Pipes and heavy plates

Continuous casting solutions for value-added grades

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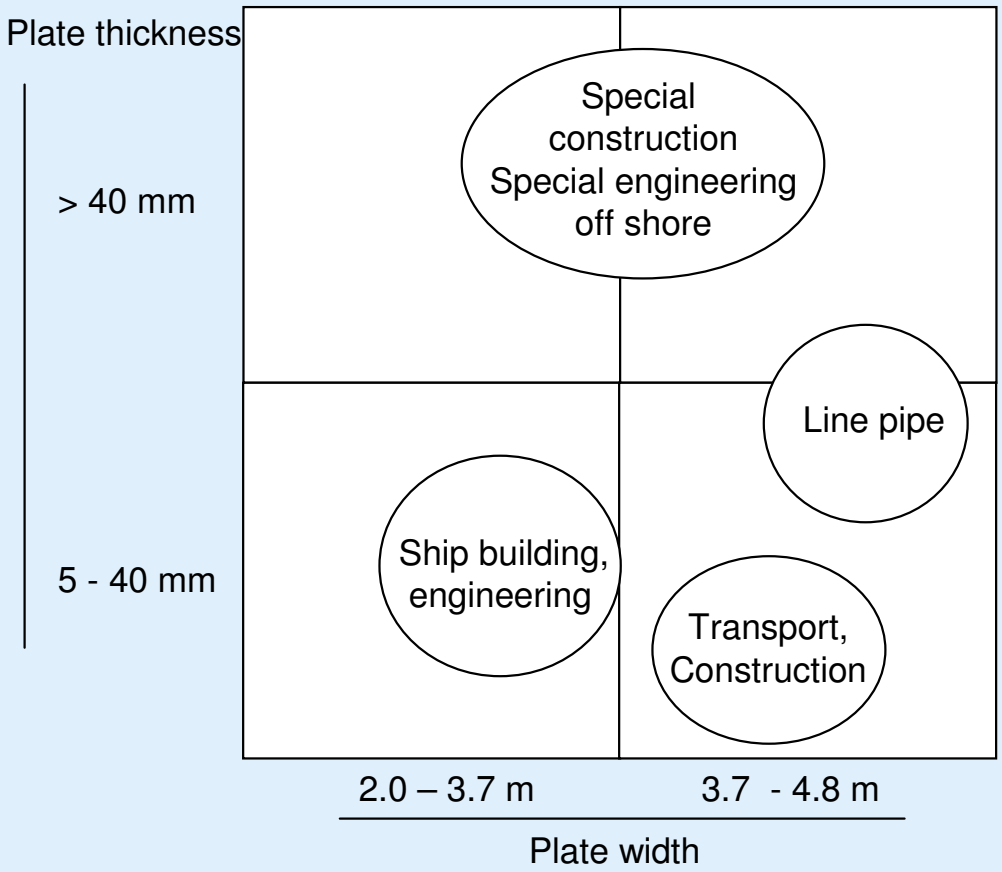
Pipes and heavy plates – Continuous casting solutions for value-added grades

Future market segments for heavy plate require capabilities to roll plate above 40 mm thickness and width up to 5000 mm

Target market for product mix from plate mill, estimated growth > 5% p.a.



Dynamic market segments require

- Excellent semis quality
  - Clean steel
  - Lowest segregation and cracking level
  - Lowest possible non metallic impurities
- Plate width 3,700 – 4,800 mm
- Plate thickness up to 40 mm serves largest share of applications
- Normalizing, quenched, thermo mechanical rolled

Source: Clippings; Press; Interviews, SMS Siemag

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Future dynamic application segments in construction require advanced technology in continuous casting and plate rolling.

Demand for heavy wide plate

Viaduct de Milleau
over 21,000 t plate from
Dillinger Hütte

Gas pipeline project
1420 mm

Typical dimensions

- Thickness: 30 – 130 mm
- Width: 4000 – 4800 mm
- Length: 6 – 12 m length
- Tensile strength: 400 – 580 MPa
- Toughness: 27 J @ - 50 °C
- Weldability with limited or no preheating

Demand for high strength plate

Shangahi World Financial
Center over 30,000 t plate
needed

Rheinbrücke Düsseldorf
Ilverich, plate from Dillinger
Hütte

Typical dimensions

- Thickness: 10 – 30 mm
- Width: 2000 – 3700 mm
- Length: 6 – 12 m
- Tensile strength: 600 – 1100 MPa

Source: Clippings; Press; Interviews, SMS Siemag

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Advanced application in plate for engineering, ship building and offshore is driven by globalization and high oil prices.

	Application references		
			
Thickness	30 – 130 mm	30 – 130 mm	5 – 120 mm
Width	2000 – 3700 mm	2000 – 3700 mm	2000 – 4800 mm
Length	6 – 12 m	6 – 12 m	
Tensile strength	400 – 580 MPa		580 - 700 MPa
Specialties	Tapered plate (Z profile)	Cryogenic grades, 9% Nickel	Tapered plate (Z profile)

Source: Clippings; Press; Interviews, SMS Siemag

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Application of wide high strength plate in transport and yellow good segment require flexible casting and rolling capabilities

Application references

Typical dimensions

- Thickness: < 10 mm
- Width: 4000 – 4800 mm
- Length: 6 – 12 m
- Tensile strength: up to 1,100 MPa
- Thermo mechanically processed

