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Optimizing Control for 20CrMnTiH(FQ) Bloom Internal Quality by EMS

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Optimizing Control for 20CrMnTiH(FQ) Bloom Internal Quality by EMS

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Abstract. Continuous casting EMS technology for 20CrMnTiH(FQ)gear steel bloom internal quality optimizing control was researched, based on the equipment of 360mmX450mm bloom casting machine conditions which is one factory of China. Ensure the install position of F-EMS which installed close at the end of liquid core by take numerical simulate calculation for the process of solidifying and heat transfer, measured the stirring magnetic field intensity(T), and carried out comparing experiment to find out the effects of stirring intensity on bloom internal quality, the optimal process parameters of combined EMS have been defined at last, taim to control 20CrMnTiH(FQ) gear steel bloom internal quality to be densify and homogenize have been realized.

1. Introduction

Gears play an extremely important role in the development of automobile industry, the special load-bearing characteristics put forward harsh requirements on the mechanical properties of gear. The quality of bloom has a decisive effect on gear performance. With the development of CC（Continuous Casting） equipment and process, the ratio of gear blooms produced by CC tend to be increase, for the high-end and large size gear blank produce relies on molded by the difficulty of bloom quality control. A factory develop the processes and technical to produce 20CrMnTiH(FQ)gear steel adapt in 360mmX450mm cross section of continuous casting machine to develop the high-end gear steel. In this paper, CC EMS(Electro-Magnetic Stirring) was studied, the reasonable stirring process parameters were developed to ensure high quality control of gear steel.

2. Testing Conditions

2.1. Casting Machine Equipment Conditions

The casting machine equipment conditions of gear steel produced by a domestic are show in table1.

Table 1. Equipment conditions of continuous casting machine

Projects	Parameters
Brand/machine	4brands with 4machines
Height of mold	850mm
CC radius	15000 mm
Cross section	360mmX450mm
Metallurgical length	40.090m
EMS	M-EMS+F-EMS
Racks of pull machine	7

2.2. Key Physical Properties of Steel

The chemical composition of 20CrMnTiH(FQ) gear steel are show in table2, the steel chemical properties could be calculated and show as fig.1 based on table2. Fig.1 shows that Tl is 1511°C, Ts is 1458°C.

Table 2. Chemical composition of 20CrMnTiH(FQ) %

Projects	C	Si	Mn	Cr	Ti	P	S	Alt
20CrMnTiH(FQ)	0.18~0.20	0.23~0.27	0.87~0.93	1.06~1.12	0.05~0.07	≤0.015	0.018~0.023	0.015~0.03

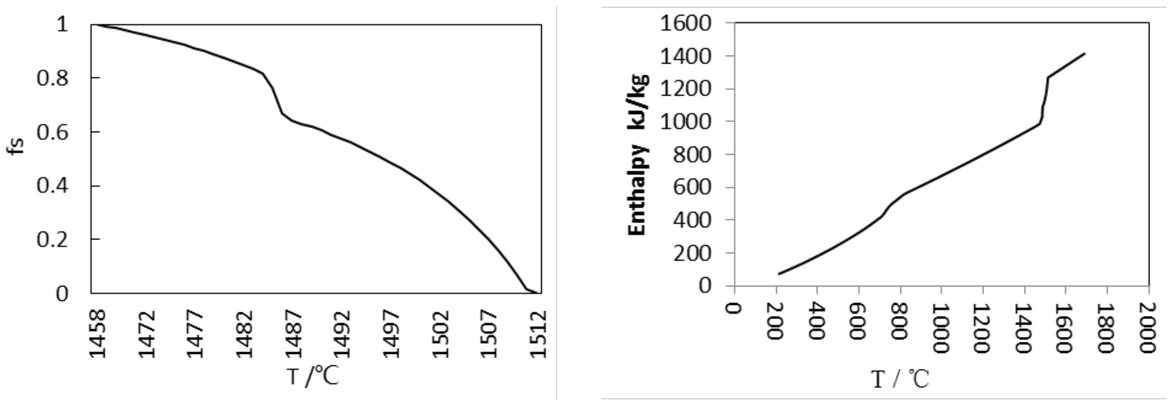


Figure 1. Key physical properties of 20CrMnTiH(FQ) gear steel

3. Research on Blooms Quality Optimizing by EMS

EMS of continuous casting is one of the most successful applications of electromagnetic fluid mechanics in iron and steel industry[1], this technical has an important effects on billets quality through a long time research and application[3], it include improve the solidification uniformity, improve surface quality, optimizing solidification structure[4] and decrease leakage rate[2], decrease secondary dendric space[5]. However the effects of EMS depends on the scientific processes parameters of stirring.

