Manufacturing Technology of High Strength, High Toughness Offshore Wind Power Structural Steel Plates

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Outline

- Introduction
- Quality Criterion of Offshore Steel
- Manufacturing Technology
- Conclusion

Underwater Foudation
SDMS Corp. in Kaohsiung

Offshore Steel Structure in Taiwan

✓**Wind power generators**

- **Rising of the sea level (to go offshore)**
- **Taiwan government has planned to establish 600 wind power generators in Taiwan strait, in order to follow the global trend of energy and ecology protection strategy.**

Steel structure has been widely used in offshore industry.

Demands of Offshore Steel

Enlarging Design

- Bigger
- Lighter
- Less Cost
- <High Strength>

Harsh Environment

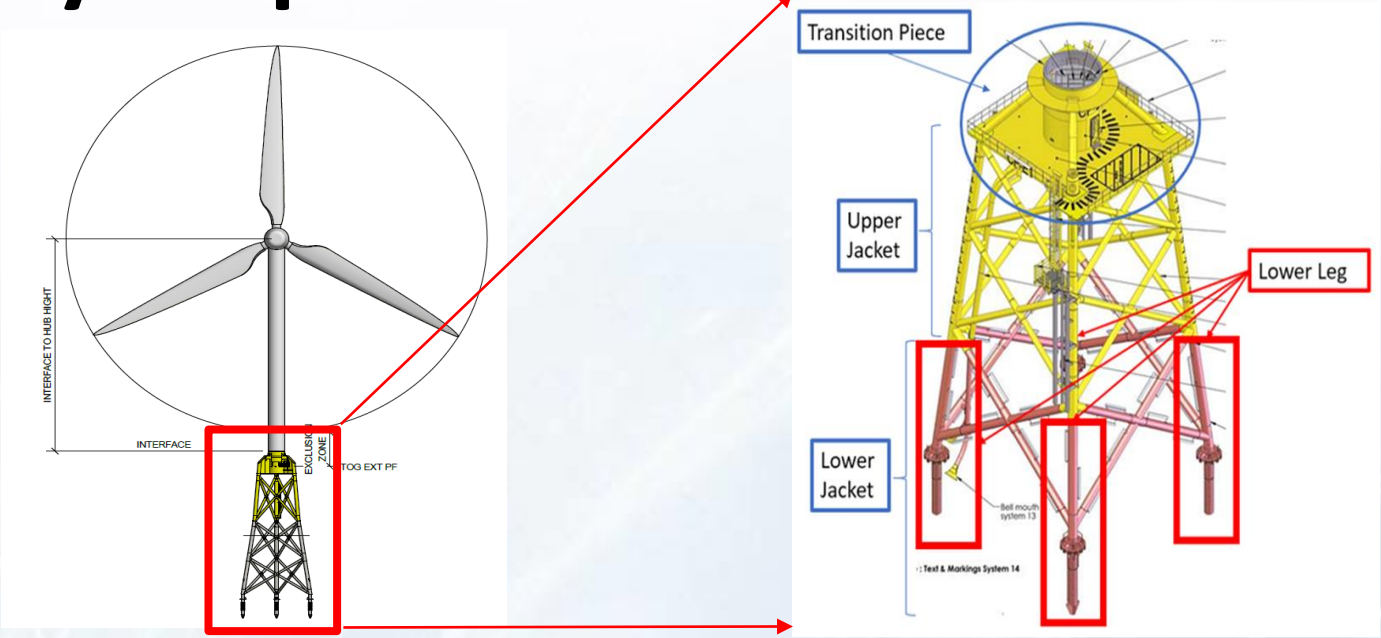
- Endurance of Wind, Wave, and Seismic Strikes
- Low Temperature
- Limited Maintenance Capability
- <Excellent Impact Resistance>

Faster Installation

- Shorter Project Lead Times
- Less Repairment after Welding
- <Better Weldability, Anti-Lamellar>