Source: Clippings; Press; Interviews, SMS Siemag

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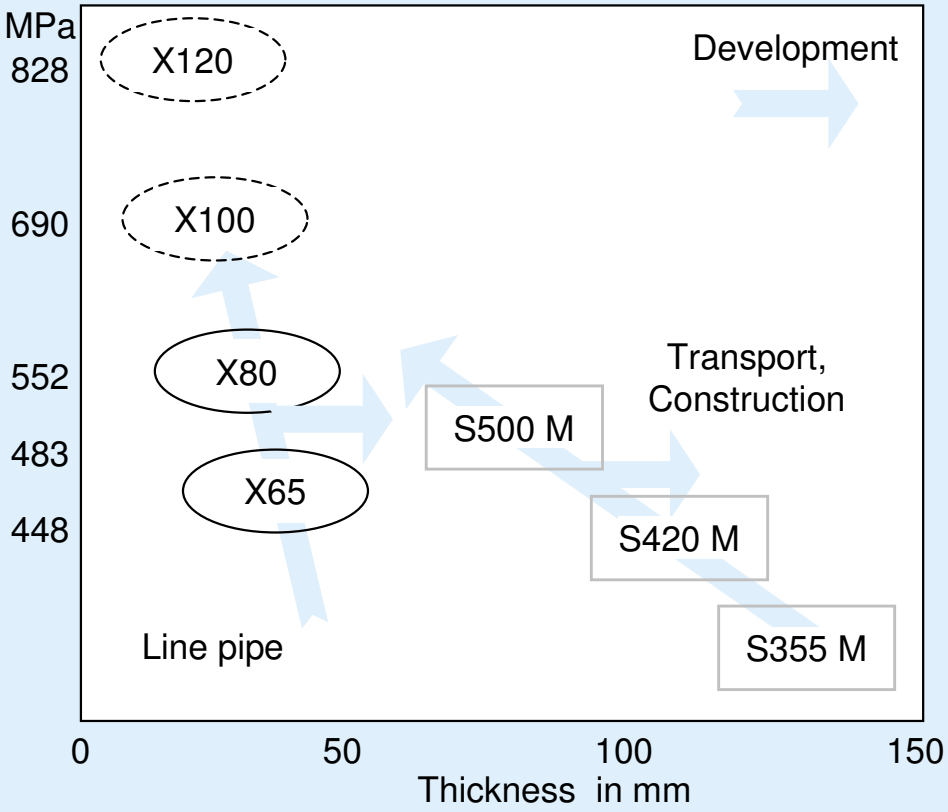
Differences in alloying concepts of API line and plate grade pipe grades require flexible casting and rolling capabilities

Development trends



Production Concepts

ksi X120	0.05 % C + Mo, Cu, Ni, Cr + Nb, V, Ti, B	1)
X100	0.08 % C + Mo, Ni + Nb, V	1)
X80	0.06 % C + Nb, Ti	2)
X70	0.12 % C + Nb, V	3)
X60	0.20 % C + V	
HIC	0.035 %C + Nb, V, Ti + ultra low P, S, H	

1) TM rolling + heavy accelerated cooling
2) TM rolling + accelerated cooling
3) TM rolling

Source: Bannenberg et al. steel research 78 (2007) No 3 p. 185-188

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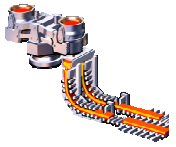
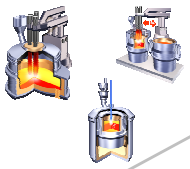
Most important caster requirements

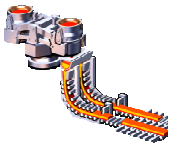
Product mix aspects



- Special caster for line pipe and plate grades
- Wide slabs i.e. ≤ 2600 mm
- Flexible thickness i.e. 250, 300, 350, 400 mm
- Capacity: 1.2 to 1.4 Mio t/a

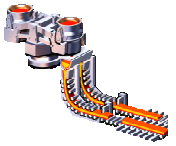
Metallurgical aspects





- Level control of C, P, S, N, H and O_{tot}
- Keep low level of relevant elements and non-metallic inclusions (NMI) in the strand – Clean steel technology
- Content and distribution of NMI

Technological aspects



- Low total strain levels at the liquid/solid interface to avoid cracks due to bending, bulging and roller misalignment
- Keep slab surface temperature > 920 °C in bending/straightening to prevent surface cracking
- Control of macro-segregation and solidification structure during final solidification

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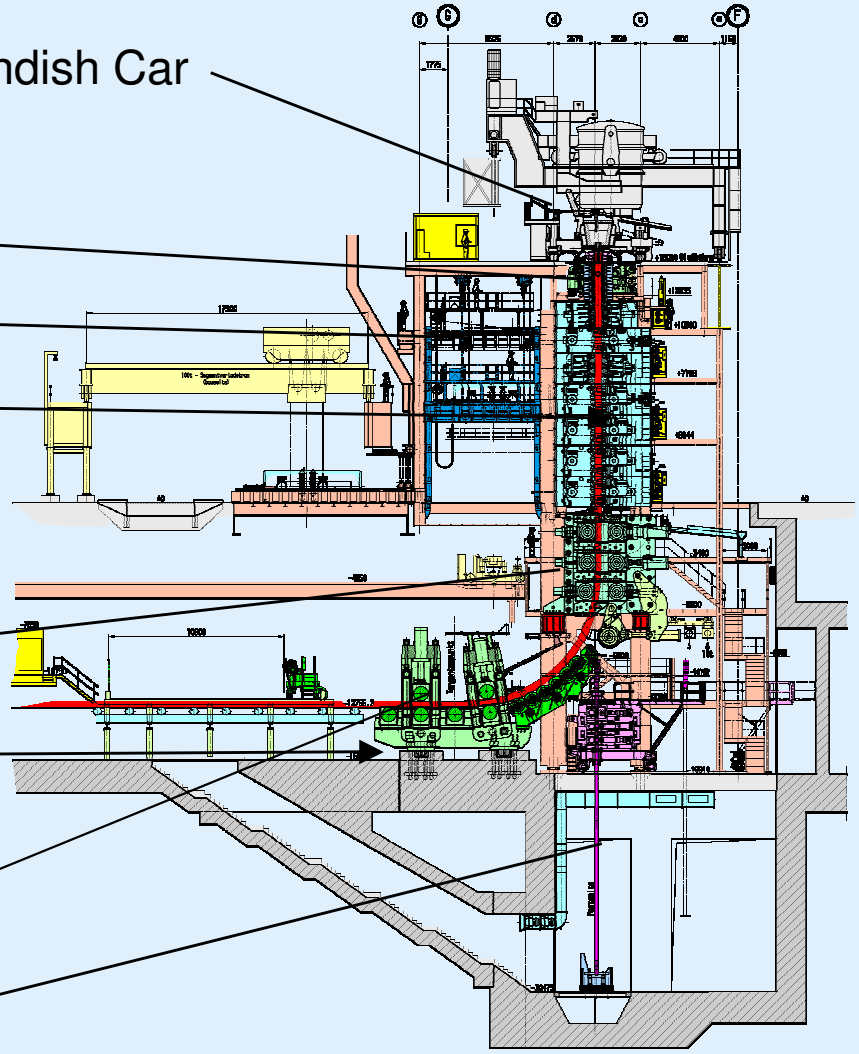
CC # 5 of Dillinger Huettenwerke – Vertical Solid Bending