3.1. Analyzing and Choice of F-EMS Install Position

For the choice of install position of F-EMS, different studies have come to different conclusions, some scholars believe that F-EMS install at the position where size of liquid core is φ35mm~φ55mm could have a significant effects for blooms[6]. However someone consider the size of cross section and believe F-EMS generally install at the position where the proportion of solidification is 70%~80%[7], and Jianchao-Li believe 80%~90% is the most appropriate interval[8], some research shows the install position should at the space where center solidification ratio is 0.1~0.15 and thickness proportion of solidified shell is 0.5~0.55. Thus it can be seen that there is an exact basis for the install position of F-EMS but the basis range is close.

This paper choose the position where the proportion of solidified shell is 0.5~0.55, and determined by carried out numerical simulation calculate for solidification heat transfer. Calculation results are show in the fig.2 and fig.3, fig.2 shows the results of model validation, fig.3 shows that the position where proportion of solidified shell is 0.50~0.55 and the corresponding distance from mold liquid surface is 10.0~11.0.

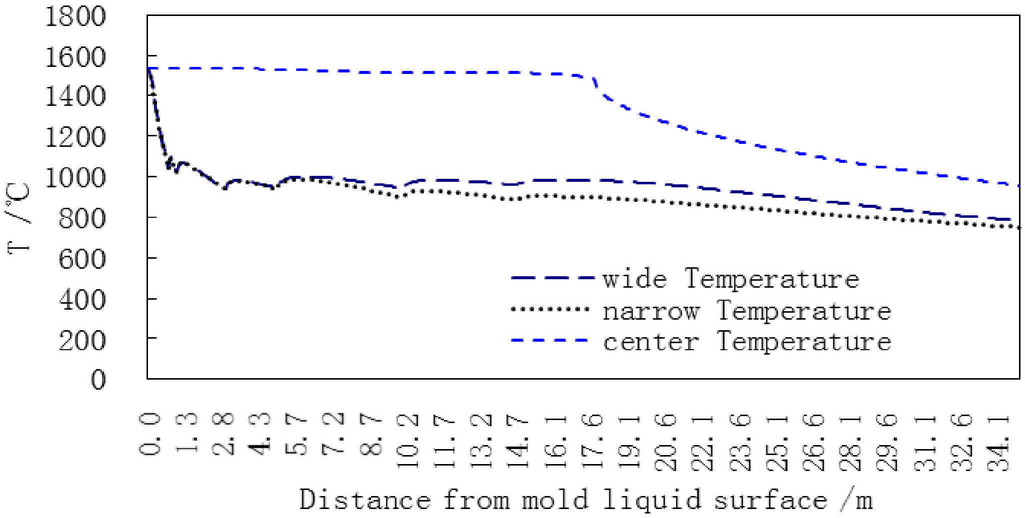


Figure 2. Compare between numerical simulate calculation and measure results

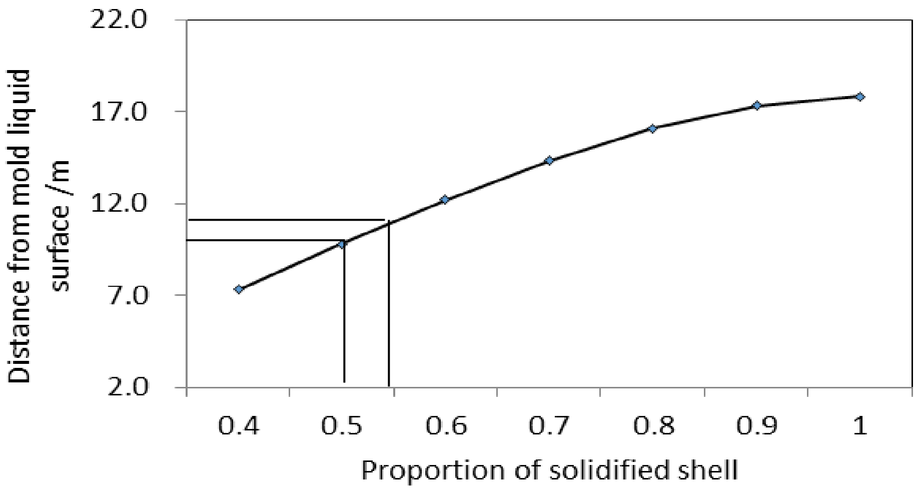


Figure 3. Development of solidifying shell size ratio

3.2. Effects of Stirring Intensity on Quality of Blooms

Keep casting speed at 0.50m/min, and carried out contrast industrial experiment based on actual intensity of magnetic field.