2025 Target: 5.5GW
(≒668 wind turbines)

Quality Requirements



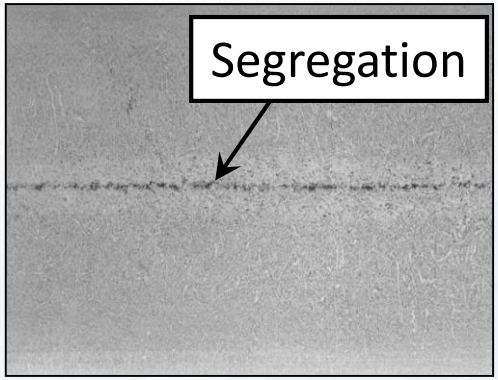
Fan/ Tower/ **Foundation**

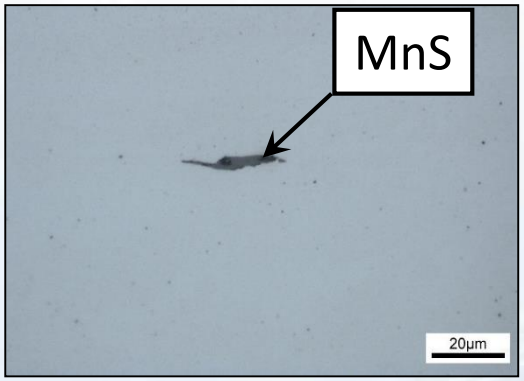
1200 ton/each
(66% of whole Wind Turbine)

S355ML Standard	Carbon Equivalency	YS (MPa)	TS (MPa)	El (%)	ZRA (%)	-40℃ Impact Energy(J)
EN10025-4	≦**0.40**	335	440~600	22	Z35	**Longitudinal≧31** **Transverse≧20**
CSC Specification	**≦0.35**	335	440~600	22	Z35	**Longitudinal≧50** **Transverse≧50**

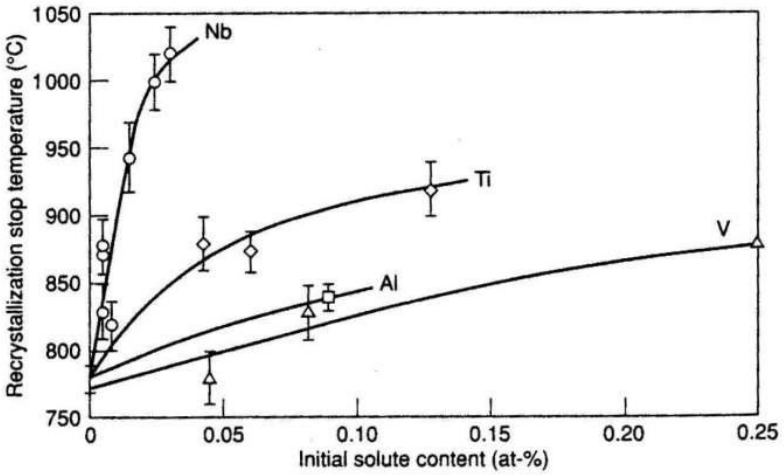
Chemical Composition

- ✓ **Ultra-low [P], [S]**
  - ➢ Avoid deleterious inclusions
  - ➢ Avoid center segregation





- ✓ **Addition of Microalloys**
  - ➢ Recrystallization Stop Temperature: Nb >Ti >Al >V
    →Grain Refinement → Strength & Toughness



$$Tnr = 887 + 464\,C + (6445\,Nb - 644\,Nb^{1/2}) + 890\,Ti + 363\,Al + (732V - 230\,V^{1/2}) - 357\,Si$$

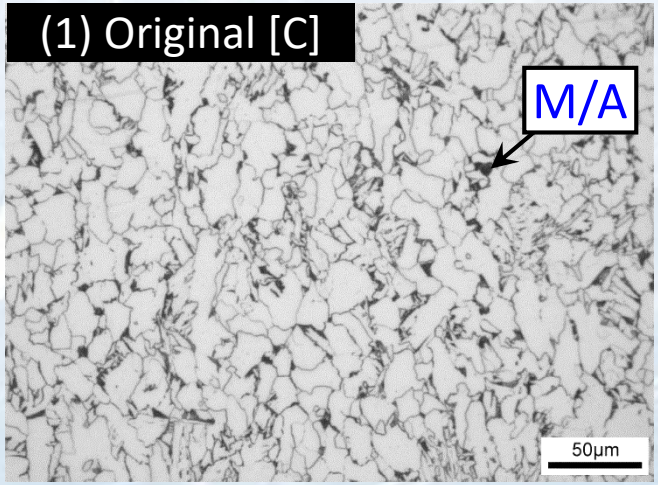
Chemical Composition(cont.)

