

2022 SEAISI Steel Mega Event & Expo
Session 9 - Technology Development

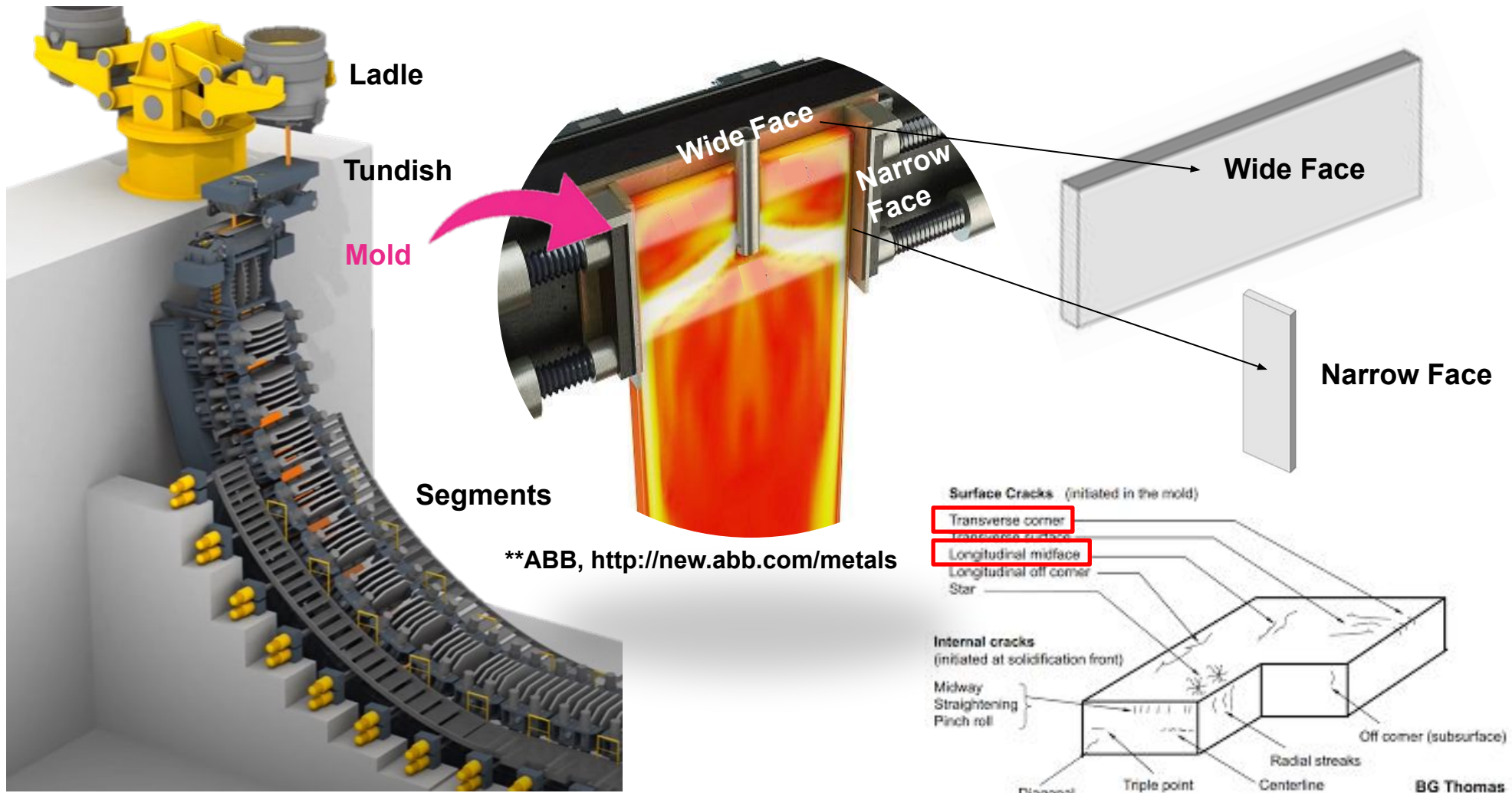
Customized Copper Plate Shape of Steel Continuous Caster for Slab Surface Quality Improvement

Hyoung-Jun Lee, Seong-Yeon Kim, Kyung-Chul Cho, Sang-Hum
Kwon

POSCO Technical Research Lab., Korea

00. What is Continuous Casting & Mold

?



*EBS Engineering, 2015, <http://www.youtube.com>

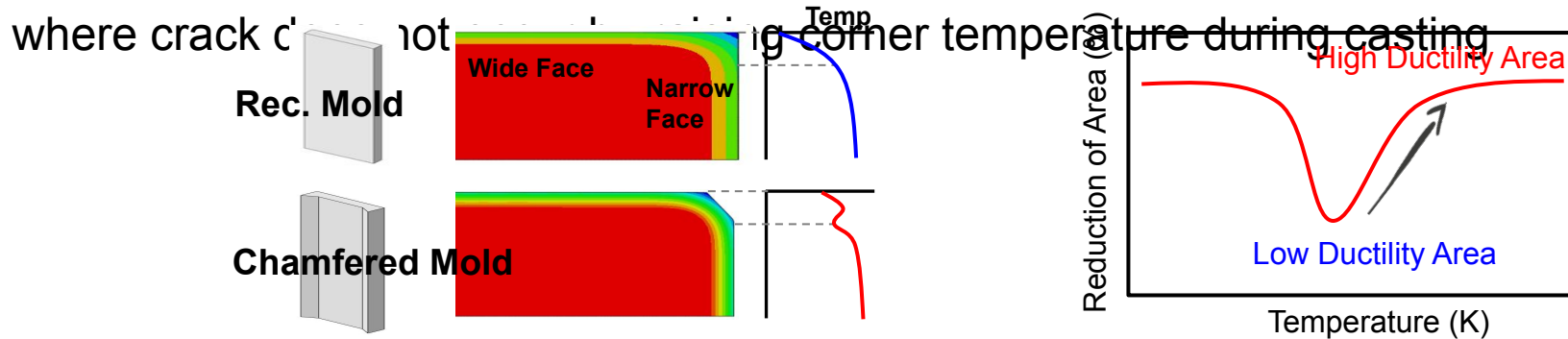
***B.G.Thomas, Colorado School of Mines

[Schematics of continuous casting process]

I-01. Background (Corner Cracks)

■ What is Chamfered Mold?