Testing result shows liquid steel surface in mold tend to be fluctuate, there is a risk of slag rolling while M-EMS magnetic field intensity above $350X10^{-4}$T, and if stirring intensity below $210X10^{-4}$T columnar crystal tend to be developed. Choose $230X10^{-4}$~$330X10^{-4}$T as the testing range of stirring intensity and carried out contrast test of stirring intensity gradient to find out the effects of M-EMS stirring intensity on quality of blooms.

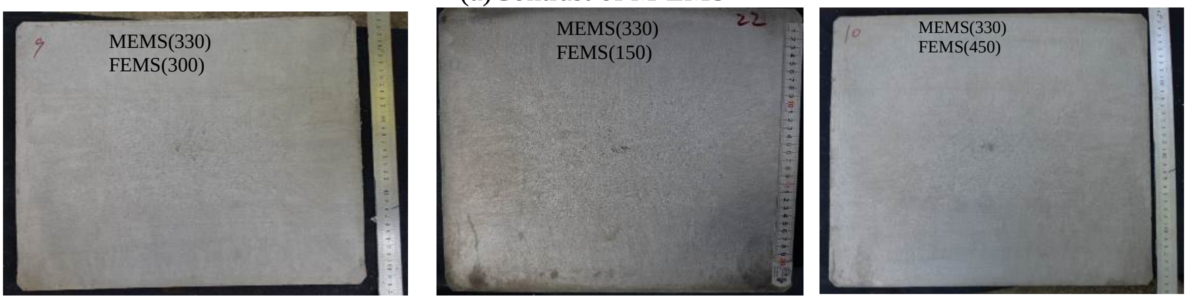
Stirring area in blooms appears with a bright white band while F-EMS stirring intensity magnetic field intensity above $470X10^{-4}$T, control results of homogeneity in bloom is not ideal, and choose $150X10^{-4}$~$450X10^{-4}$T as the testing range of stirring intensity and carried out contrast test of stirring intensity gradient to find out the effects of F-EMS stirring intensity on quality of blooms.

3.2.1. Effects of EMS stirring intensity on macro-quality of blooms

The typical macrograph of test blooms are shown in fig.4, and the rating results are shown as table3, results shows that blooms appeared shrinkage cavity and equiaxed-crystal ratio is low while M-EMS stirring magnetic field intensity is $230X10^{-4}$T, control of bloom porosity is better while M-EMS is

280X10^{-4}T than 330X10^{-4}T. Segregation of blooms is obviously while F-EMS is 150X10^{-4}T, statistical results of blooms macro-quality that center porosity and segregation rating ≤1.0 is shown in fig.5, results show that blooms quality is the best while M-EMS is 280X10^{-4}T and F-EMS is 300X10^{-4}T.