✓ Low Carbon Content

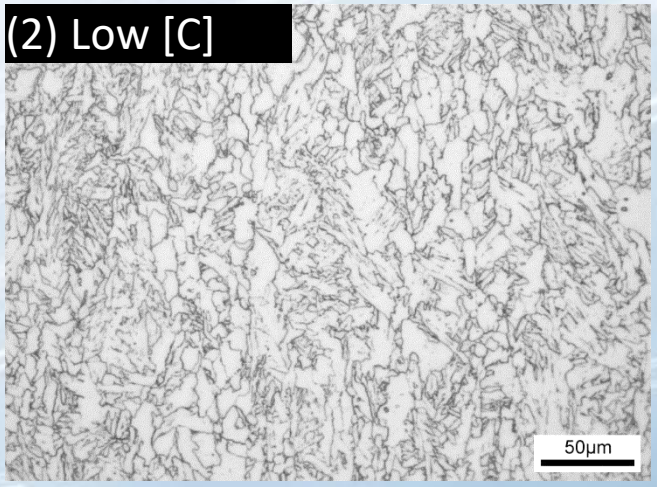
- ➢ Less M/A →Less brittle texture
- ➢ The impact toughness was increased approximately by 30J in average.

Content	Tensile Test			ZRA (%)	Temp -40℃ Charpy Impact Energy (J)	