- Chamfered Mold is a technology that reduces corner cracks by bending slab at temperature ranges

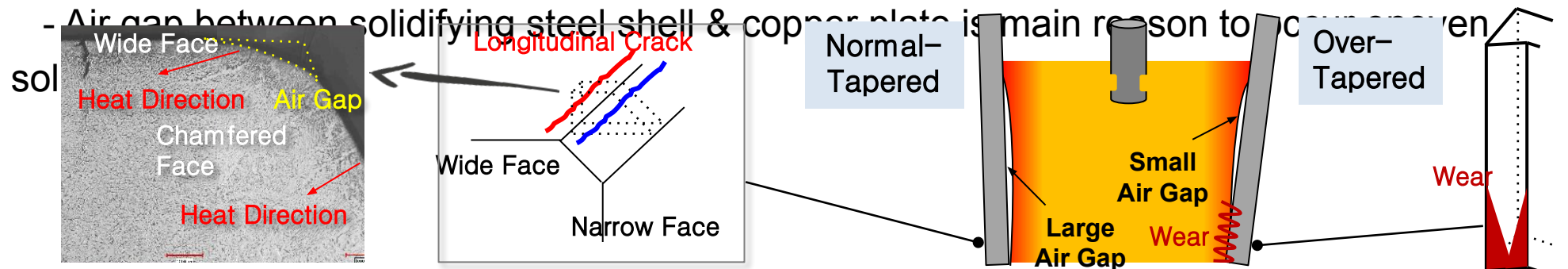


[Slab corner temp. profile with different types of mold]

[Higher ductility with chamfered mold]

■ Side Effects

- Chamfered Mold is known to reduce corner cracks, but longitudinal cracks on chamfered face are issued



[Side effects of narrow face taper]

■ Present Application Status of Chamfered Mold in World Wide

- Many Chinese steelmakers adopt chamfered mold, also release many patents and publications

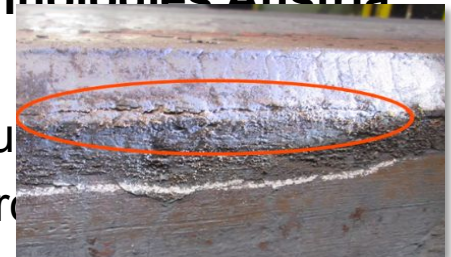
*Top steel-producing companies 2020, The World Steel Association

Ranking	Company	Nationality	Crude Steel Production [million tonnes]	Chamfered Mold Application ('18 Year)
1.	B-Company	CN	115.29	Test
2.	A-Company	Multi	78.46	Test
3.	H-Company	CN	43.76	100%, Batch, Test
4.	S-Company	CN	41.59	Batch
5.	N-Company	JP	41.58	None

■ [Conference] ‘Implementation of Chamfered Mold Technique at ArcelorMittal Eisenhüttenstadt’

B. Joern, et al., ArcelorMittal Eisenhüttenstadt, Primetals Technologies Austria ESTAD, 2021

- More than 1,500 heats application, 20–70% coil edge defects reduced
- Longitudinal cracks on chamfered face are occurred, but it is controlled with mold flux



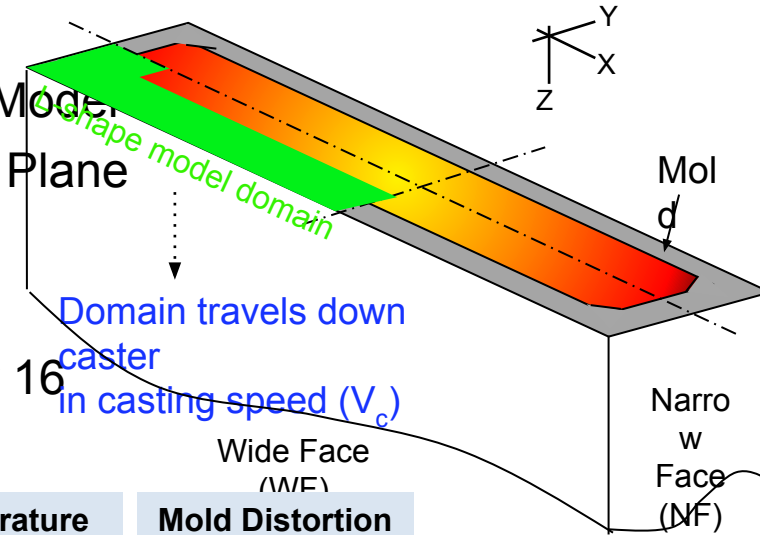
[Longitudinal crack on chamfered face]

I-03. Simulation Domain & Boundary Conditions

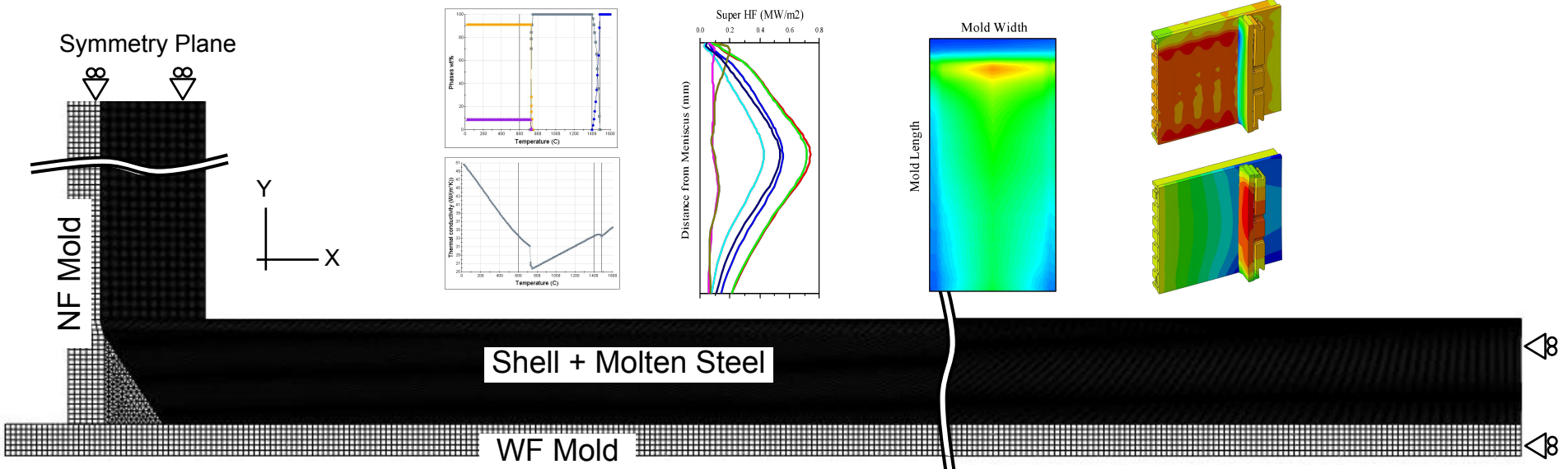
■ Quarter Model of 0.6%[C] Steel (Abaqus 2017®)

- Analytical Model : Coupled Temperature-Displacement Model
- Mesh Information : CPEG3HT, CPEG4HT (Generalized Plane Strain)
- No. of Mesh : 112,470 (Shell), 3,122 (Mold)

- Analysis Time : 10 days with POSCO Simulation Server 16 CPUs
 - Lagrangian reference frame moving downward with steel shell at casting speed.

