

# Cause and Measures of Transverse Corner Crack in Hull Structural V-Containing Steel CC Slabs

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**Abstract:** The reasons of transverse corner crack in hull structural steel CC (continuous casting) slab have been analyzed in this paper. The influence of steel-making, continuous casting technics and micro alloy element has been discussed. The improving measures are put forward and better effects have been obtained.

**Key words:** CC slabs; transverse corner crack; vanadium hot; ductility

## 1 Introduction

The surface crack of CC slab is an important problem, which affected the continuous caster yield and the quality of the slab. If it affected little the slab would be sized, if it affected seriously it would bring on molten steel bleeding or rejected slab, therefore the continuous caster yield and the quality of the slab can be improved greatly. In the producing of the hull structural steel in Shougang, the transverse corner crack in the slab occurred more, which made difficult to plan the producing and affected the order of Shougang hull structural steel finished punctually.

To reduce the transverse corner crack in the hull structural slab, the authors of this paper traced the process and sampled in many slab on which have defects of transverse corner cracks to analyze the reason of the cracks, and then modified some in the process and got a good result. The percent of pass about the slab improved greatly, for example the incidence

rate of the transverse corner crack from 11.9% down to 0.10%.

## 2 The Character of the Transverse Corner Crack

### 2.1 The component design and the CC caster parameters of Shougang hull structural steel

#### 2.1.1 The component design

To ensure the performance of the hull structural steel, the composition control of 355MPa grade in Shougang was designed in table 1 as follows.

To ensure the suitable carbon equivalent, the carbon content of the steel is controlled from 0.12 % to 0.15% as a matter of fact, however it was just in the peritectic range, in which crack-sensitivity would be higher and the little fluctuation of the process would lead to the crack.

Table 1 The composition control of 355MPa grade in Shougang

Steel plate	C	Si	Mn	P	S	A <sub>It</sub>	V	C <sub>eq</sub>
A36	0.12-0.18	0.20-0.50	1.30-1.60	≤0.025	≤0.020	0.020-0.050	0.05-0.10	≤0.40
D36	0.12-0.18	0.20-0.50	1.30-1.60	≤0.020	≤0.017	0.020-0.050	0.05-0.10	0.40

### 2.1.2 The CC caster parameters

CC caster style: straight mold multiple-point gradual bending, straightening arc-shaped slab caster  $R=9500\text{mm}$ ,  $L=31.58\text{m}$ ; cross section (mm):  $220\times 1600$ ,  $220\times 1800$ ,  $250\times 1600$ ,  $250\times 1800$ ; pulling rate:  $0.8\sim 1.5\text{m/min}$ ; cut lengths:  $2000\sim 3000\text{mm}$ ; amplitude range:  $0\sim 4\text{mm}$ ; frequency:  $0\sim 200/\text{min}$ .

## 2.2 The character of transverse corner crack

### 2.2.1 The macroscopic character of transverse corner crack

The character of transverse corner crack was showed as figure 1 (sketch). The transverse corner crack of the slab in the production was showed as figure 2. The transverse corner crack in Shougang hull structural slab often happened at inner arc of the slab, also at the deep of oscillation mark. The cracks took place at the corner and extended to the broad and narrow face. The length of the crack was about  $2\sim 10\text{mm}$ , and the depth of it was about  $2\sim 5\text{mm}$ .

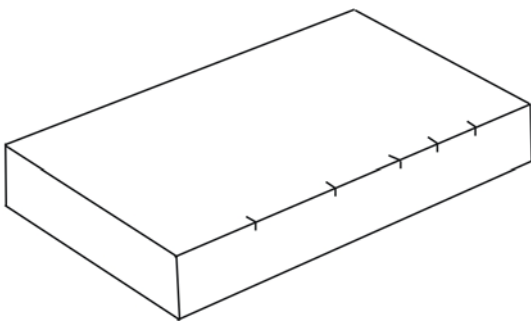


Fig. 1 The sketch of transverse corner cracks.

### 2.2.2 The microscopic character of transverse corner crack

Figure 2 is the metallograph of the transverse corner crack in Shougang hull structural slab. We can see from it that around the crack there is no visible decarburizing and oxidizing, and the crack expands along the boundary of austenite grain.



(a) The crack surface end ( $\times 25$ )



(b) The crack inner end ( $\times 100$ )

Fig. 2 The transverse corner cracks of the slab.

## 3 Analyzing of How the Transverse Corner Cracks Happened

### 3.1 The influencing factor of the transverse corner crack

#### 3.1.1 The affect of the chemistry component

##### (1) The affect of microalloy in the steel

According to some data, the crack happened in the V, Nb, Ti-containing steel is an international problem which affected the quality of the slab. Many researchers such as Mtntzl, Meahara published many articles about the transverse corner crack in the steel, they thought that the separation of carbide, nitride and carbonitride in the slab lead to the embrittlement in steel, and it was the inherence reason, in this way the oscillation mark furthered the transverse corner crack happening. In the straightening process the temperature of the slab corner located in the highly happened range of the separation of the

fine carbide, nitride. For the embrittlement and deforming of the steel in the straightening process, the crack happened in the deep of oscillation mark easily. Therefore, the key to solve the problem is to control the separation of the fine grain in the steel and straightening in the higher temperature.