	TS (MPa)	YS (MPa)	EL (%)		Longitudinal	Transverse
Original	499	394	28	66	**264**	**252**
Low Carbon	495	387	31	71	**299**	**285**

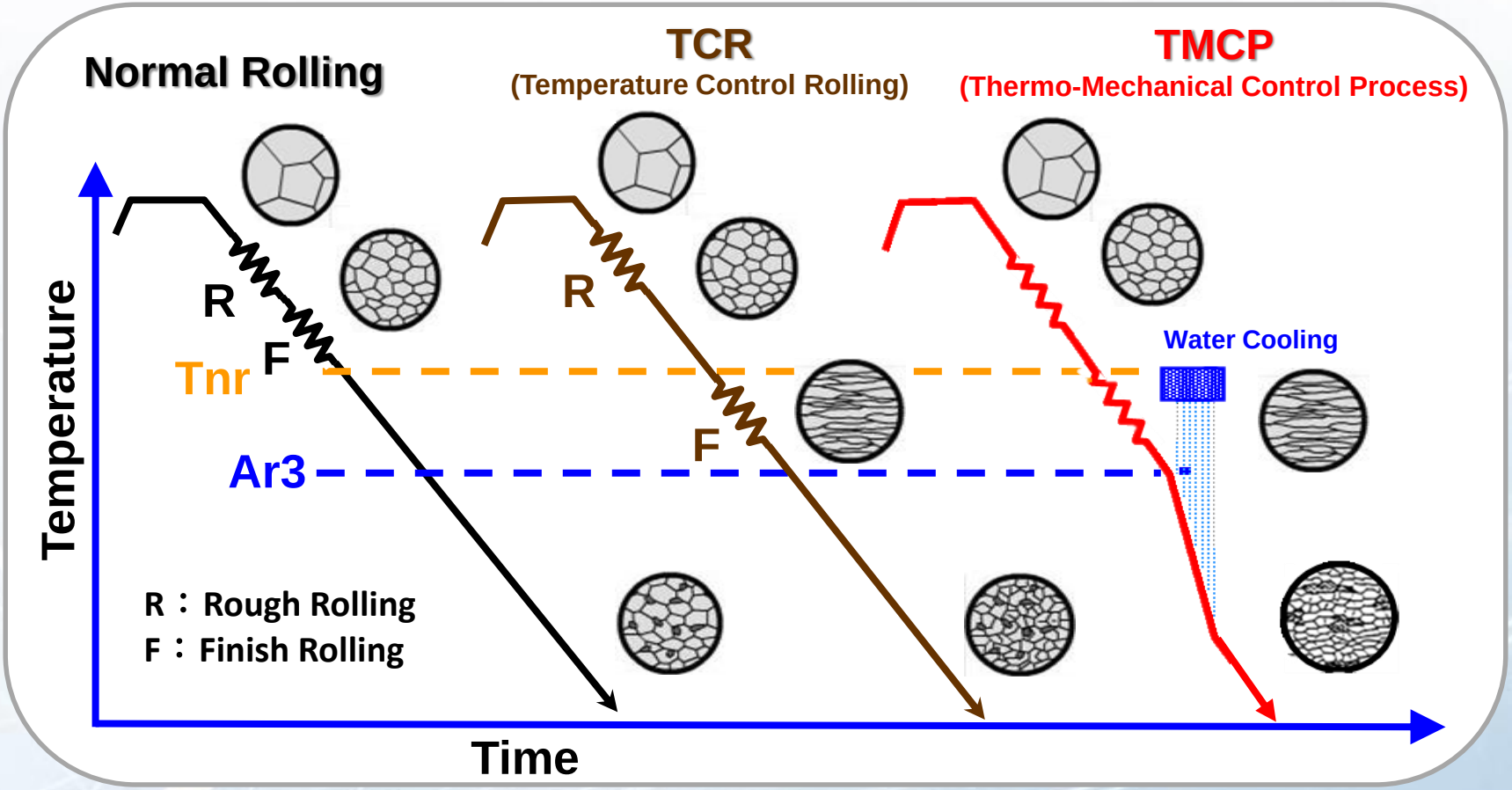
(1) Original [C]