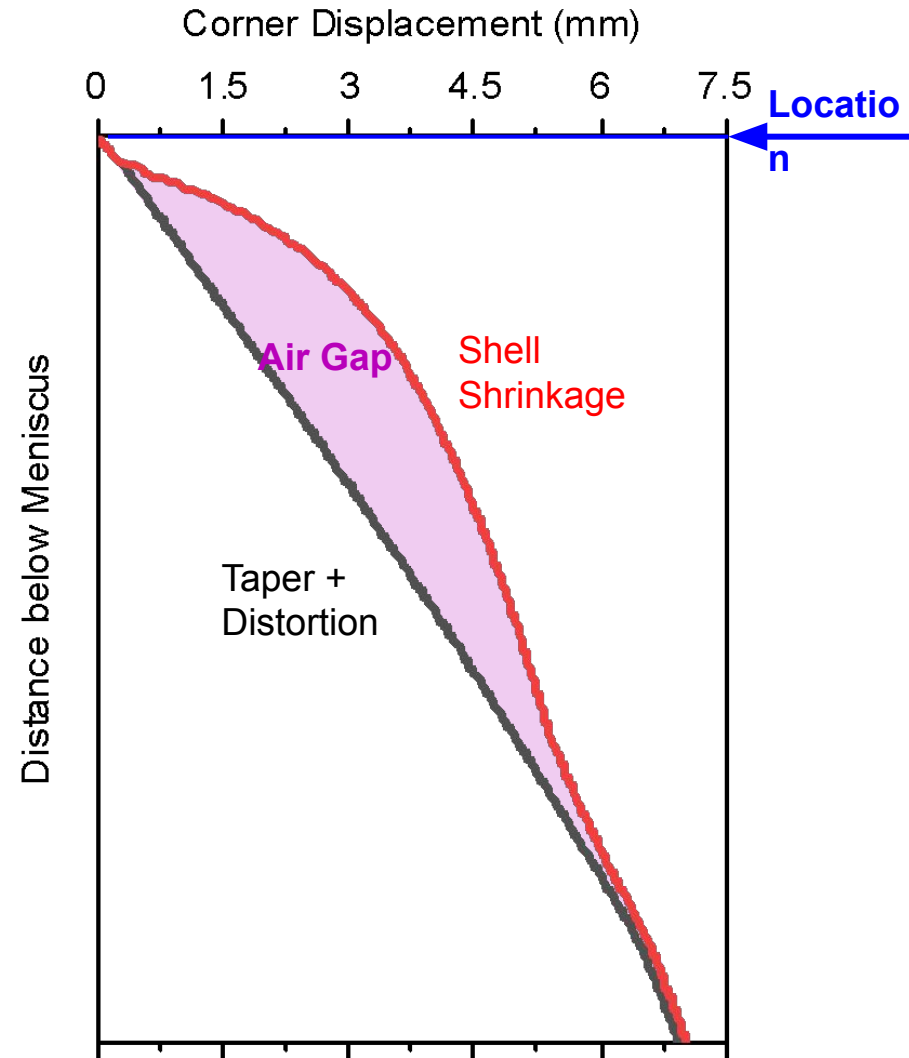
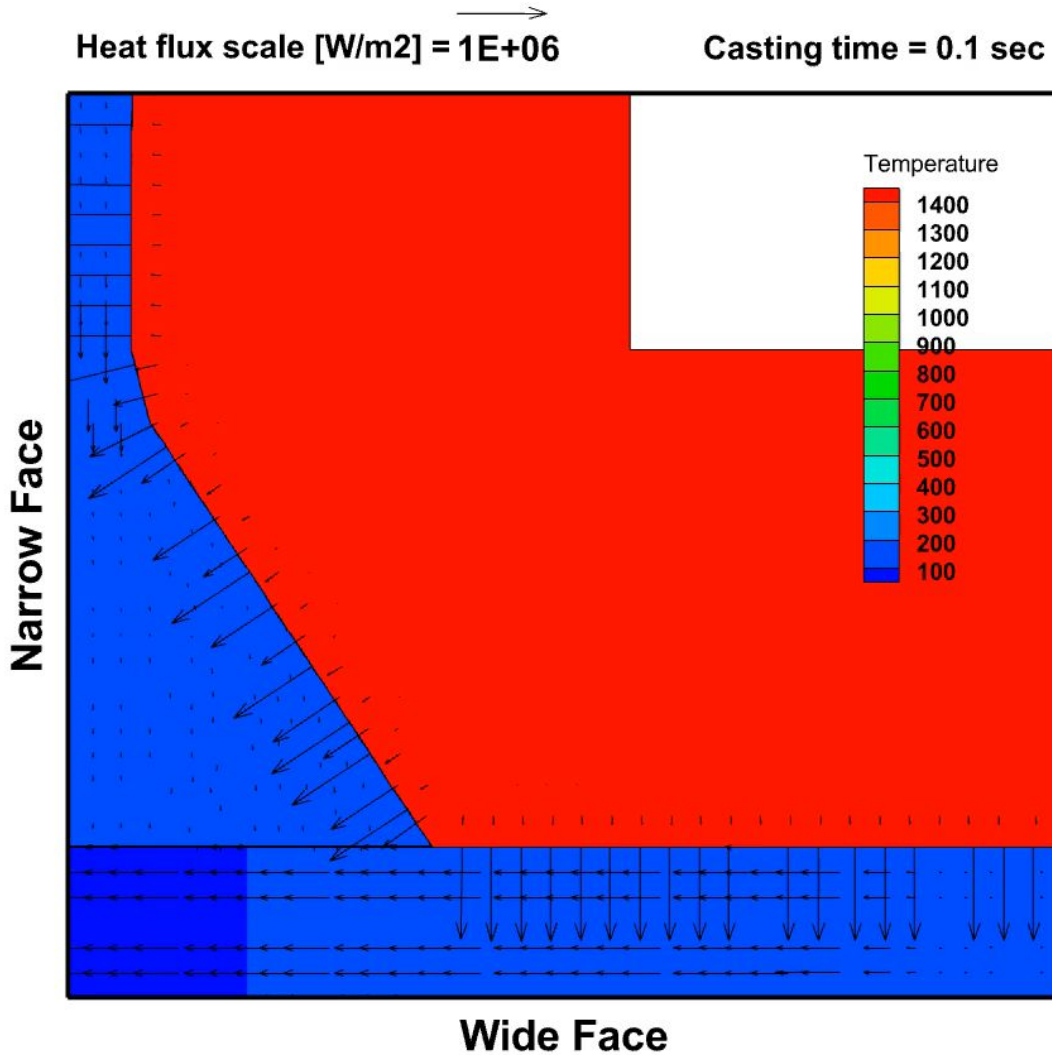


