Study on controlled rolling and cooling process of CH1T steel
High speed wire 1# shaoguan steel

Guanghua Zhang¹, Jietao Dai²*, Ju Yan¹, Liejun Li³

¹Shaoguan Iron & Steel Co., Baowusteel Group, Shaoguan 512123, China
²School of mechanical and electrical engineering, Guangzhou University, Guangzhou, Guangdong, China
³South China University of Technology School of Mechanical & Automotive Engineering, Guangzhou 510641, China

*Corresponding author: *email: daijietao@gzhu.edu.cn

Abstract: Under the background that the high-grade industrial wire rod such as cold heading steel is mainly developed in the first line of Shaoguan Iron and Steel Co., Ltd., the controlled rolling and controlled cooling process of ultra-low carbon cold heading steel ch1t is studied in this paper. A large number of high-temperature tensile tests for CH1T are carried out on Gleeble 3800 thermal simulation testing machine, and the high-temperature plastic characteristics of CH1T and stress-strain curves at different temperatures are obtained. At the same time, the transformation points Ac1, Ac3, Ar1 and Ar3 of ch1t steel and the dynamic CCT curve were measured, and the process improvement measures were formulated on the basis of experimental research. The field practice shows that the proposed process improvement measures have greatly improved the problem of low yield of ch1t cold heading steel in the first line of Shaoguan Iron and Steel Co., and achieved remarkable economic benefits.

1. Introduction
The Gaoyi production line of Songshan special rolling plant of Baowu Zhongnan iron and Steel Co., Ltd[1], was completed and put into operation in December 2004, with a maximum design rolling speed of 110 m / s. One set of torsion free cold rolling mill for the whole line (the total number of stands is 30), of which 6 are arranged for rough, medium and pre finishing rolling. Pre finishing rolling 13#, 14# are Morgan models and 15# to 18# are Danieli models. Bgv, TMB, caliper and spinner are the latest technologies and products of Danieli company in Italy. After 2015, relying on the technical support and product transplantation of Baosteel Group[2], SISG successfully developed 8 series and 36 brands of alloy cold heading steel, free cutting steel and spring steel, realized the batch supply of 11 new brands and the market expansion of secondary fire materials and spring steel such as SCM435, ml40cr, swrch10a, 20CrMnMo and 30crmnti, and SISG cold heading steel has taken the step towards medium and high-end products.

In the rolling process of producing ultra-low carbon cold heading steel CH1T[3], due to small flow per second, long on-line rolling time and large temperature drop, the middle tail often appears, especially the tail temperature is lower than 1000 ℃, which makes it difficult to control the tension and affects the head and tail size and cold heading stability. At the same time, in the controlled cooling stage, because the dynamic CCT curve of CH1T is not analyzed, the cooling rate needs to be further optimized[4].
In order to analyze the influence of temperature in the process of controlled rolling and controlled cooling, the controlled rolling and controlled cooling process of the high line of Shaoguan Iron and Steel Co[5].

2. High temperature tensile test

2.1 Test scheme
Under the vacuum condition, firstly, heat the uniform temperature zone of the sample to 1300 °C at the heating rate of 10 °C/s for 5 minutes[6], then, cool to the specified tensile temperature at the cooling rate $T = 5 \, ^\circ\mathrm{C}/\mathrm{s}$ for 90 seconds, and finally, press $\varepsilon = 1 \times 10^{-3} \, \mathrm{S}^{-1}$ until fracture. Figure 1 below shows the fracture diagram of high temperature tensile specimen.

2.2 Test result
A large number of high temperature tensile tests for CH1T were carried out on the Gleeble 3800 thermal simulation test machine of SISG, and the high temperature plasticity of CH1T was obtained, as shown in Figure 3 below.

Fig1 Fracture shape diagram

Fig2 Relationship between tensile temperature, reduction of area and tensile strength of CH1T steel
Fig.3 800°C Stress-strain curve

Fig.4 900°C Stress-strain curve

Fig.5 1000°C Stress-strain curve
Fig. 6 1100°C Stress-strain curve

Fig. 7 1200°C Stress-strain curve

Fig. 8 1300°C Stress-strain curve
From the above diagram of the relationship between the tensile temperature of CH1T steel and the reduction of area and tensile strength, as well as the stress-strain curves at different temperatures, it can be seen that the plasticity of CH1T steel, deformation rate = $1 \times 10^{-3} \text{s}^{-1}$, in the temperature range of 1000℃~1150℃, the overall plasticity of the material is relatively balanced, in the high plasticity range, and the surface shrinkage is between 80%±3%; the plasticity decreases in the temperature range of 1200℃~1300℃, and the plasticity at 1300℃ is the lowest; in the temperature range of 1000℃~875℃, the plasticity of the material decreases, the fracture becomes worse, and the shape looks like rotten steel, but the ductility of the material is improved; In the temperature range of 850℃ ~ 700℃, the plasticity of the material is high and shows a decreasing trend. At 850℃, the plasticity is the highest value of overall plasticity and the area shrinkage is 88.10%. The overall deformation resistance increases with the decrease of temperature, but there is abnormality in the temperature range of 900℃~850℃, which is lower than that at both ends.[7]

3. Dynamic CCT curve measurement
In order to formulate a reasonable controlled cooling process, the transformation points Ac1, Ac3, Ar1 and Ar3 and the dynamic CCT curve of CH1T steel were measured. The test results show that the transformation point temperature of ch1t steel is Ac1=835℃, Ac3 =1023℃, Ar1=878℃, Ar3=914℃.

