# DEVELOPMENT OF A NEW METHOD FOR PREDICTING BREAK OUT IN CONTINUOUS CASTING


BY

LIAO, JEN-CHI*, XU, MING-HAO, WU, CHENG-HAN



SYNOPSIS：

In this study, a visual model in the continuous casting process was built by the CAE software and compared the thickness distribution of the condensing shell of the Martensite Stainless Steel in different cooling rate, whether the initial casting Break Out occurred or not. At the same time, by the analysis results of the cracking Break Out steel billet. It is proved that the uneven thickness of the condensing shell is the cause of the Break Out.

It is confirmed that when the thickness difference of condensing shell over 30%, there is a risk of the Break Out occur. The cause of the uneven condensing shell is the high cooling rate. And the cooling rate is affected by relative heat input and relative heat extraction. In this research, these two factors have a positive correlation with the Break Out in continuous casting process. The risk indicator was built for prevent the Break Out before manufacture. By using the theory of indicator, the continuous casting process was tracked over 6 months. And the result shows that the theory was useful in prevent the Break Out occur.



**Keywords**：the cracking Break Out, predict, relative heat input, relative heat extraction



*Thermal Engineer, Stainless steel Products - Walsin Lihwa Corporation, Tainan, Taiwan

## Introduction

In the stainless steel melting process, the solidification behavior and material characteristic in high temperature are quite different from carbon steel because there are amount of alloy elements in stainless steel. Therefore, the steel billet has defects, such as cracking, pits slag and etcetera, which effects the surface quality and yield rate.

Especially, the cracking of the martensitic stainless steel is more severe, and it is difficult to cope with the cause of the defect. The defect will result the product losing in the follow-up treatment process. If the defect becomes serious, The Break Out will occur, which wastes a lot of time and cost.

According to the experience and related research on cracking of martensitic stainless steel. Theoretically, the thickness of the condensing shell depends on the cooling rate in the mold. Hence, the heat input and heat extraction in the mold will be the target in research. But previous research only focused on the reducing heat extraction (such as mold water flow rate, high basicity casting powder) to prevent the defects from the steel billet. There is no specific way to predict or handle the Break Out.

In this research, Computer Aided Engineering (CAE) and Computational fluid dynamics (CFD) were used to simulation and visual the solidification behavior in the mold. The different of cooling rate and the thickness distribution of the condensing shell were be compared between the Breal Out occurred or not. At the same time, the Break Out steel billet was observed to confirm that the crack was occurred in the thinner of condensing shell. Then, the simulation result and the experiments are used to verify the speculated cause of Break Out. By using the theory in this research, finding out the crux of Break Out.

## Literature Review

Qie et al [1] found that there were occurred cracking at thin part of condensing shell, when the condensing shell was uneven. They also mentioned that there was directly relation between the steel biller quality and the characteristic of steel fluid. It means, heat transfer control in the mold was the vital in improvement of the steel billet quality.

Chen rt al [2] analyzed the effect of impurity elements and degree of superheat in the steel billet surface quality. When the carbon content in 0.12%~0.17%, there were uneven condensing shell in the mold let to cracking. They also mentioned if the degree of super heat was larger, the opportunity of cracking was higher.

Liu et al [3] researched the theory to decrease the cracking opportunity in the steel billet surface. They mentioned the flow fluid variation in the mold will affect the cause of cracking. They also mentioned uneven condensing shell was the cause of steel billet surface cracking. So, the cooling rate was the vital in surface quality.

Yu et al [4] analyzed the cause and control theory of cracking in steel billet surface. They mentioned that if the degree of superheat overed the normal range, the temperature drops between mold and the flow steel become larger. When the cooling rate in the mold was increased, the heat stress at the surface will be increased too. That was the cause of the Break Out.

Ding et al [5] found the cause of cracking in the steel surface. It was mentioned that, slowly cooling rate was better to even condensing shell and decreased the opportunity in cracking. They also tried to decrease the flow rate in the continuous casting process. It was useful to decrease the cracking.