Properties (JMatPro®) Superheat Flux (CFD) Temperature (Optical Fiber) Mold Distortion Analysis



I-04. Simulation Results (Movie)

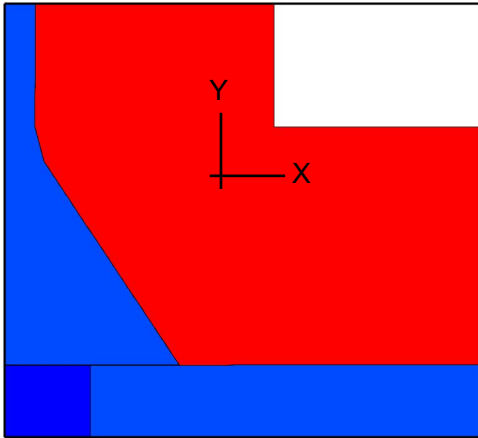
■ Corner Behavior of Chamfered Mold



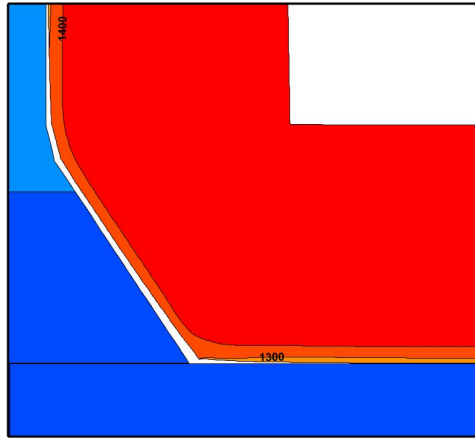
I-04. Simulation Results (Snapshot)

