temperature℃	controlled cooling	Return temperature ℃
20	42	870 - 840	840 - 825	y	680 - 700
25	46	870 - 845	830 - 820	y	680 - 700
32	68	860 - 825	840 - 820	y	680 - 700

3. Experimental results and discussion

The mechanical properties of Q460E hot rolled specimens are shown in Table 5, the grain size is shown in Table 6 table 5 and 6 using visible, two stage and two stage preheating control rolling, rolling plate can improve the effective grain size, reach the 10 level, which can significantly improve the steel yield strength and tensile strength; toughness steel plate has no obvious worse, and has a great amount of surplus.

Table 5 mechanical properties of Q460E test

mark	Standard/ mm	Yield strength / MPa	Tensile strength / MPa	Extensibility %	-40℃V Type impact			cold bending
1#	20	485	595	20.5	141	145	140	qualified
2#	20	480	580	27	204	179	217	qualified
3#	20	485	590	28	215	205	210	qualified
4#	20	495	610	23	71.2	63.9	33.1	qualified
5#	25	475	595	26	165	164	170	qualified
6#	25	485	595	25.5	165	166	169	qualified
7#	25	480	610	23.5	184	73.4	150	qualified
8#	25	495	605	27	200	197	203	qualified
9#	25	475	605	28	175	177	180	qualified
10#	32	440	580	25	179	190	195	qualified

The trial plate at 1/4 thickness microstructure as shown in Figure 1. The thickness of steel plate 1/4 tissues of ferrite and pearlite and the grain size is 10, respectively. The volume fraction of ferrite pearlite 38%. 62%, pearlite and fine dispersed, so the strength of the steel plate is obviously improved.

Table 6 Q460E grain size

Steel grade	Inclusion rating	Metallurgical structure	Grain size
Q460D	$A_{0.5}C_{0.5}D_{0.5}$	F+P	10

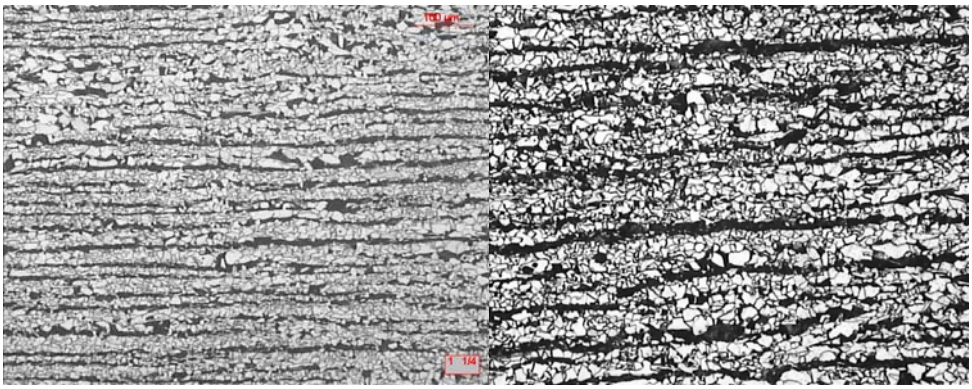

Fig. 1 Q460E metallographic structure

3.1. Temperature schedule

The yield strength, tensile strength and toughness of Q460E plate are improved, which is closely related to the system of slab heating . The slab of Nb, V mainly to large particles of carbon, nitrogen form, when heating at low temperature, which is below 900 DEG C, Nb, V carbon, nitrogen is insoluble, dissolved NB carbon, nitrogen retention in coarse particles after rolling steel plate on the tissue, almost no strengthening effect; began to dissolve, exceed 990 DEG C, therefore, 1000 degrees (or 1040 DEG C) heating temperature to ensure there is enough Nb, V solid solution in the austenite.

At the same time, the heating temperature can not be too high, which is due to the size of austenite grain size after heating will directly affect the grain size after rolling .Usually the austenite grain at 1150 DEG C size uniform, more than 1180 degrees, due to the grain boundary of carbon, nitrogen dissolution, on grain growth inhibition effect disappeared, the austenite grain began to rapidly grow, so the heating temperature should not exceed 1180 degrees. Due to lower heating temperature, is

conducive to the precipitation of niobium with carbon, nitrogen, to inhibit the grain growth, and reduce the heating temperature can shorten the residence time in the high temperature zone after rolling, avoid continuous recrystallization of austenite grain in the high temperature zone of the growth, the grain size increases.

3.2. Controlled rolling

The two stage is the rolling control, some special functions of micro alloying elements can only be achieved under certain conditions based on the mechanism of the influence of body performance of material is more sensitive to the process parameters, the two phase control rolling can better play the role of alloying elements such as recrystallization. According to the rolling of niobium in austenite and niobium delay the carbide, nitride dissolution precipitation characteristics.

The austenite recrystallization rolling, rolling billet temperature is 1050 to 1100 DEG C, in the first stage using features of rolling deformation resistance of high temperature steel is low, as far as possible the use of large amount of pressure, to refine the austenite grain, in control of more than 10% pass reduction rate.