## Experimental

In this research, we confirmed the cause of cracking in the initial melting and found out the vital manufactory parameters. There are four steps in this research. First step: CAD software was used to build 3D model geometric. Second step: Built the continuous casting model by using CAE software. Third step: Verified the correlation between the simulation model and the theoretical speculation at cracking in continuous casting. Fourth step: Compared the different parameters between the Break Out occurred or not.

### 3D geometry model in the continuous casting.

According to the engineering graphs, build the independent parts in the continuous casting by using SOLIDWORKS. The parts are shown in figure 1. Then, combined these parts to finish the 3D geometry. The combination part is shown in figure 2.

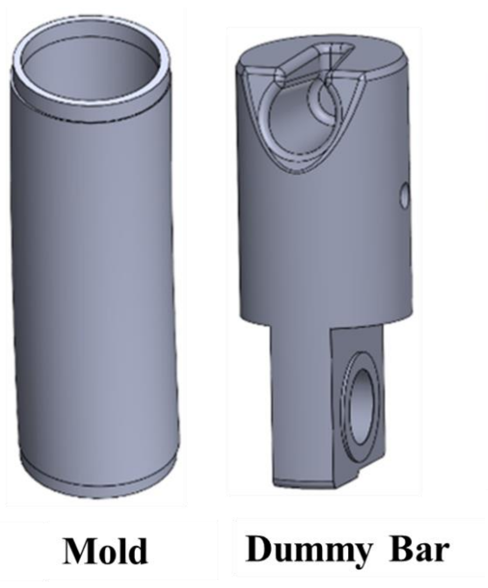


figure 1: parts in the mold

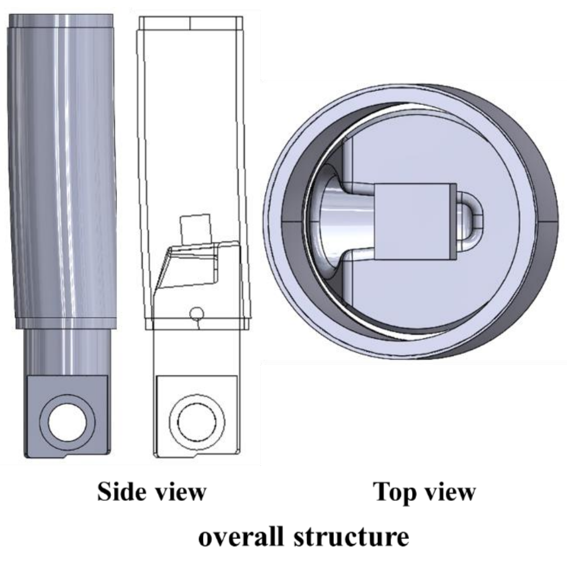


figure 2: 3D geometry in mold

### CAE model in continuous casting

There were three parts in building simulation model. Meshing, boundary condition setting and post processing.

In the first part, import the CAD geometry. After that, mesh the geometry and set the property of steel fluid and the mold. The initial condition of tundish temperature input the first testing temperature. And the temperature of mold set the environment temperature. The material properties in the simulation model were computed by JMatPro which is a software to calculate the material property in different temperature or pressure. Second part, input the boundary conditions parameters, define the surface between mold and steel fluid, set the heat transfer parameters in the model, input the flow rate for heat extraction in the mold then calculate. Third part, export the results from simulation such as temperature distribution and the thickness of condensing shell. The result is shown in figure 3.