- Casting Floor, Ladle and Tundish Car
- Mold and Segment 1
- Segment Manipulator
- Segment 2-8
- Bending Machine
- and Bending Roll
- Straightening Machine
- Dummy Bar and D/B-Car



DILLINGER HÜTTE

Pipes and heavy plates – Continuous casting solutions for value-added grades

Main technical data – CC # 5 of Dillinger Huettenwerke – Vertical Solid Bending

- Type of caster: vertical - solid bending
- Number of machines: 1
- Number of strands: 2
- Production 1.400.000 tpy
- Nominal heat size: 185
- Slab dimensions: 1.400 - 2.200 mm
- Slab thickness: 230 – 350, 400, **450 mm**
- Slab length: max. 10.8 m
- Metallurgical length: approx. 15.8 m
- Main machine radius: 8.0 m
- Vertical length: approx. 19.256 m
- No. of segments: 8
- Softreduction: Segment 4- 8
- Slab bending: as multi-point
- Height of casting floor: approx. 27.8 m
- Machine speed: 0.10 - 2.50 m/min
- First Cast: September 1997

DILLINGER HÜTTE

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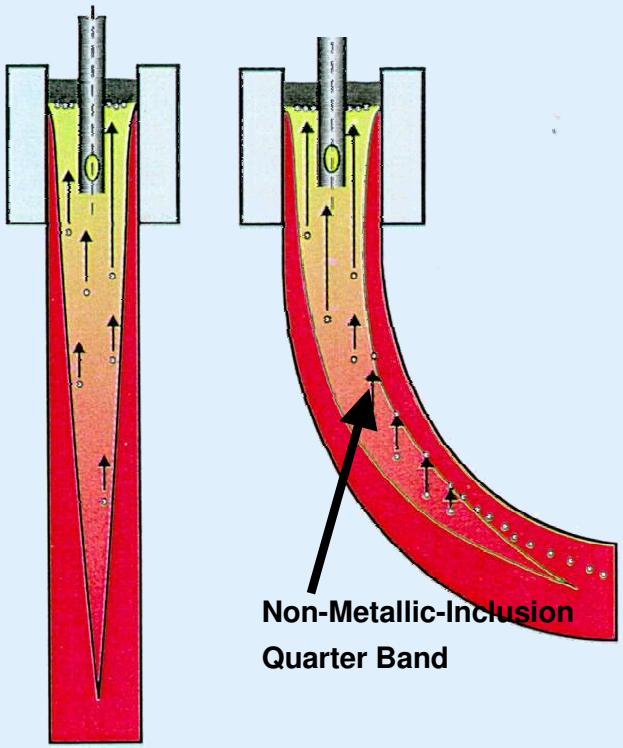
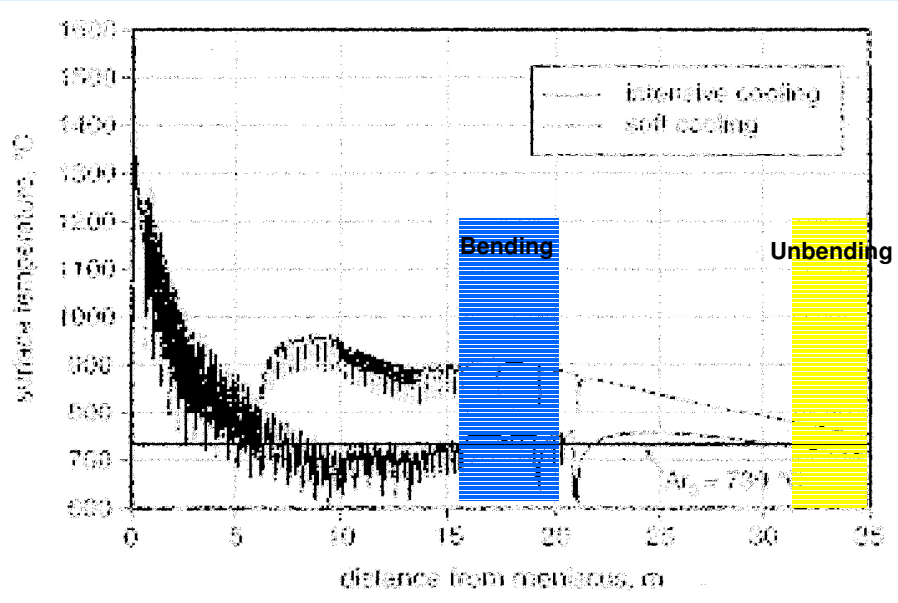
CC # 5 of Dillinger Huettenwerke – Vertical Solid Bending

Caster of no compromises regarding quality

Ultra low and homogeneous Non-Metallic-Inclusion distribution



Full Flexibility in secondary cooling strategy Cold-Cold or Hot-Cold during bending



Bending/straightening at
- **Intensive-Cooling: Surface temperature below Ar_3 (cold)**
- **Soft-Cooling: Surface temperature above 910°C (hot)**