(2) Low [C]



Rolling Process- Increase Holding Thickness

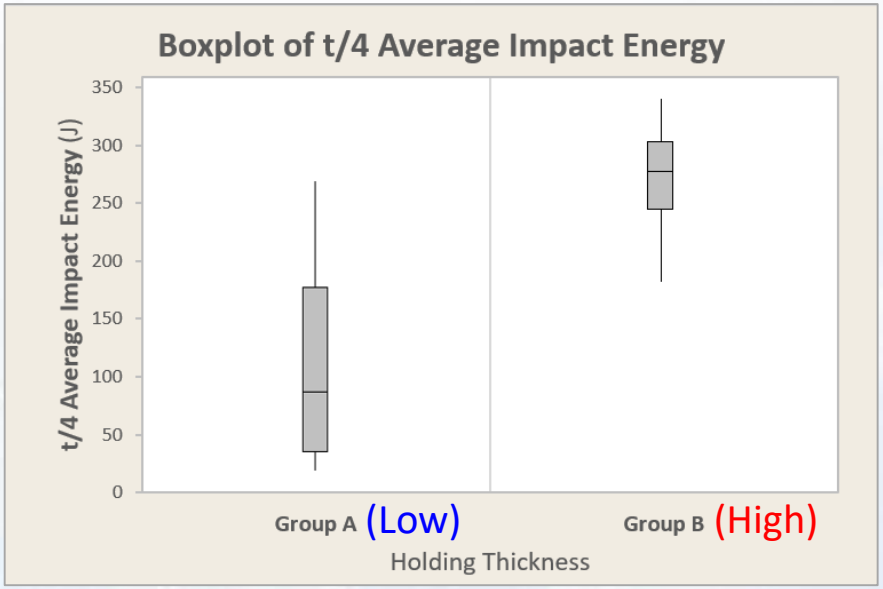


✓ Higher Holding thickness, Higher Finish reduction ratio

➢ Accumulation of substantial strain energy

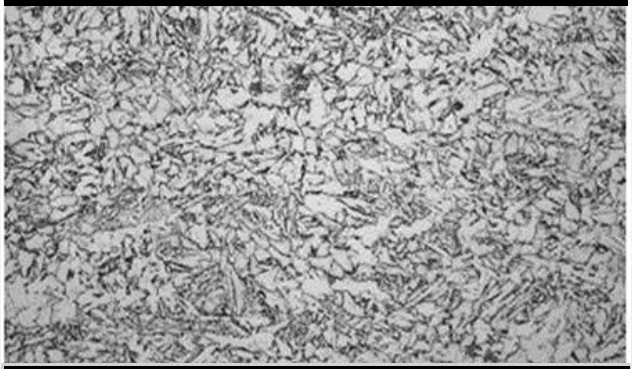
→ Induce more nucleation sites → Grain Refinement

Increase Holding Thickness (cont.)

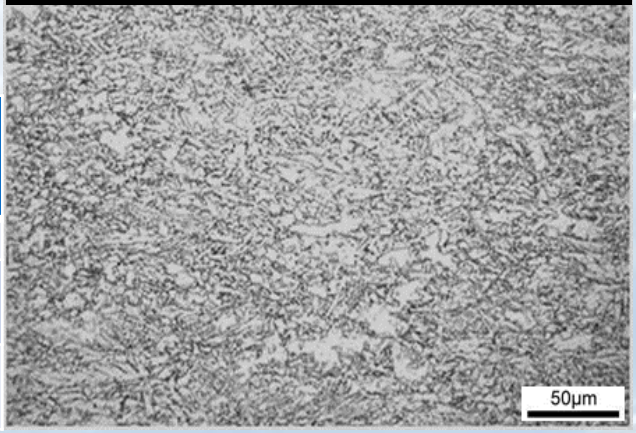


Group	Holding Thickness	Tensile Test			ZRA (%)	Temp -40℃ Charpy Impact Energy (J)	
		TS (MPa)	YS (MPa)	EL (%)		Longitudinal	Transverse
Group A (Control)	Low	514	380	26	67	136	85
Group B (Test)	High	499	394	28	66	264	252