(a)Contrast of M-EMS



(b)Contrast of F-EMS

Figure 4. Present photographs of experiment blooms (X10^{-4}T)

Table 3. Results of blooms present macrograph rating(X10^{-4}T) /grade

Processes		Center	Center	Center	Center	Middle	Subsurface
MEMS	FEMS	Segregation	Porosity	shrinkage	crack	crack	crack
230	300	0.5	0.5	0.5	0	0	0
280	300	0.5	0.5	0	0	0	0
330	300	0.5	1.0	0	0	0	0
330	150	1.0	0.5	0	0	0	0
330	450	1.0	0.5	0	0	0	0

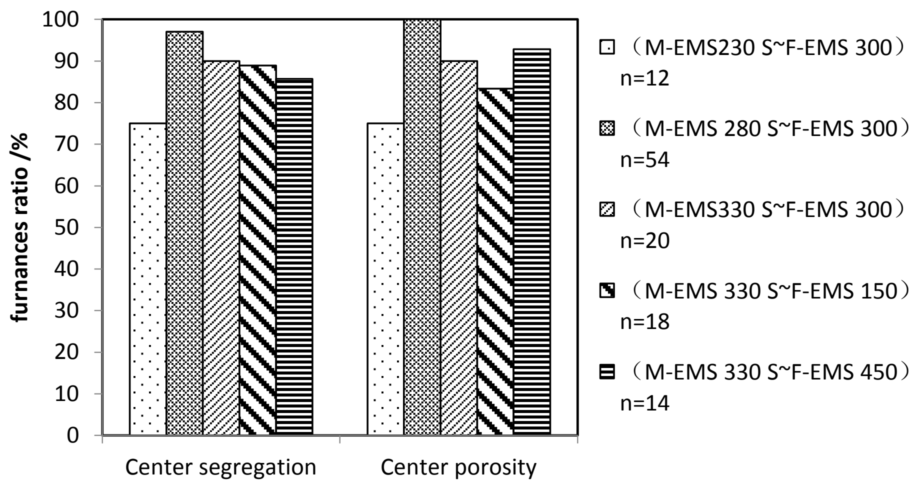


Figure 5. Effects of combined EMS processes on macro-quality(X10^{-4}T)

3.2.2. Effects of EMS stirring intensity on the homogeneity of bloom

Sampling points show in fig.6, take samples to carry out chemical segregation test by using drill that size of diameter is φ6mm.

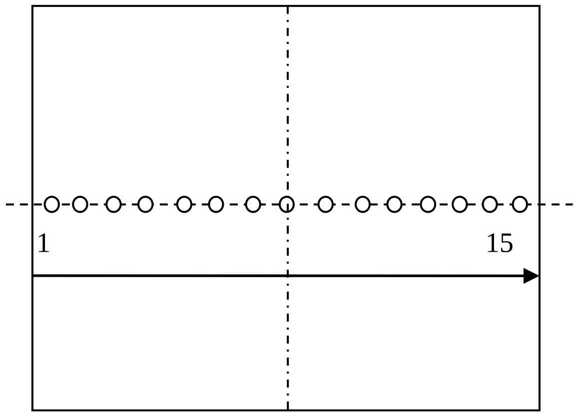


Figure 6. Diagram of sampling points distribution

Bloom carbon segregation shows in fig.7 that produced with the conditions that stirring magnetic field intensity of F-EMS is 225X10^{-4}T and comparing among different stirring magnetic field intensity of M-EMS, result shows that with the stirring intensity increase the negative segregation of stirring acting brand tend to be more serious, and with the thickness of solidified shell increase the alternation of negative to positive segregation tend to be more obvious, means homogeneity of the area tend to be worse. Therefore for soft stirring intensity is helpful for the control of homogeneity of bloom surface, but the full section uniformity is the pursue goal, and the centre segregation need to give consideration.