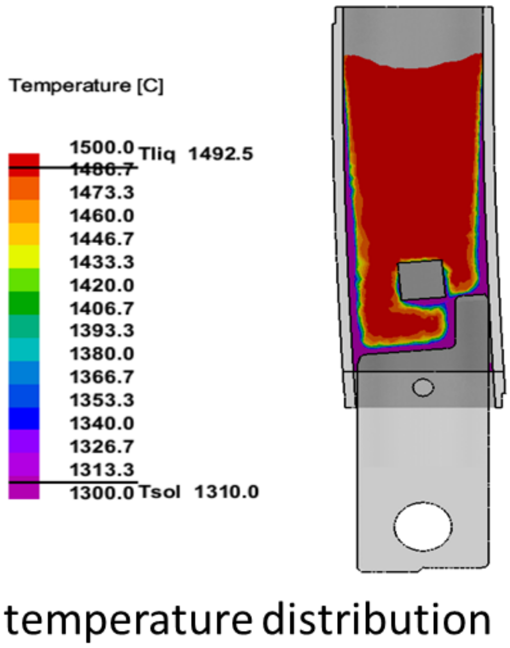


figure 3: temperature distribution in simulation

## The Break Out steel billet analysis

In order to verify the speculation and compare the simulation result, the Break Out steel billet was sampled to observe whether cracking led to the Break Out and uneven thickness of condensing shell at cracking part existed or not. The result is shown in figure 4. Compared the different parameters between the Break Out was occurred or not and compared the different between the simulation results and the Break Out cracking, then observed the thickness of condensing shell between the Breal Out occurred or not. Found the vital to prevent the Break Out.

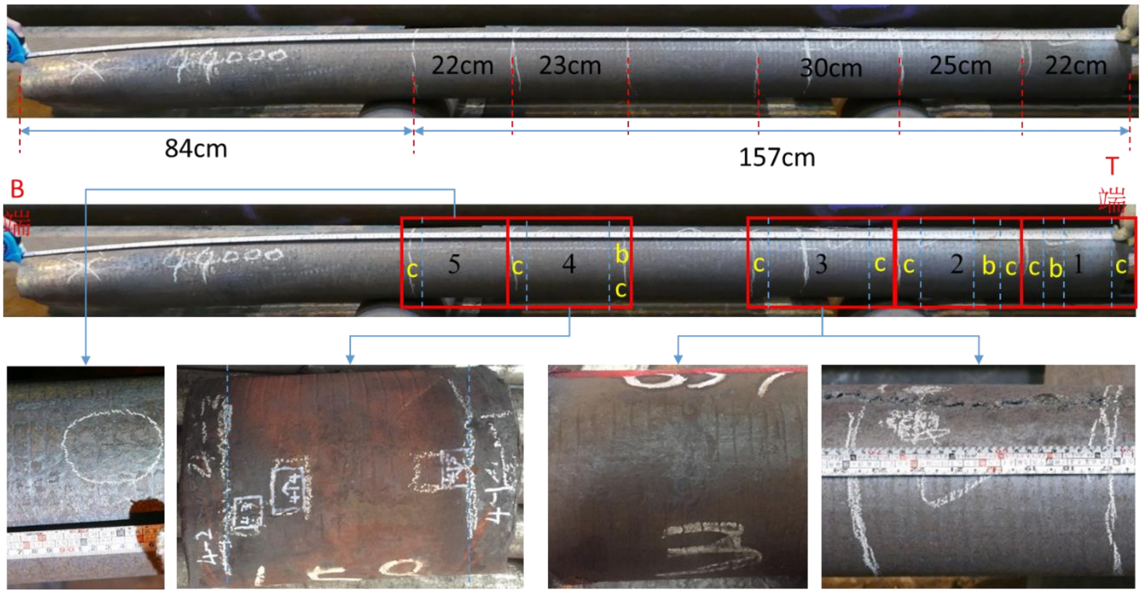


figure 4: sampling of Break Out steel billet

## Result and Discussion

As the results of simulation and the analysis of the Break Out steel billet, the cause of the Break Out was confirmed by uneven condensing shell. The vital of the condensing shell thickness was the cooling rate in the mold. We can know that the Break Out was occurred at the thin part of condensing shell. The result is shown in the figure 5. From the result in simulation, we can know that, if the Break Out cracking was occurred, the heat extraction rate was faster and uneven of condensing shell was more serve. The results are shown in the figure 6 and 7.