(A)Low Holding Thickness



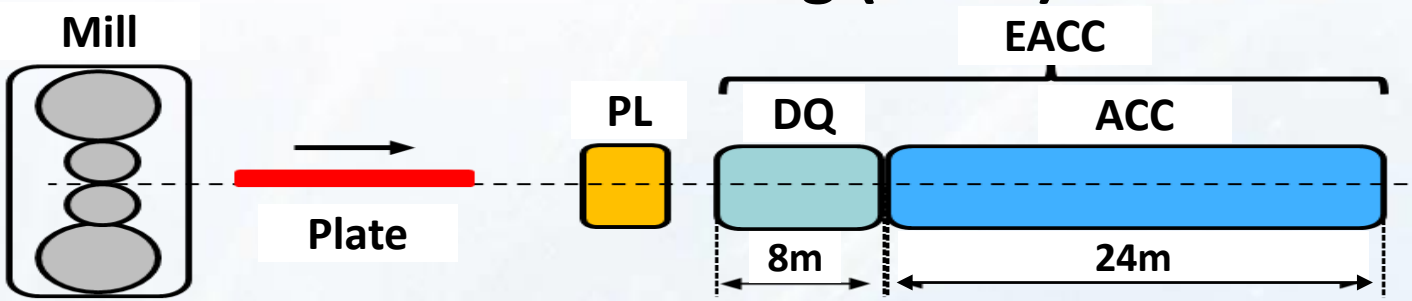
(B)High Holding Thickness

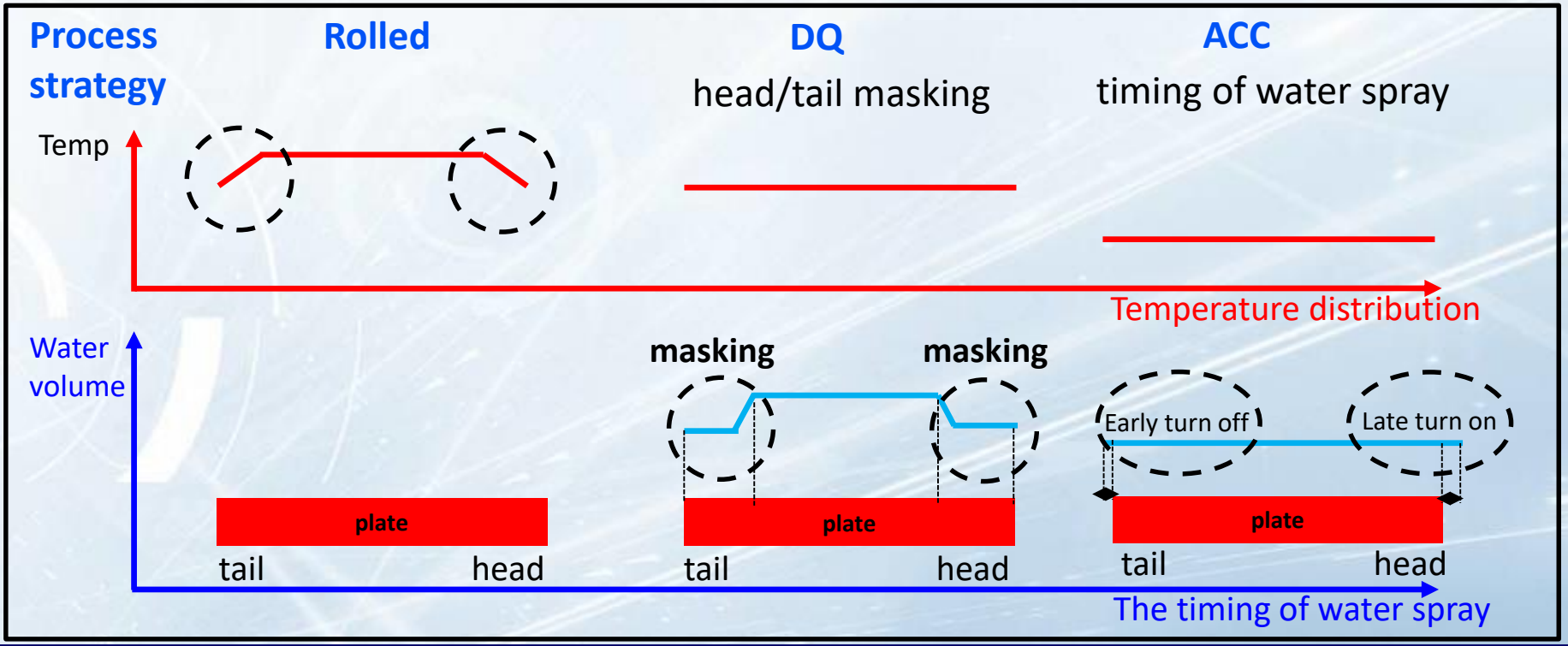


- ✓ **Remarkable Improvement of Impact Resistance**
- ✓ **No Extra Cost**

Cooling Technique

✓ Extended Accelerated Cooling (EACC)