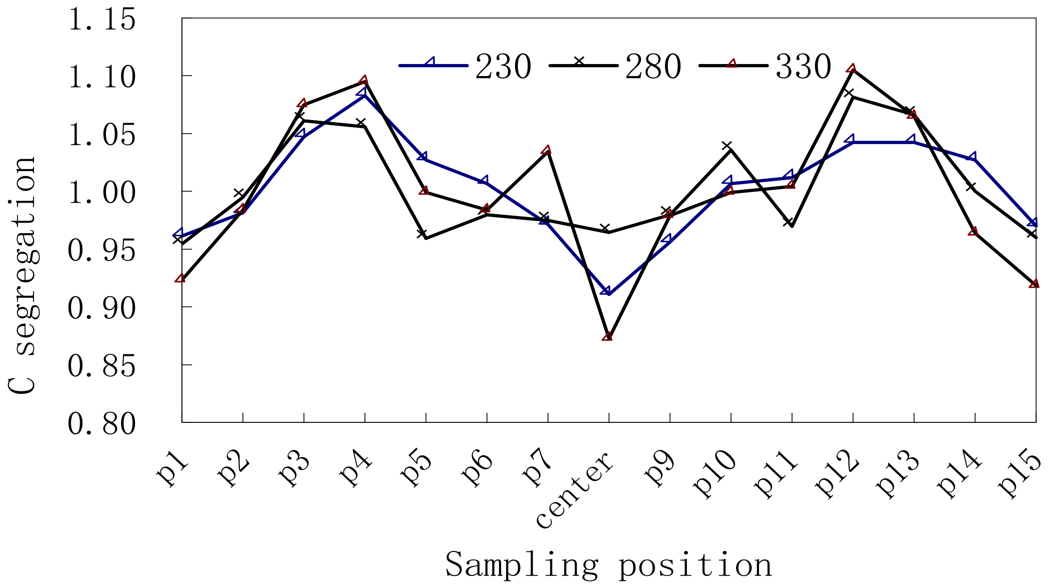


Figure 7. Effects of M-EMS stirring intensity on C segregation of bloom(X10^{-4}T)

The segregation testing statistics results of different stirring processes show in table4. Results show that bloom segregation control is the best while M-EMS is 280X10^{-4}T and F-EMS is 300X10^{-4}T, and it's match with the testing results of macro-tests.

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Table 4. C segregation statistics results of difference combine EMS processes ($X10^{-4}T$)

Processes M-EMS	Processes F-EMS	Scope (ratio>85%)	Range(range/average)	Standard mean square deviation(range/average)
230	300	0.92~1.08	0.12~0.18 0.17	0.06~0.10 0.080
280	300	0.95~1.05	0.06~0.12 0.09	0.05~0.08 0.060
330	300	0.91~1.09	0.12~0.20 0.15	0.06~0.11 0.081
330	150	0.90~1.09	0.17~0.21 0.18	0.06~0.09 0.072
330	450	0.92~1.07	0.14~0.21 0.16	0.07~0.12 0.091

3.2.3. Effects of EMS stirring intensity on the density of bloom center

The sampling area to take test shows in fig.8, testing the samples by metal original position analyzing machine and statistics the testing results.

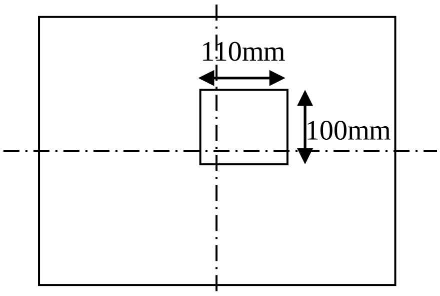

Figure 8. Diagram of density testing area by metal original position analyzing machine

The representative testing results of bloom centre area show in fig.9（scale:1/3）, results show that bloom produced with the processes that M-EMS is $280X10^{-4}T$ and F-EMS is $300X10^{-4}T$ is the best, the loose area in the center of bloom is small and the loose distribution is dispersive. The statistics results show in table5, the density range of bloom center area is 0.89~0.95 and the average is 0.92, better than the other process conditions.