■ Corner Behavior of Chamfered Mold

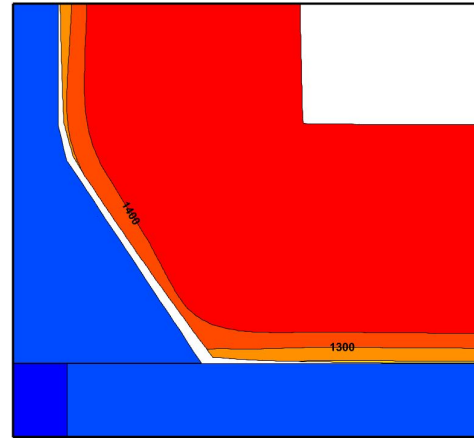
- Meniscus



- 100mm below Meniscus



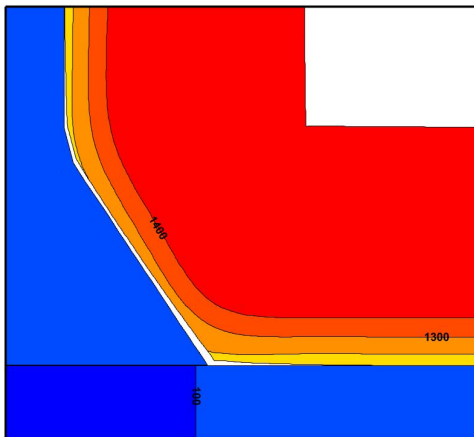
- 200mm below Meniscus



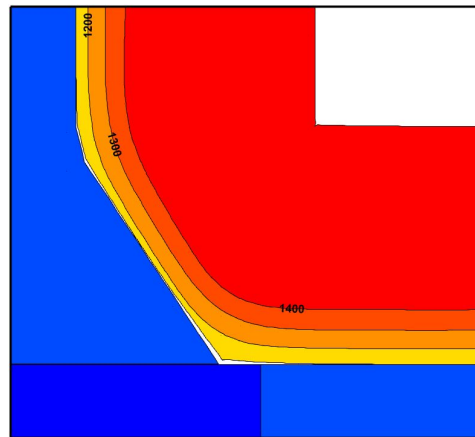
- 300mm below Meniscus



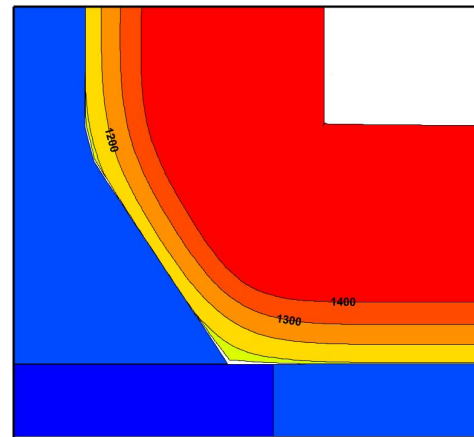
- 400mm below Meniscus



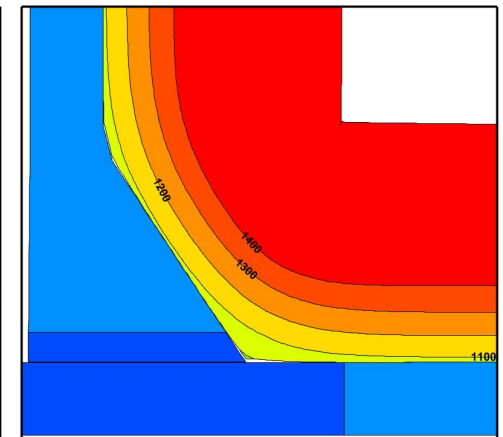
- 500mm below Meniscus



- 600mm below Meniscus

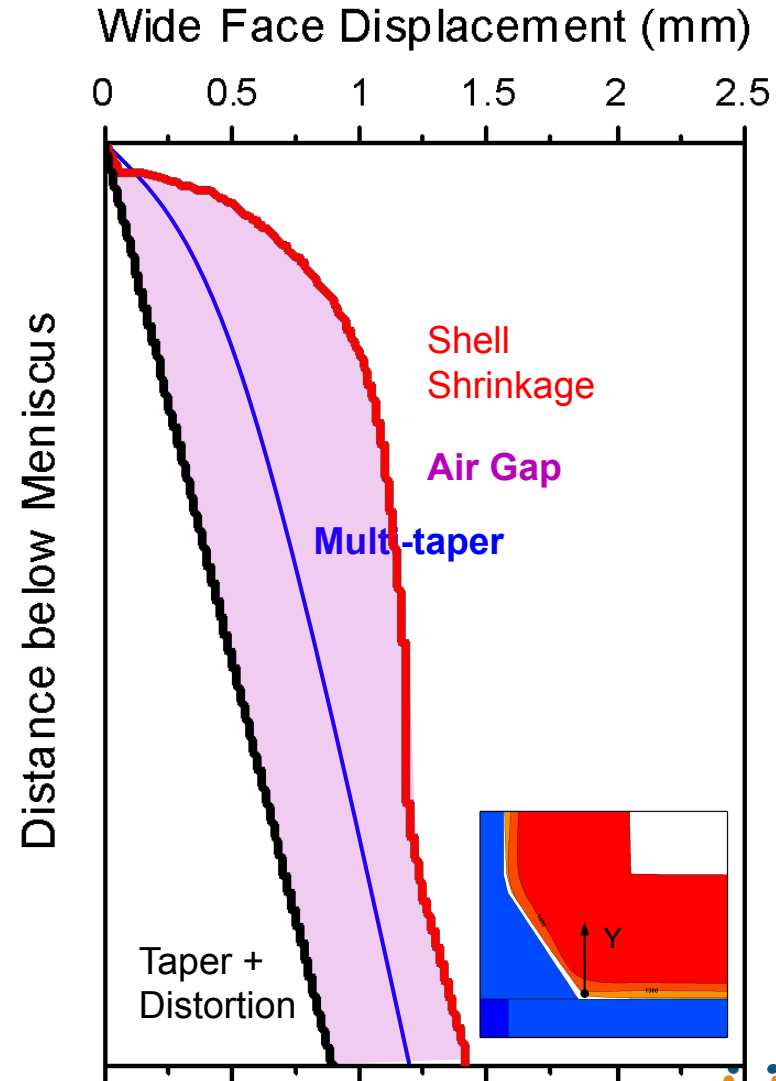
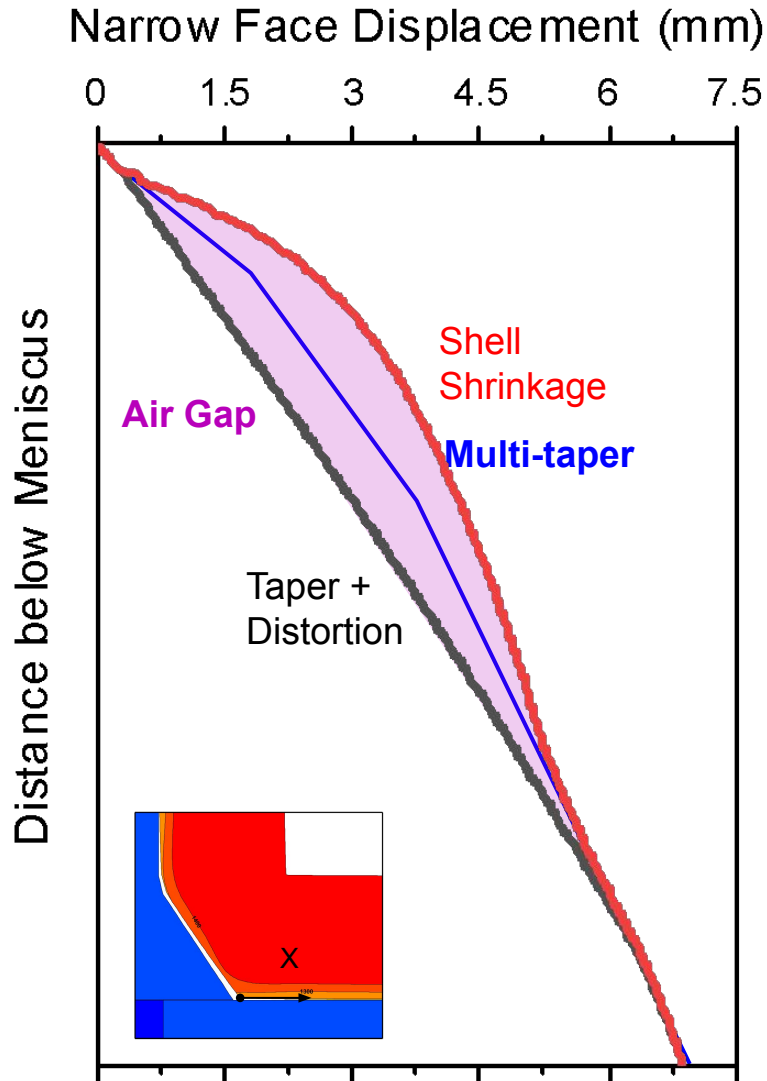