DILLINGER HÜTTE

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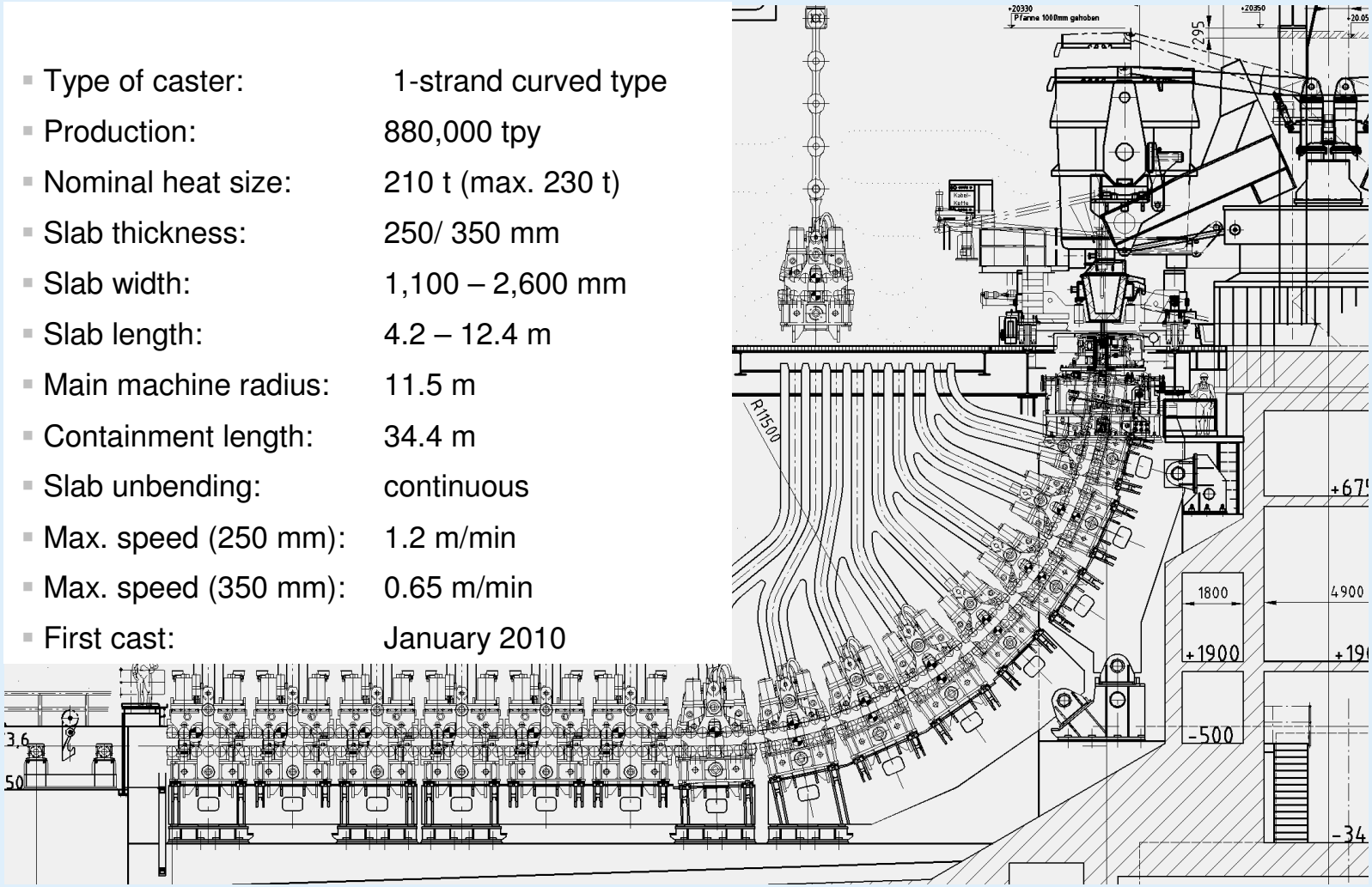
Main technical data – CC #4 at Salzgitter Flachstahl AG

SALZGITTER AG
Stahl und Technologie

- Type of caster: 1-strand curved type
- Production: 880,000 tpy
- Nominal heat size: 210 t (max. 230 t)
- Slab thickness: 250/ 350 mm
- Slab width: 1,100 – 2,600 mm
- Slab length: 4.2 – 12.4 m
- Main machine radius: 11.5 m
- Containment length: 34.4 m
- Slab unbending: continuous
- Max. speed (250 mm): 1.2 m/min
- Max. speed (350 mm): 0.65 m/min
- First cast: January 2010