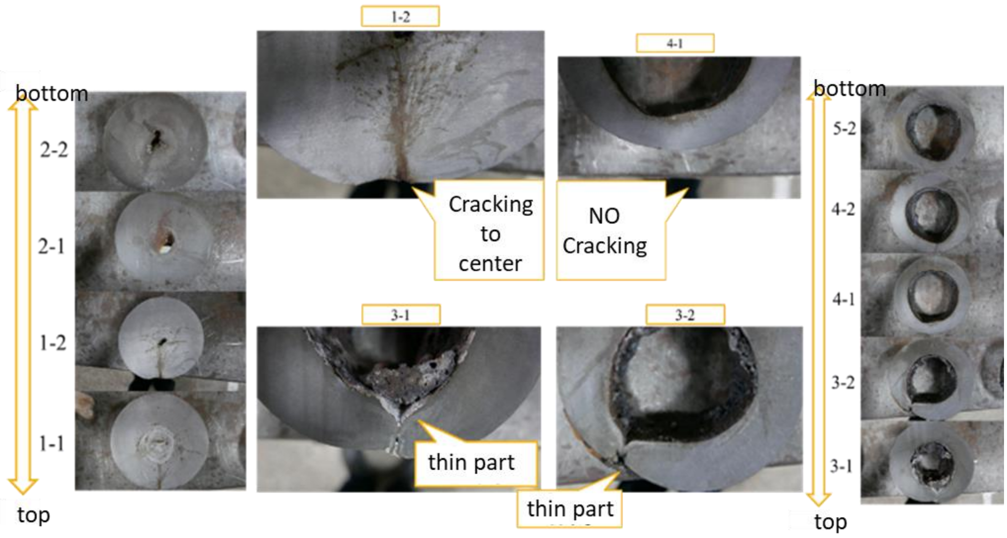


figure 5: analyzing of Break Out steel billet

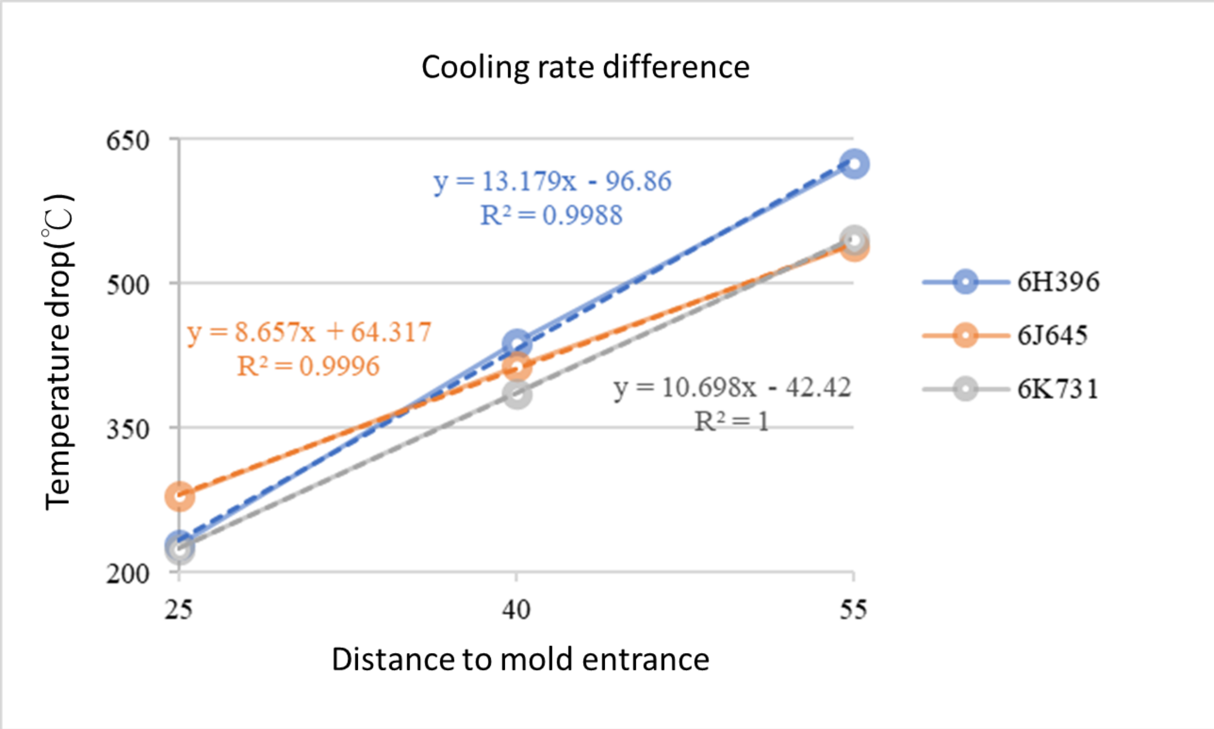


figure 6: the cooling rate in the Break Out occurred or not

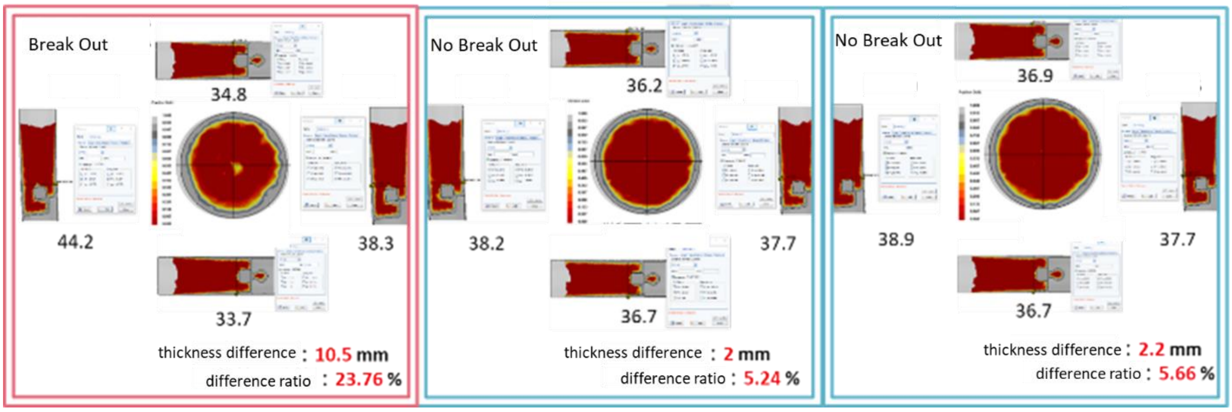


figure 7: the thickness distribution in the Break Out occurred or not

By analyzing the simulation result and the historic product data, the vitals of cooling rate were relative heat input and relative heat extraction. Relative heat input was defined as the temperature difference between first measurement temperature in Tundish and the solidification temperature of steel fluid. And relative heat extraction was defined as the time difference between the beginning of continuous casting and the extraction starting. Both of these parameters have the positive correlation of the Break Out. So, we formulated an indicator to judge the risk about the Break Out in continuous casting. The indicator formula can be shown as.

$$I = T_{in} \times T_{out}$$

$I$ = indicator

$T_{in}$ = relative heat input

$T_{out}$ = relative heat output

This indicator formula only was used in stable manufactory situation, such as Vacuum Oxygen Decarburization. And the temperature drop in Tundish should be in normal range. Also, all the manufactory parameters should be the same in process, or there would be some unpredictable risk in the indicator.

Built the risk indicator by the steel billet which were occurred the Break Out. If the value from the formula was over the risk indicator, there was a risk of Break Out. Otherwise, it was safety in manufactory process. If the value was over the risk indicator in manufactory, adjusted the relative heat extraction to decrease the risk. The judgement process is shown in figure 8.

We tracked the martensite manufactory process over half year by using this theory. The results of the steel billet were the same as the speculation. It can prove this theory was useful to prevent the Break Out in continuous casting process.