- Mold Bottom



I-05. Customized Chamfered Mold Shape

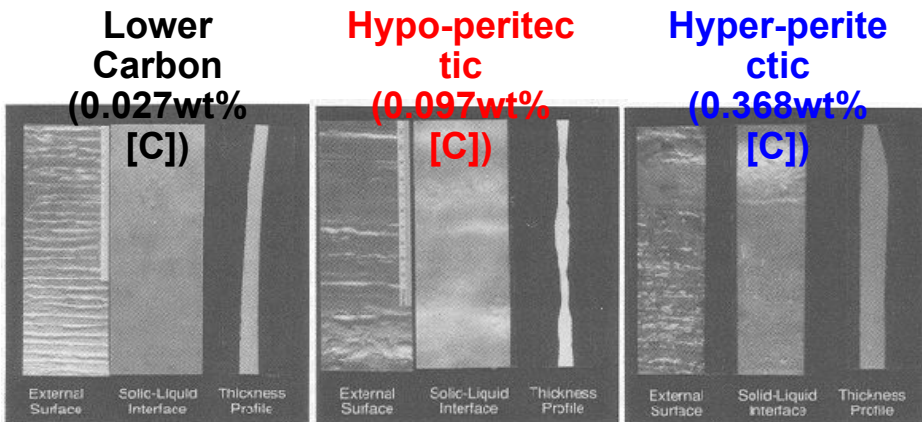
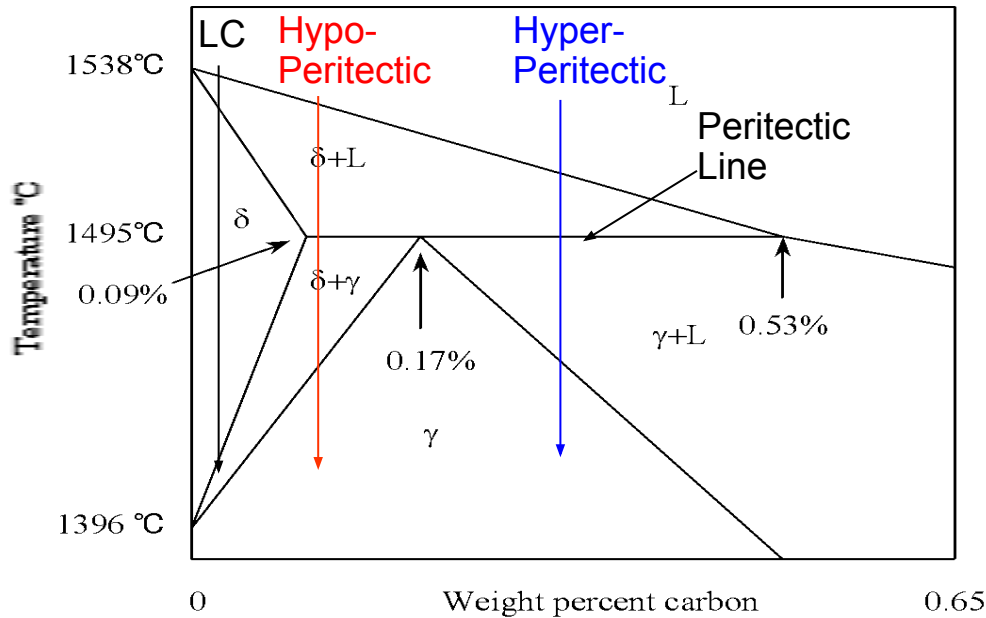
Multi-Taper Mold Profile Design for Minimizing Air Gap



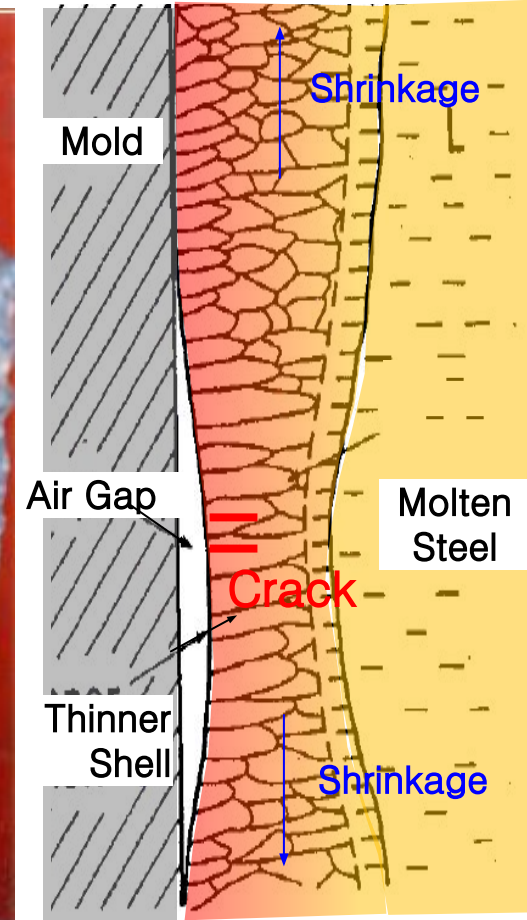
II-01. Background (Longitudinal Cracks)

Why Longitudinal Cracks are Formed Especially in Hypo-Peritectic Steel?

*M.Wolf, Iron & Steelmaking, 13(1986), pp 248



Hypo-peritectic carbon steel longitudinal crack formation breakout shell



Logitudinal Crack Formation Mechanisms

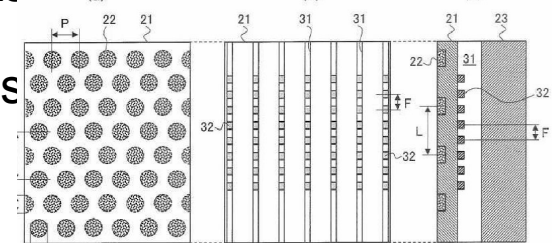
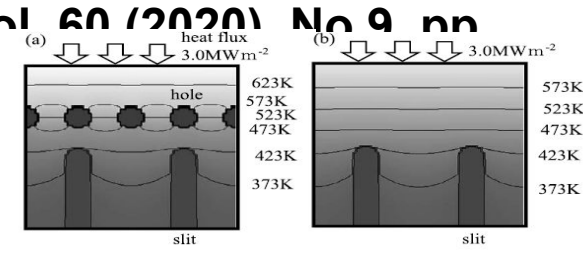
■ [Journal] ‘Initially Solidified Shell Growth of Hypo-Peritectic Carbon Steel in Continuous Casting Mold’, H. Mizukami, et al. (NSC), ISIJ International, Vol. 16, No. 9, pp. 1061-1068, 1987

1968-77

- Longitudinal cracks form on wide face especially in hypo-peritectic steel
- Temperature distribution on copper plate in width direction must be uniform

■ [Patent] ‘鋼の連続铸造用铸型及び鋼の连续铸造方法’ JFE Steel Corp. JP WO2020-095932 (May, 2020)

- therefore additional cooling hole can be effective to reduce cracks
- Different material is irregularly filled in copper plate near meniscus
- Artificial irregularity makes regular and uniform solidification