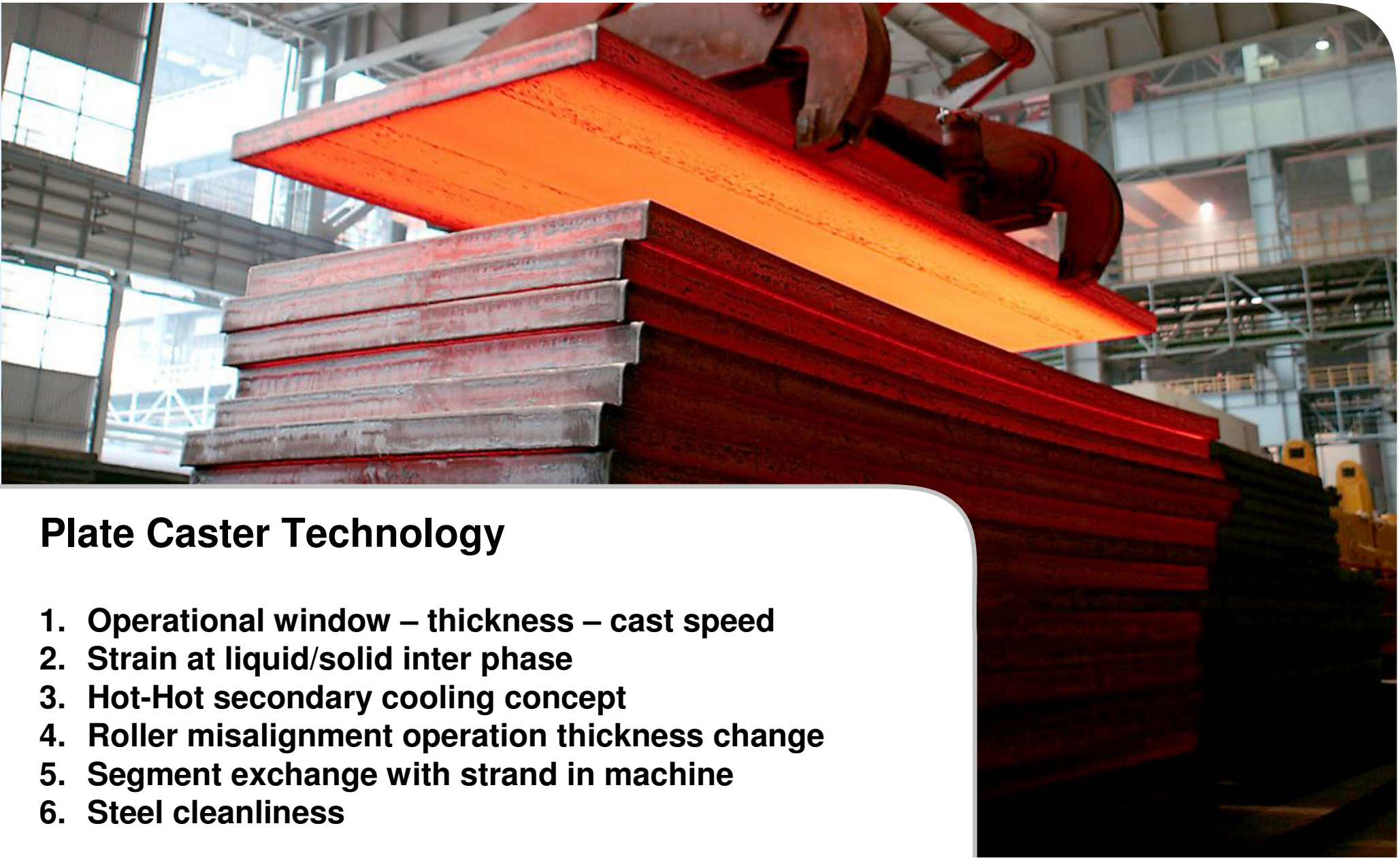


Plate Caster Technology

1. Operational window – thickness – cast speed
2. Strain at liquid/solid inter phase
3. Hot-Hot secondary cooling concept
4. Roller misalignment operation thickness change
5. Segment exchange with strand in machine
6. Steel cleanliness

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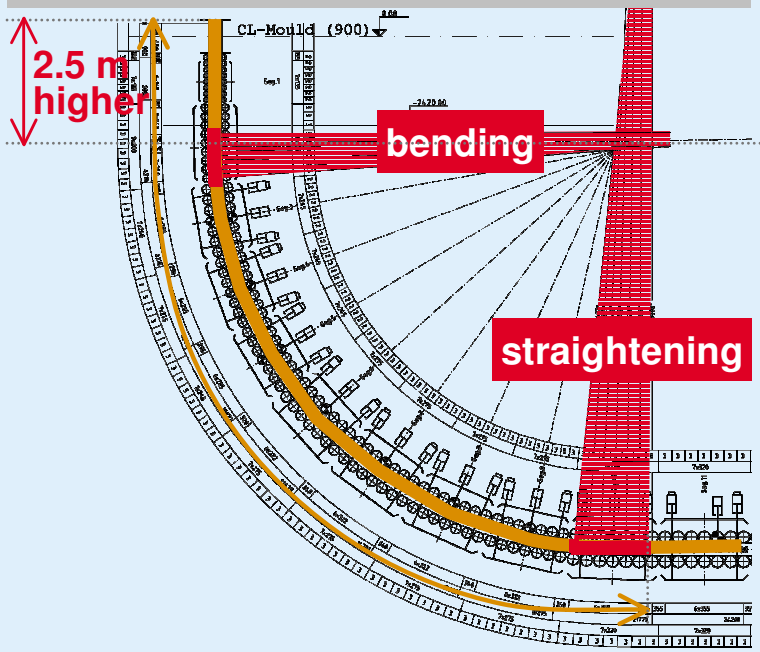
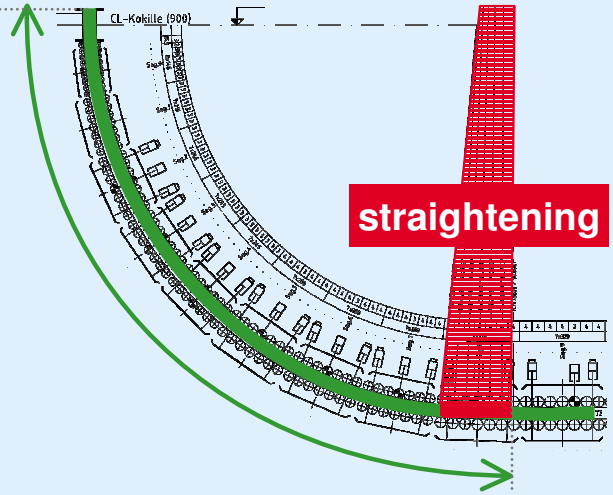
Caster design study for 250 to 400 mm slab thickness

Vertical bending type



- 2.5 m vertical section
- 11.0 m machine radius
- 19 – 21.5 m distance to straightener
- 45 m machine length

Curved type



- 11.5 m machine radius
- 17 – 19.5 m distance to straightener
- 45 m machine length