4. Process adjustment of controlled rolling and cooling
According to the above experimental results, the controlled rolling and cooling process of CH1T steel is formulated as follows:

(1)The start rolling temperature is adjusted to 1030℃ at the head, 1000℃ in the middle and 1050℃ at the tail;

(2)7.0 for the first 5 steels of the following specifications, the cooling water of the 1# rolling mill shall be closed when the steel tail is about 1.5m away from the 1# frame to eliminate the temperature drop at the tail.

(3)The deformation temperature of each pass shall not be lower than 935℃, otherwise it will be rolled in two-phase zone, which will cause problems such as uneven microstructure and performance. The cooling of the water tank also determines the inlet and outlet temperature of the water tank according to the phase change point temperature, and the water volume of the water tank is automatically adjusted;

(4)Spinning temperature and cooling of air cooling line shall be determined according to CCT curve. The air cooling line adopts two-stage cooling process, which is fast cooling at a cooling rate of ≥5℃/s above 630 ℃, slow cooling at a cooling rate of 0.1 ~ 3℃/s below 630℃, and air cooling to room temperature below 200℃.
5. Application effect
Since January 2020, the surface defect rate and finished product rate of CH1T have been greatly improved through process adjustment. In 2019, the surface defect rate of CH1T steel has accumulated 3.42%, and the surface defect rate of cold heading steel from August 2020 to February 2021 has reached the key project goal of ≤ 1.5% every month; In 2019, the finished product rate of CH1T steel is 93.1%, and the finished product rate of CH1T from August 2020 to February 2021 has reached the key project goal of ≥ 96.1% every month.

6. Conclusion
In view of the problems existing in the controlled rolling and controlled cooling process of Gaoyi line of Shaoguan Iron and Steel Co., Ltd., the on-site controlled rolling and controlled cooling temperature is optimized by means of Gleeble 3800 thermal simulation high temperature tensile test and CCT dynamic curve measurement, and remarkable results are obtained.

Acknowledgments
The authors gratefully acknowledge the financial support of Guangzhou Science and Technology Project [grant number: 202007020007]; And Shaoguan Science and Technology Planning Project [grant number: 2018CD11803]; And Guangdong Science and Technology Project[grant number: 2017B090907015].

References
[1] GuoYuan,Dong Chen,Jian Kang,Zhenlei Li,& Guodong Wang.(2019).Development and application of a new generation of controlled rolling and cooling technology based on ultra fast cooling in large hot continuous rolling line.Journal of Iron and Steel. Research(02), 150-158.doi:10.13228/j.boyuan.issn1001-0963.20180335.
[2] Fengbao Chen.(2017).Application of controlled rolling and cooling technology in seamless steel pipe production. Southern agricultural machinery(23), 85-86, doi: CNKI: SUN: NFLJ.0.2017-23-064.
[3] Xianda Liu,Yanying Hao,&Yunna Liu.(2019).49MnVS3 Research and application of controlled rolling and cooling technology of non quenched and tempered steel for crankshaft.Special steel(04),31-33.doi:CNKI:SUN:TSGA.0.2019-04-010.
[4] Shenhong Sun,Jianke Niu,Bing Zhao,Chen Yu,Zhongmao Guo,Gangjian Wang,&Xiangfei Han.(2015-04-30).Study on key technology of controlled rolling and cooling of stainless steel and alloy structural steel.2021-08-15,https://kns.cnki.net/KCMS/detail/detail.
[5] Wei Yu,Di Tang,Qingwu Cai,Tao Liu,Chunyu He.(2019).Development of controlled rolling and cooling technology and its application in plate production.Tree Genetics & Genomes.
[6] Shengli Li,Jianzhong Xu,Guodong Wang,&Xianghua Liu.(2006).Simulation and analysis of controlled rolling and cooling process of large section bearing steel.Journal of Northeast University (NATURAL SCIENCE EDITION)(06),658-661.
[7] Lan Qi,Zhongqian Du,Chao Lu,Xiaoya Zhu,Qingjuan Wang,Min Zhou.(2020).G20crni2moa Study on thermal simulation of controlled rolling and cooling process of bearing steel.Steel rolling,v.37;No.236(04),51-55.
[8] Hu Zhao,Weizhao Song,Hao Zhu,& Hua Xiang.(2019).Q460c Development of controlled rolling and cooling process for medium and heavy steel plate.Xinjiang Iron and Steel(1),22-26.
[9] Huiyao Liu.(2019).Study on controlled rolling and cooling process of nano precipitation strengthened steel containing Ti and Mo.(Doctoral dissertation,Northeastern University).