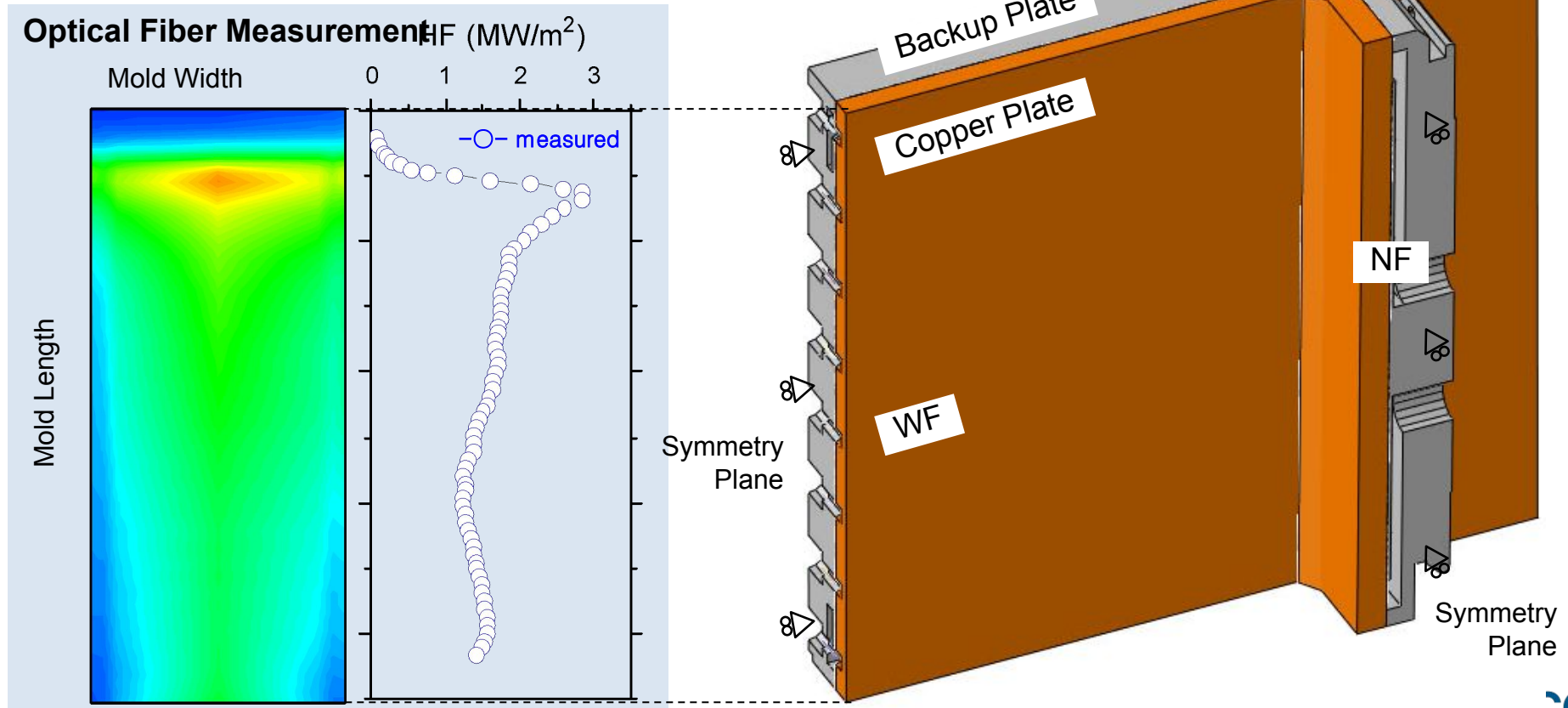
■ Present Longitudinal Crack Rate in POSCO

Ranking	Carbon Content [wt%]	Additional Alloy	Longitudinal Crack Ratio
1.	0.14	Niobium	90 %
2.	0.15	Niobium, Titanium	70 %
3.	0.10	-	60 %
4.	0.16	Niobium, Titanium	35 %
5.	0.12	-	20 %

II-03. Simulation Domain & Boundary Conditions

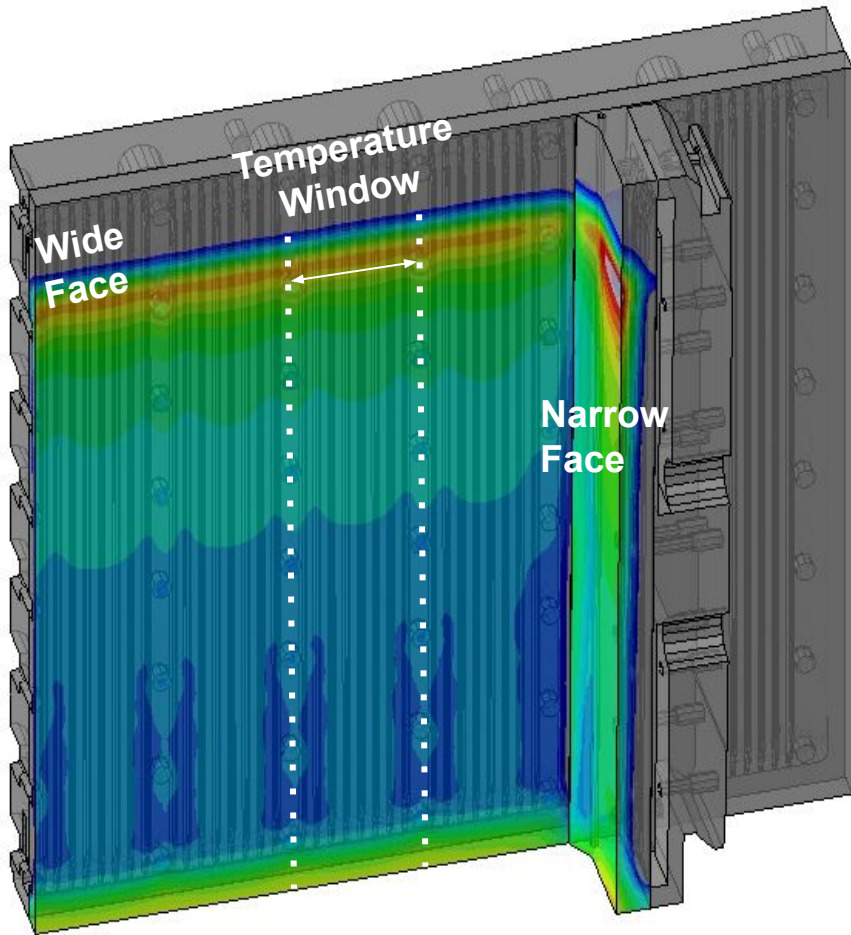
■ Quarter Model of Casting Mold (Abaqus 2017®)

- Analytical Model : Coupled Temperature-Displacement Model
- Mesh Information : C3D4T, T3D2T
- No. of Mesh : 1,526,770 (Copper Plate), 545,429 (Backup Plate), 69 (Tension Bolt)
- Analysis Time : 2 hours with POSCO Simulation Server 16 CPUs