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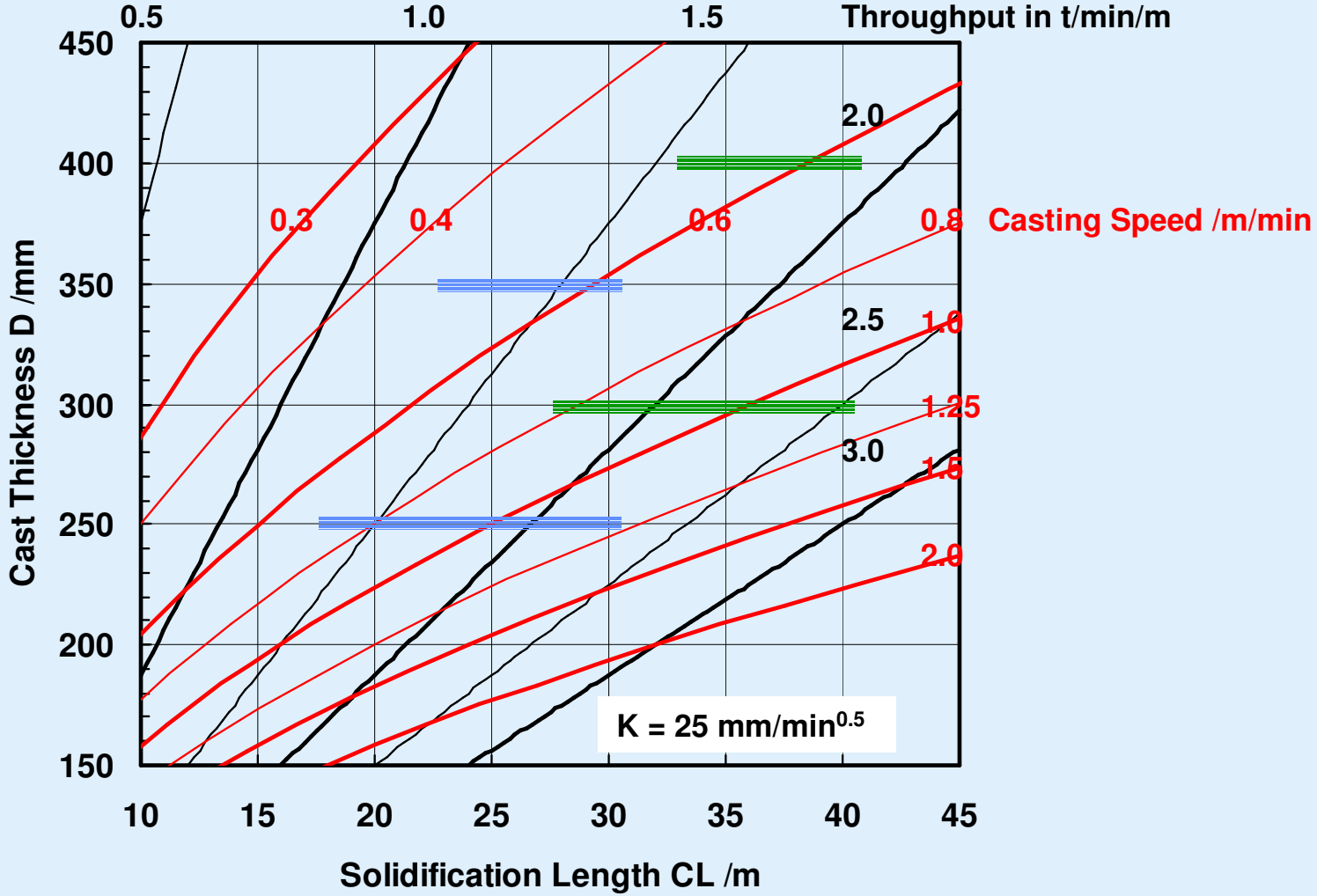
Operational window for 250 mm to 400 mm thickness
Max. v_{cast} for peritectic grades is 0.7 m/min at 400 mm



Productivity Increase

$\Delta M/M = (CL_2/CL_1 - 1)$

$\Delta M/M = (D_1/D_2 - 1)$

- API X65 und X70 in peritectic carbon range (0.10 bis 0.15% C)

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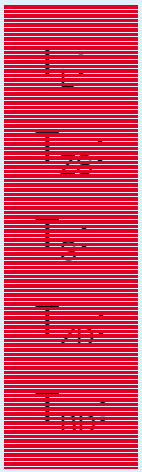
Risk of Cracking – Internal and Surface Cracking

Material
- Micro/Macro segregation
- Precipitation forming
- Material transformation