To be warm, with decreasing the rolling temperature, into the recrystallized austenite part, in this interval rolling, only part of the austenite recrystallization, resulting in austenite grain size is not uniform, and may form part of the large grain, causing serious mischcrystal. Mischcrystal structure appears, it will be difficult to eliminate, and reduce the steel toughness. To this end, the use of intermediate temperature system, when rolled to the finished steel plate thickness of 2 to 3 times when the temperature began to avoid the austenite recrystallization zone rolling.

To this end, the use of intermediate temperature system, when rolled to the finished steel plate thickness of 2 to 3 times when the temperature began to avoid the austenite recrystallization zone rolling. The type Nb bearing steel rolling, when the temperature is below 950 DEG C that has no dynamic recrystallization can. So the Q460E second stage for the rolling temperature is less than or equal to 950 DEG C, the finishing temperature is 860 ~ 790 degrees. When 12 ~ 20mm thick plate rolling, finish rolling temperature from ceiling to prevent the smooth pass too fast temperature drop, the temperature is too low, have an adverse effect on the roll surface; when the thickness was more than 20mm, the final rolling temperature in the lower limit. Until the temperature after cumulative reduction ratio is more than 50%, the deformation rate greater than 12% times; the last one according to the shape and thickness can be decreased properly, shorten dearance time to grain refinement to improve strength and toughness of steel.

3.3. Controlled cooling process

Control in the process of rolling, recrystallization through repeated deformation, can refine grain and improve the strength and toughness of the steel, but the deformation induced transformation, the Ar3 temperature increased, resulting in ferrite in high temperature precipitation, such as slow cooling after rolling is easy to make the grain growth, so to control the cooling speed. According to the appropriate system the thickness of different laminar cooling after rolling with different cooling pipe, by adjusting the number of groups, Q460E red temperature controlled at 670-700 DEG C.

Control in the process of rolling, recrystallization through repeated deformation, can refine grain and improve the strength and toughness of the steel, but the deformation induced transformation, the Ar3 temperature increased, resulting in ferrite in high temperature precipitation, such as slow cooling after rolling is easy to make the grain growth, so to control the cooling speed. According to the appropriate system the thickness of different laminar cooling after rolling with different cooling pipe, by adjusting the number of groups, Q460E red temperature controlled at 670-700 DEG C.

4. Conclusion

(1) The system of rolling process of Q460E plate for the rolling control two stage preheating and two stages, the first stage in the austenite recrystallization zone rolling billet rolling temperature is 1050 to 1100 DEG C, in control of more than 10% pass reduction rate; the second stage in austenite non

recrystallization zone rolling, rolling the temperature is less than or equal to 950 DEG C, the finishing temperature is 860 to 790 DEG C, until the temperature after the cumulative reduction ratio is more than 50%, the deformation rate greater than 12% times; the laminar cooling patterns.

(2) Two stage control of rolling and rapid cooling after rolling, the grain refinement is the fundamental reason for Q460E to obtain excellent mechanical properties

Acknowledgments
Project supported by the science and technology research project of Hebei higher education institutions, the project number: QN2016168 and Hebei College of Industry and Technology ZY2016006, ZY2016004

References

[1] Wenchao Li,Fangfang Liao,Tianhua Zhou,Harm Askes. Ductile fracture of Q460 steel: Effects of stress triaxiality and Lode angle [J]. Journal of Constructional Steel Research, 2016, 123: 1–17.
[2] Wenchao Li,Fangfang Liao,Tianhua Zhou,Harm Askes. Ductile fracture of Q460 steel: Effects of stress triaxiality and Lode angle [J]. Journal of Constructional Steel Research, 2016 : 917-921.
[3] Yansheng Du,Zhihua Chen,Ming-Xiang Xiong. Experimental behavior and design method of rectangular concrete-filled tubular columns using Q460 high-strength steel [J]. Construction and Building Materials, 2016, 125: 856–872.
[4] Wenchao Li,Luca Susmel,Harm Askes,Fangfang Liao,Tianhua Zhou. Assessing the integrity of steel structural components with stress raisers using the Theory of Critical Distances [J]. Engineering Failure Analysis,2016, 70: 73–89.
[5] CUI Zhanbin, WANG Qian, CUI Zhanhui, FAN Lei, WANG Qingfeng. Effect of self-tempering of temperature on microstructure and mechanical properties of a Q460E class high rise building [J]. Journal of Iron and Steel Research, 2014,(05): 61-63.
[6] ZHANG Qiang. Study on controlled cooling technology for Q460E heavy plate [J]. Steel Rolling, 2014,(05): 61-63.
[7] LIU Haitao, XU LIyong, LIU Donghua, WU Jianding. Welding process research of high strength steel Q460E rolled by TMCP [J]. Electric Locomotives & Mass Transit Vehicles, 2016,(01):64-67.
[8] Mao Guohua. Research and Development of Q460E Micro Alloyed Steel [D]. Xi`an University of Architecture and Technology, 2014.