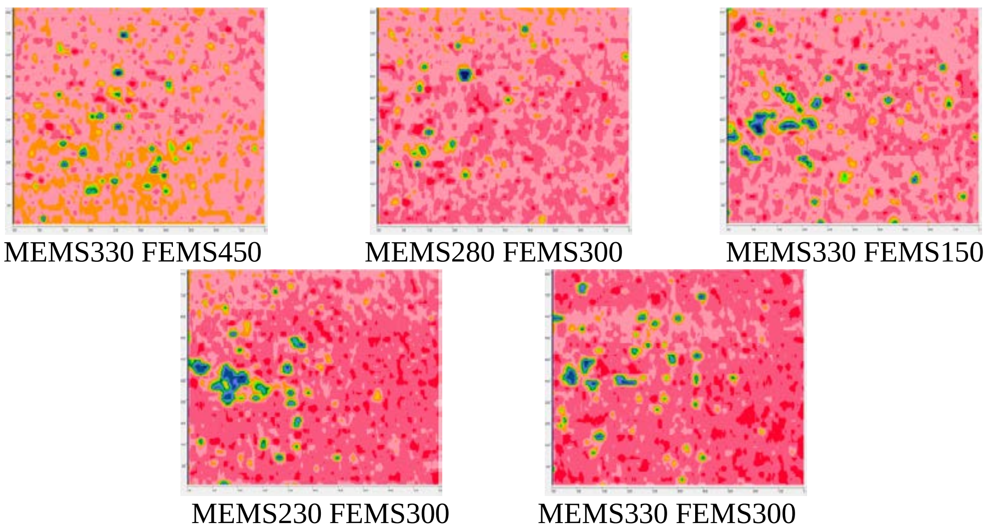

Figure 9. Scanning results of density at bloom central area($X10^{-4}T$)

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Table 5. Density statistics results of bloom central area(X10^{-4}T)

Processes		Density of center area in blooms	
MEMS	FEMS	Range	Average
330	450	0.87~0.91	0.89
280	300	0.89~0.95	0.92
330	150	0.86~0.89	0.87
230	300	0.85~0.92	0.88
330	300	0.87~0.91	0.89

4. Conclusions

(1)produce 20CrMnTiH(FQ)gear steel with the 360mmX450mm cross section of continuous casting, choose the specific install position where is 10.0~11.0m away from mold liquid steel surface according to the proportion of solidified shell thickness is 0.50~0.55.

(2)With the stirring intensity increase the negative segregation of stirring acting brand tend to be more serious, and with the thickness of solidified shell increase the alternation of negative to positive segregation tend to be more obvious.

(3)Testing results shows that bloom produced with the processes that M-EMS is 280X10^{-4}T and F-EMS is 300X10^{-4}T is the best, the scope of C segregation is 0.95~1.05, range of segregation is 0.06~0.12 and average of range is 0.009, the average of Standard mean square deviation is 0.060, the density range of bloom center area is 0.89~0.95 and the average is 0.92.

5. References

[1] Jia Guanglin, Pang Weicheng. Principles and processes of electromagnetic metallurgy [M]. Shen Yang: Northeastern University Press, 2003: 143-182.

[2] Kittaka S, Watanabe K, Kanki T, et al. Nippon steel in-mold electromagnetic stirrer “M-EMS ”for slab cater[J]. Nippon Steel Technical Report, 2002, 86(7):68-72.

[3] Kyung Shik OH,YongW on CHANG. Macrosegregation Behavor in Continuously Cast High Carbon Steel Blooms and Billets at the Final Stage of Solidification in Combination Stirring [J]. ISIJ International, 1995,35(7):866-875.

[4] Charles Vives. Elaboration of semisolid alloys by means of new electromagnetic rheo-casting Processes[J]. Metall. Trans.B, 1992,(23B):189-206.

[5] Mao Weimin, Effects laws of EMS on Renewal α-Al for semi-solid stat-e AlSi7Mg alloy [J]. Acta Metall Sinica, 1999, 35(9):971-974.

[6] Flemings M C. Behavior of Metal Alloys in the Semisolid State[J]. Metallurgical Transactions A, 1991, 22(4): 957-981.

[7] Zhu Huigang, Miu Xinde, Tao Jianjun, et al. Study on F-EMS process for CC billets [J]. Continuous Casting, 2007,(6):35-36.

[8] Li Jianchao, Wang Baofeng, Wang Xiaodong, Pei Haijun, Wang Shaobing.Optimizing for F-EMS Install Position And Process Parameters With CC Rou-nd billets [J]. Special Processes of Metal Casting and non-ferrous alloy, 2014,34(08):853-856.