### ***(2) The affect of carbon content in the steel***

The carbon content in the steel affected the crack in the slab greatly. When the carbon content is in the range of 0.09%~0.16%, the crack-sensitivity would be higher. It is because that around the meniscus the shell of the slab would happen peritectic reaction, when the capacity and linear shrinkage happened, and in this carbon content range as cast austenite grain higher caused the elongation percentage reducing.

### ***(3) The affect of Al and N content in the steel***

Sampling in different slabs which have the transverse corner cracks or not and analyzing them the results indicated that in the same Al content level the N content which have the transverse corner crack was higher than the N content which haven't it. According to the data, the arithmetic product of the Al content and the N content (the formula as follows) in the Al-containing steel can be used to evaluate the crack.

$$[Al \times N = A]$$

The research indicated that to get satisfactional quality of the slab surface the Al content in the steel must be controlled lower than  $3 \times 10^{-8}$ .

## **3.1.2 The affect of the technics**

### ***(1) The casting temperature and the casting speed***

The casting temperature and the casting speed have affected evidently on the surface crack in the slab. Low degree of superheat, the steady casting speed and the tranquil fluid level of the crystallizer will be benefit to the decrease of the cracks in the slab. If the degree of superheat in liquid steel is more than 30°C, or if casting speed and fluid level of the crystallizer are undulant distinctly, the probability of occurrence that the cracks are

generated in the slab will increase. Therefore, decreasing the degree of superheat in liquid steel, keeping the steady casting speed and tranquil fluid level of the crystallizer that will help to decrease or avoid the cracks generated in the slab of high-strength hull structural steel are the important measures. Those technological datum above are from practical industrial run.

### ***(2) The affect of the temperature in the straightening slab***

The inner arc will be bear tensile stress and the positive camber bear compression stress when the slab is being straightened. During this process, the stress generated by the vibratile trace will be concentrated if the temperature of straightening the slab is from the fragile temperature province, the probability of occurrence that the cracks are generated in the slab will increase accordingly.

For the microalloyed steels, the carbide segregation and the nitride segregation will enlarge the fragile temperature provinces. So, avoiding straightening the slab during the fragile temperature provinces, these measures, adjusting the intensity of cooling water in No 2 cooling area, configuring reasonably the cooling water for the wide-face and the small face of the slab, are all indispensable. Furthermore, avoiding the asymmetry of the temperatures in the slab corner is necessary too.

## **3.2 The reason of the transverse corner cracks of Shougang hull structural**

Compared with HSLA simple steel, No 3 fragile temperature province of Shougang microalloyed hull structural steel of 355MPa grade will be enlarged for the precipitation of the carbide and the nitride, which upper limit value increases from 850°C to 920~930°C and which lower limit value decreases from 720°C to 650°C. All those will magnify the difficulty of avoiding straightening during No 3 fragile temperature provinces. The conclusion has been testified in our thermal simulation test and showed in figure 3 followed.

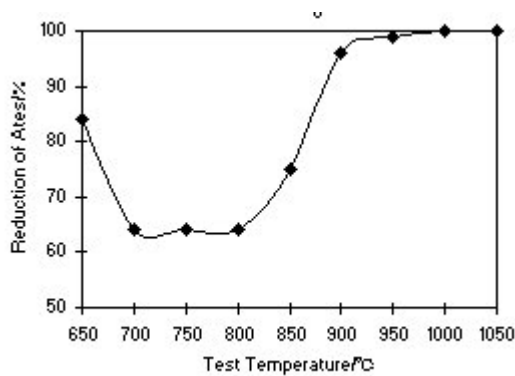


Fig.3 Reduction of area changed by the test temperature of D36 grade

#### 4 The Improvement of the Technics and the Effect

Seen from the measured temperature of the slabs in № 2 steel making plant, straightening temperature is usually 880~900°C. It is the main reason that results in the transverse corner crack happened not keeping away from № 3 fragile temperature province in its entirety. So some measures followed should be taken:

- (1) To ensure the casting liquid steel in low degree of superheat that is less than 25°C.
- (2) To maintain the stability of the casting speed and the fluid level of the crystallizer.
- (3) To decrease the cooling intensity by lessening the cooling water in № 2 cooling

area.

- (4) To increase the casting speed reasonably.

Applied these measures above, the asymmetry of the temperature in the slab has been bettered and the measured temperature of straightening the slab has been increased to 930~950°C. The probability of occurrence that the transverse corner cracks are generated in the slab has decreased consumedly from 11.80% down to less than 0.1%, which betters evidently the quality of the slab and reduces the cost of the industrial production.

#### 5 Conclusions

(1) It is the main reason not keeping the temperature of straightening the slab away from № 3 fragile temperature provinces in its entirety, which directly results in the transverse corner crack happened in Shougang microalloyed hull structural steel of 355MPa grade.

(2) Showed in our test, those measures introduced in the article are effective distinctly through adjusting the intensity of cooling water in № 2 cooling area, configuring reasonably the cooling water for the wide-face and the small face of the slab and improving the temperature of straightening the slab