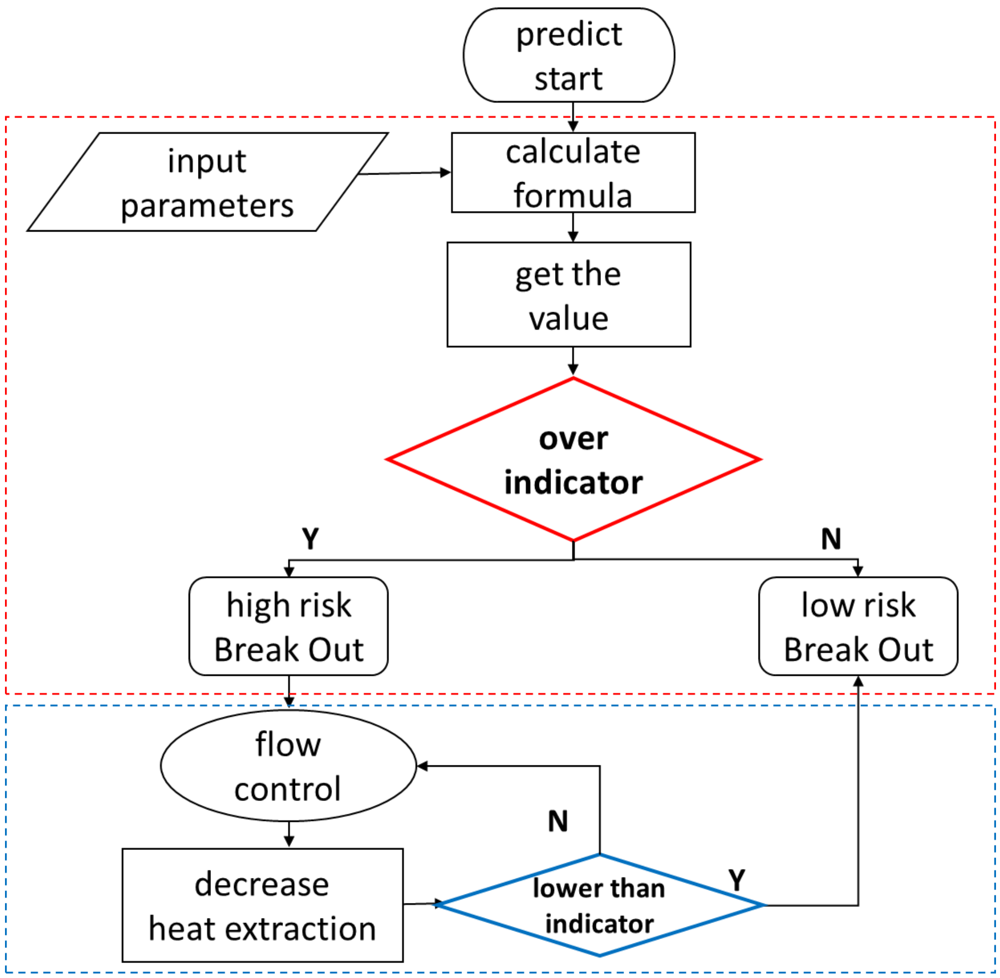


figure 8: judgment process

## Conclusion

In this research, there have three conclusions.

1. By observing the results of simulation and the experimental, the cause of the Break Out was the uneven condensing shell which was affected by high cooling rate, especially in martensite stainless steel.
2. The cooling rate was affected by two parameters: relative heat input and relative heat extraction. These parameters correspond the temperature difference and time difference in the continuous casting process.
3. In this research, we built the indicator to prevent the Break Out risk in continuous casting process. And confirmed this theory in our manufactory to improve the produce technology and reduce the cost in steel billet follow-treatments.

## Literature


[1] 郄俊懋，” 304 不锈钢高温力学性能及热物理性能研究”，***內蒙古科技大學***，2014。

[2] 劉小軍，李惠蝶，” 減少连铸坯表面纵裂工艺研究”，***2013 年低成本炼钢技术交流论坛论文集***，第 138-143 頁，2013。

[3] 劉小軍，李惠蝶，” 減少连铸坯表面纵裂工艺研究”，***2013 年低成本炼钢技术交流论坛论文集***，第 138-143 頁，2013。

[4] 于海濤，劉軍，曲亮，” 宽板坯表面纵裂成因分析及控制措施”，***第八届(2011)中国钢铁年会论文集***，第 1-6 頁，2011。

[5] 丁志龍，” 连铸坯表面纵裂的形成原因及对策”，***现代连铸技术进展***，第 130-133 頁，2003。