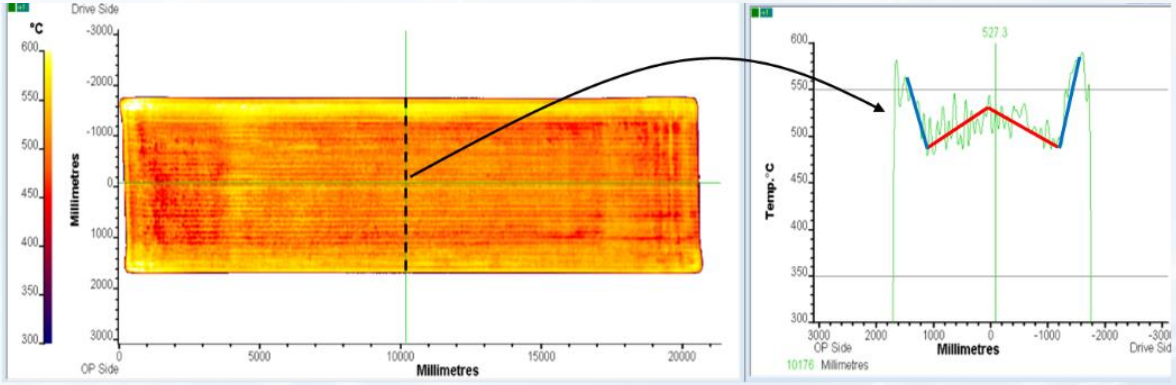




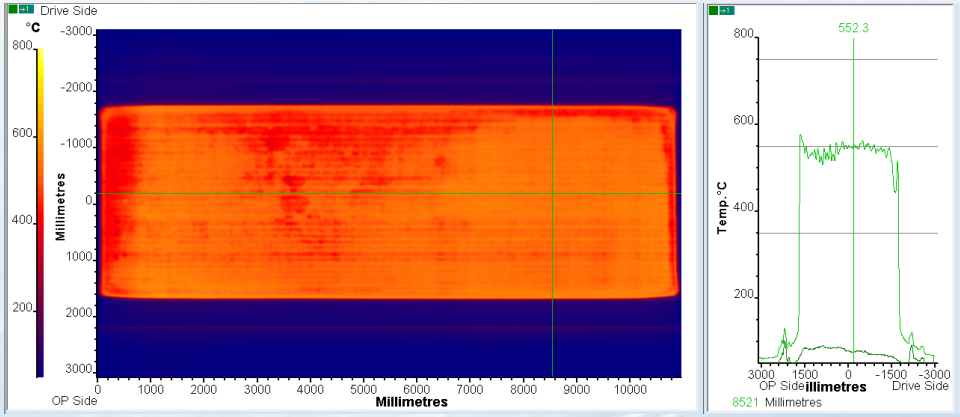
Cooling Technique- EACC (cont.)

Temperature profile in following cooling process:

(a) ACC

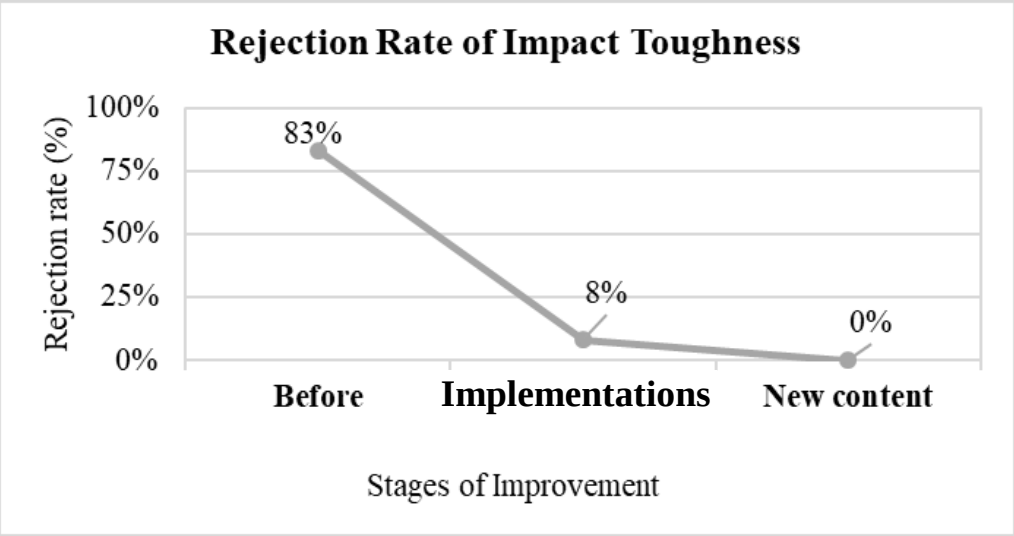


(b)EACC



- Overcooling near head and edge portion were greatly resolved by EACC cooling system.

Conclusion



- ✓ After the implementations including control of [P], [S], addition of microalloys, reduction of carbon content, and production by increasing holding thickness, and EACC cooling system, the defect rate dropped from 83% to 0%.
- ✓ Offshore steel with stable quality and better performance has been developed.
- ✓ In 2021 July, Taiwan's first indigenous underwater foundation is built.


Thanks for
your attention!