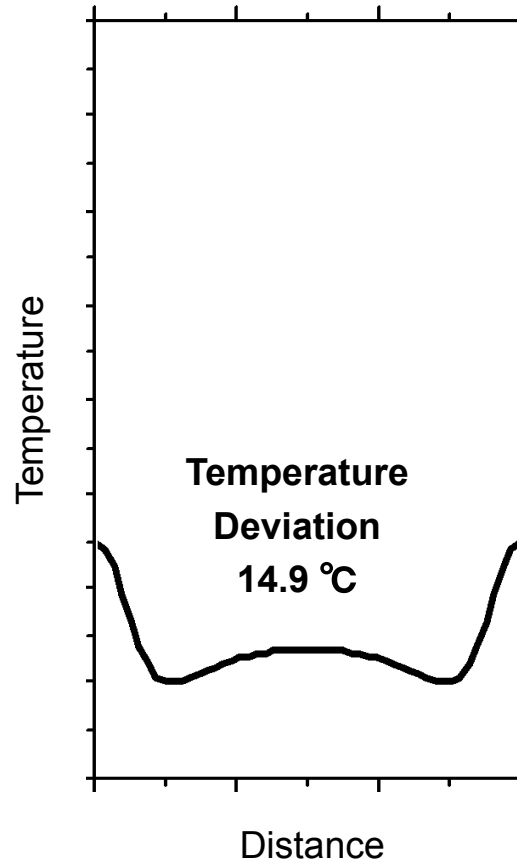


II-04. Simulation Results

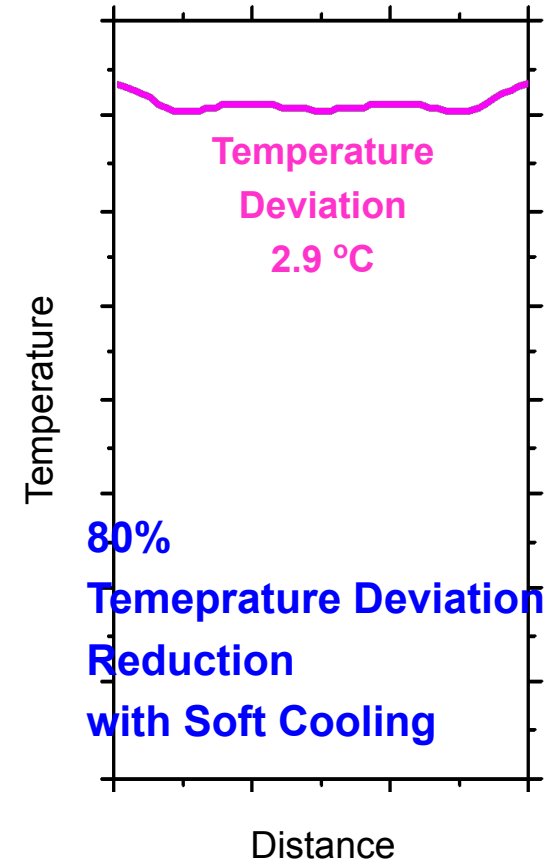
■ Temperature Distribution Before/After Customization of Copper Plate



Before Customization



After Customization



**80%
Temperature Deviation
Reduction
with Soft Cooling**

[Temperature profiles 65mm below from meniscus]

■ Modification Items and Details for Uniform Cooling on Wide Face

No.	Items	Details
1.	Copper Plate Customization	Optimization of thickness and water channel for uniform cooling
2.		CFD Analysis of new cooling water channel
3.	Mold Engineering	Foot roll choke location change
4.		Foot roll water spray nozzle length change
5.		Piping set modification between loose side and side frame
6.		Clamping cylinder end length check
7.		Meniscus level sensor location change
8.		Guide plate change
9.		Joint between oscillator and mold frame check
10.		Cooling water plate under side frame change
11.		Width control cylinder location change
12.		Interference check between lower width control cylinder and oscillator
13.		Eccentric shaft change
14.		EMS bracket length change
15.		Mold cover slit change

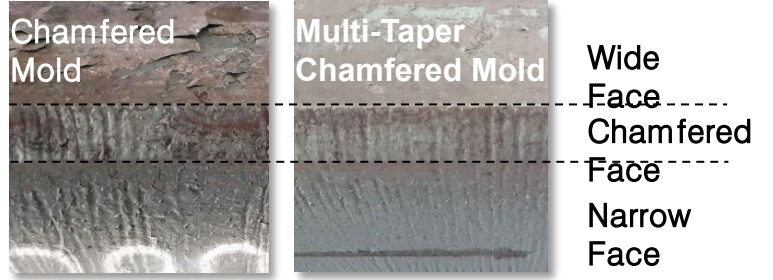
III.

Results

■ Result of Multi-Taper Chamfered Mold of Narrow Face

- More than 1.3 million tonnes of slab were casted by multi-tapered chamfered mold in both Steel Works

- It is possible to achieve zero longitudinal cracks on chamfered face

Caster		No. of Heat	Longitudinal Crack Rate	Remark		
Pohang	A	1,500	0 %		Wide Face ----- Chamfered Face ----- Narrow Face	
	B	4,200	0 %			
Gwangyang	C	3,000	0 %			
	D	1,000	0 %			

[High carbon steel slab surface quality]

■ Result of Uniform Cooling Mold of Wide Face

- Uniform cooling mold is applied to caster that generates the longitudinal crack the most in Pohang Works

- About 40% of longitudinal cracks on wide face

Caster		No. of Heat	Longitudinal Crack Rate	Remark
Pohang	B	8,200	4.1 → 2.4 %	Strand Comparison

Both technologies are no operation instability such as breakout & severe mold level fluctuations, etc.

IV. Summary & Conclusions

■ **Multi-Taper Chamfered Mold of Narrow Face for Reducing Corner Cracks**

- Chamfered mold is effective to reduce corner cracks, but longitudinal cracks on chamfered face
- According to simulation results, longitudinal cracks on chamfered face is caused by larger shear stress compared to given mold taper especially in mold top corner region
- Multi-taper mold which can compensate initial shell contraction is possible to utilize stably without any cracks in slab corner

■ **Uniform Cooling Mold of Wide Face for Reducing Longitudinal Cracks**

- Temperature deviation on copper plate along width direction can initiate longitudinal cracks on wide face especially in hypo-peritectic steel grade
- Longitudinal cracks on wide face can be reduced more than 40% with customized uniform cooling

Thank you for attention

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