Strain/Stress
- Thermal strain
- Creeping
- Bulging/Bending
- Alignment



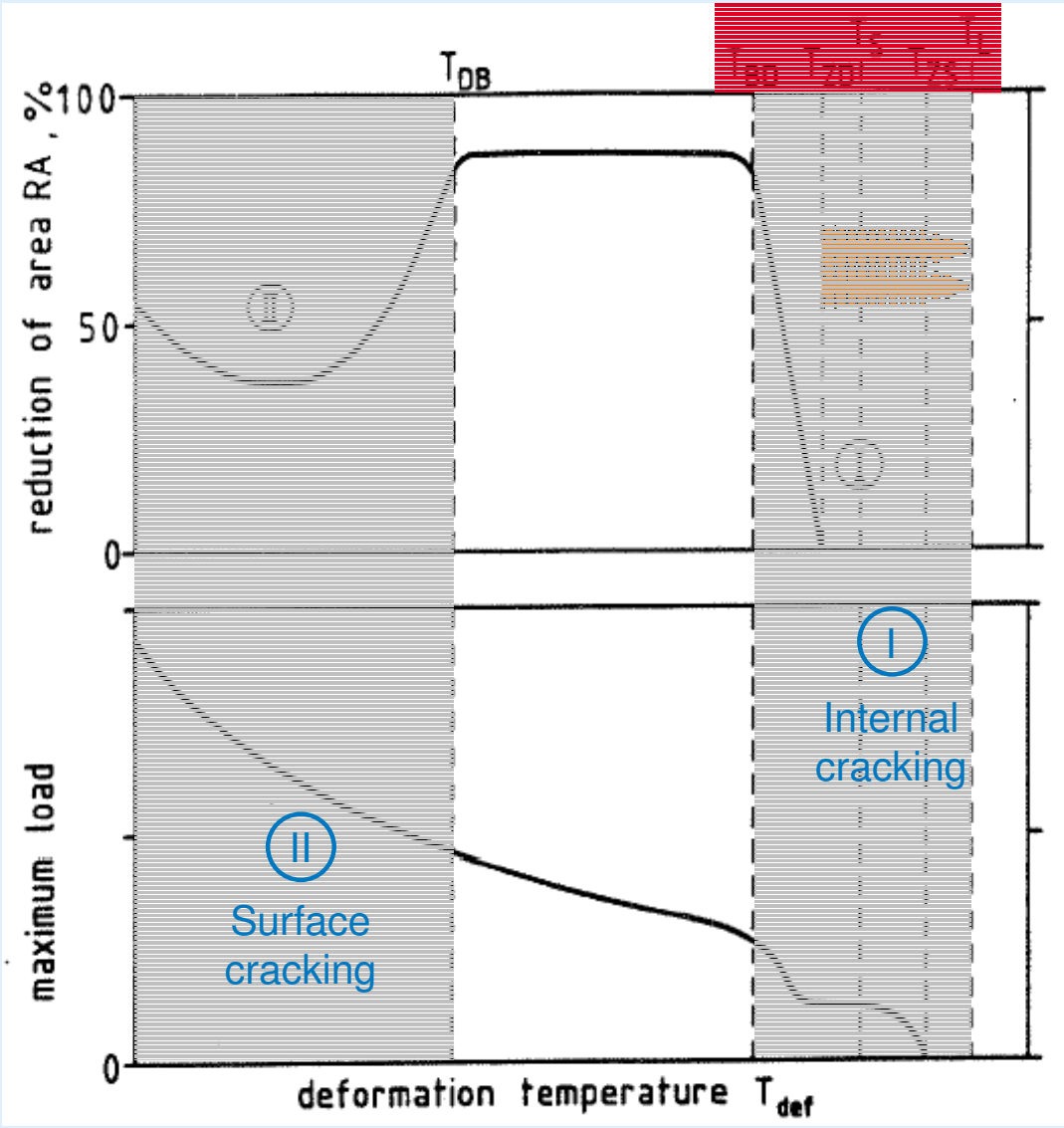
Liquidus

Zero Strength

Solidus

Zero Ductility

Transition Brittle / Ductile



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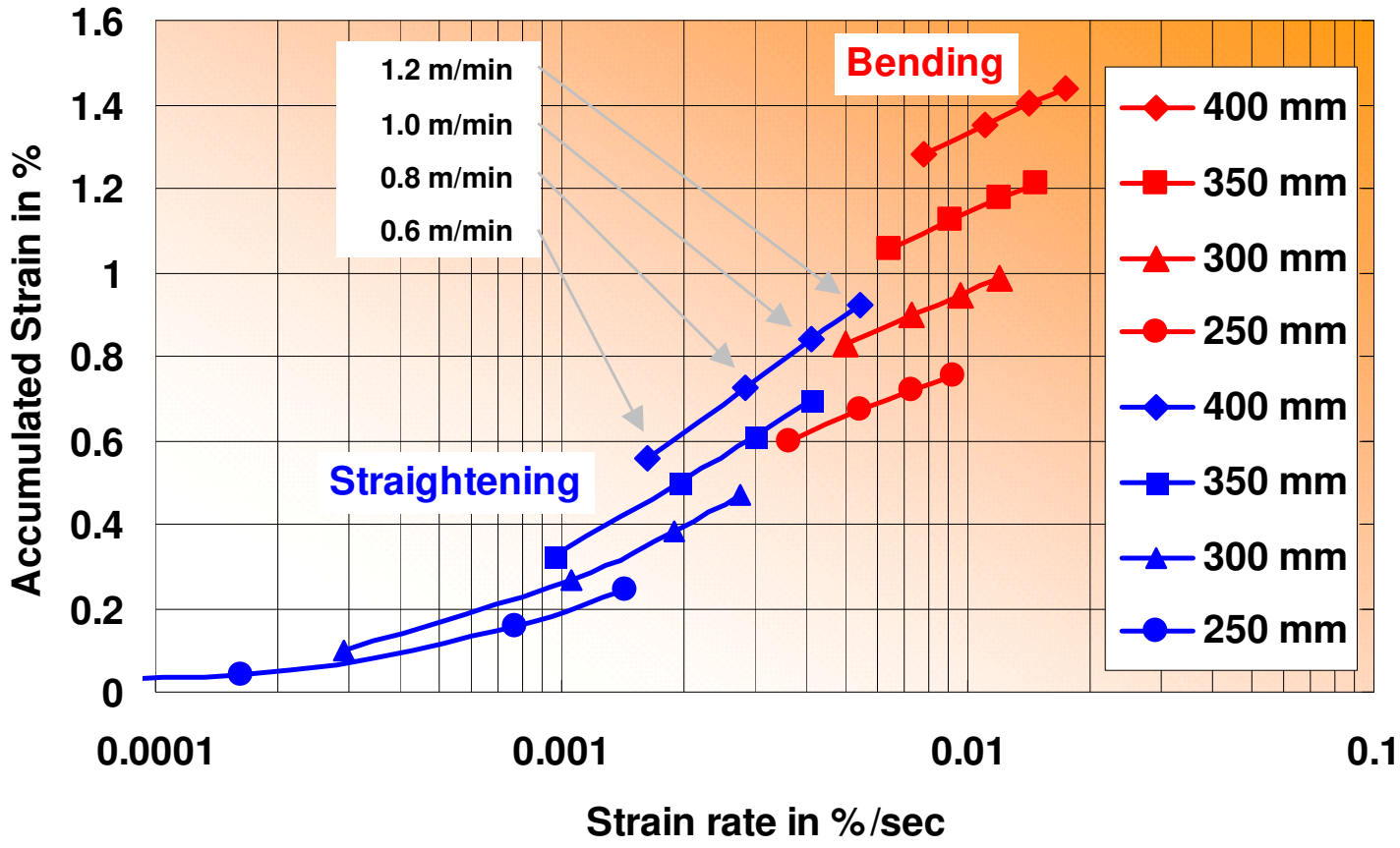
Risk of bending-induced cracking - Increasing with thickness and cast speed



Slab bending is more crack sensitive than slab straightening
Cracking risk increases with slab thickness and cast speed

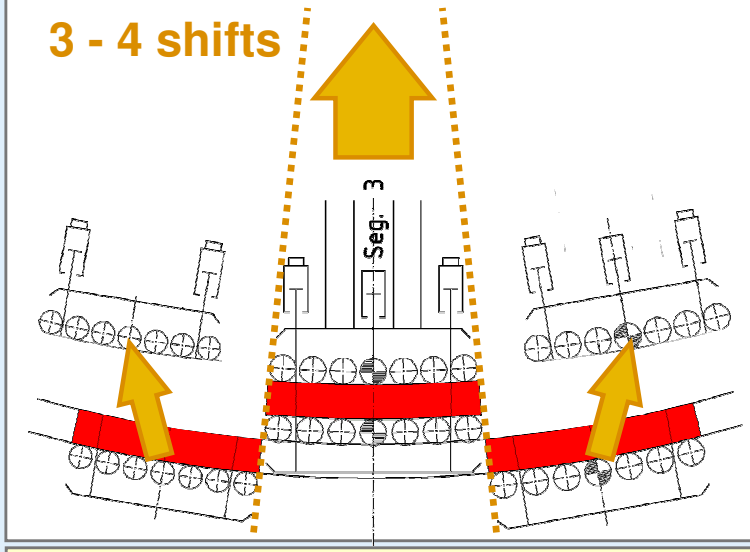
Pipes and heavy plates – Continuous casting solutions for value-added grades

Segment exchange with stuck slab is essential for a single caster operation – caster availability

Vertical bending

1. Cut slab
2. Dismantle adjacent segments
3. Remove segment top frames
4. Remove segment 3

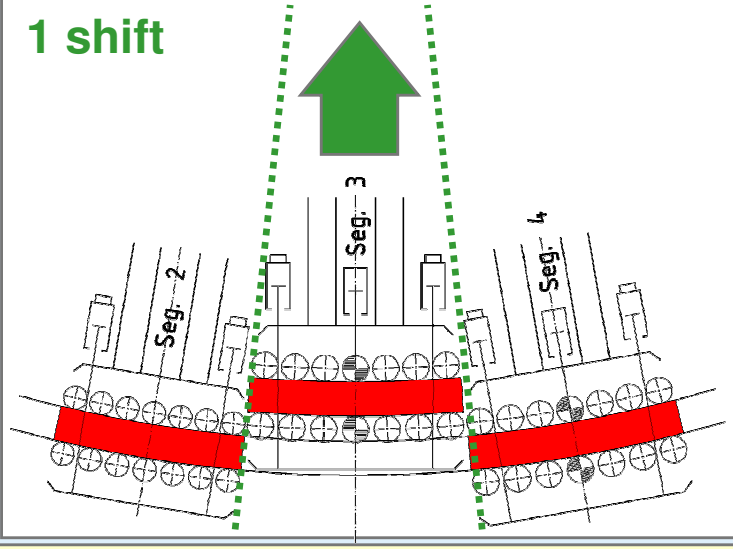
3 - 4 shifts



Curved-type

1. Cut slab
2. Remove segment 3

1 shift



Bow-type caster ensures fast machine recovery after stuck slab e.g. after a break-out, when steel has spilled into the bow section

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Clean steel technology

Metallurgical aspects

- Ladle slag detection
- Ladle shroud protection against nitrogen and oxygen pick up
- Fluid flow control in the tundish
  (dam and weir combination)
- Sufficient steel residence time for inclusion separation
- Correct selection of active tundish fluxes
- Customized casting nozzle (SEN) design
- High accuracy mould level control
- Optimum casting powders for the different steel grades
- Inclusion distribution in the strand

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Evaluation of cleanliness and homogeneity of steels

Microscopic

Small inclusions

≤ 20 µm in diameter

Mesoscopic

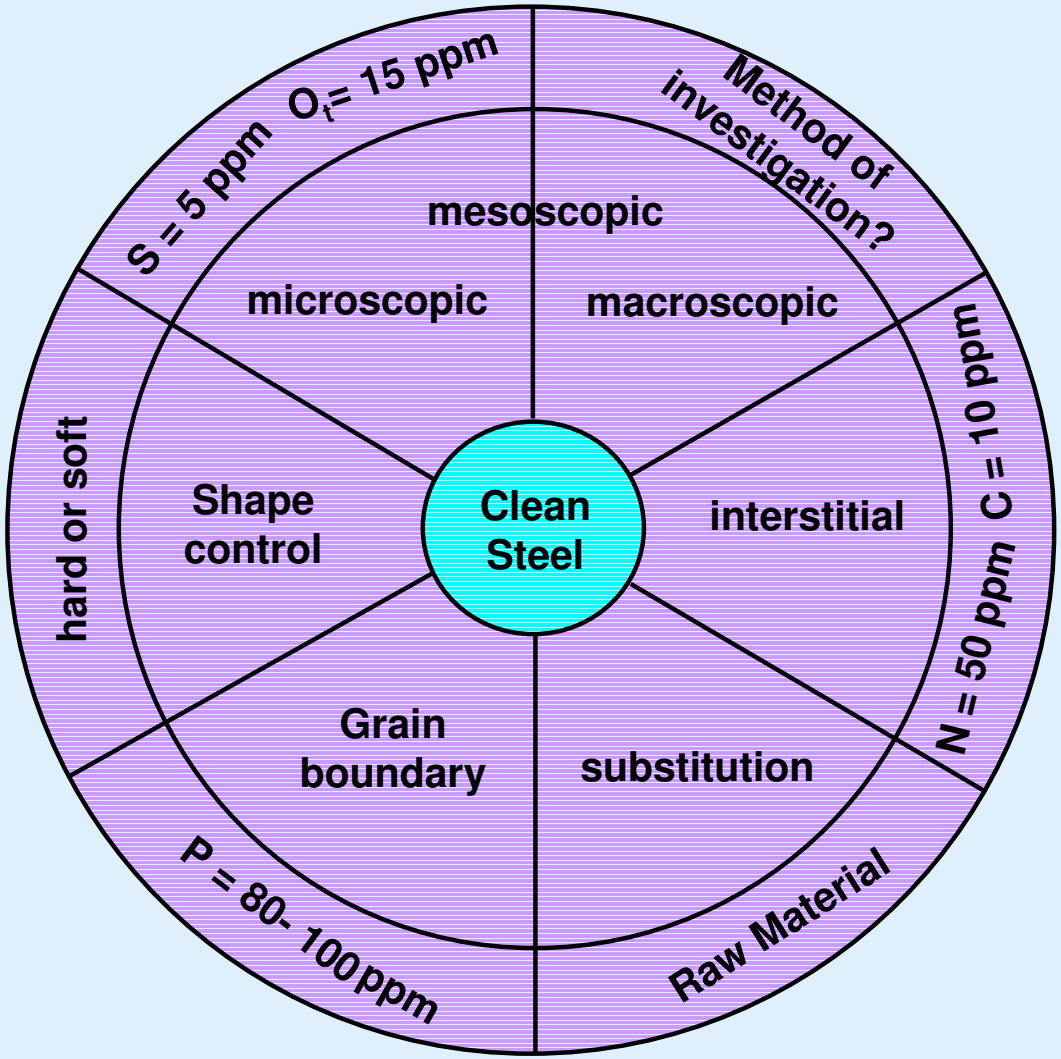
Medium size inclusions

20 - 120 µm in diameter

Macroscopic

Large inclusions

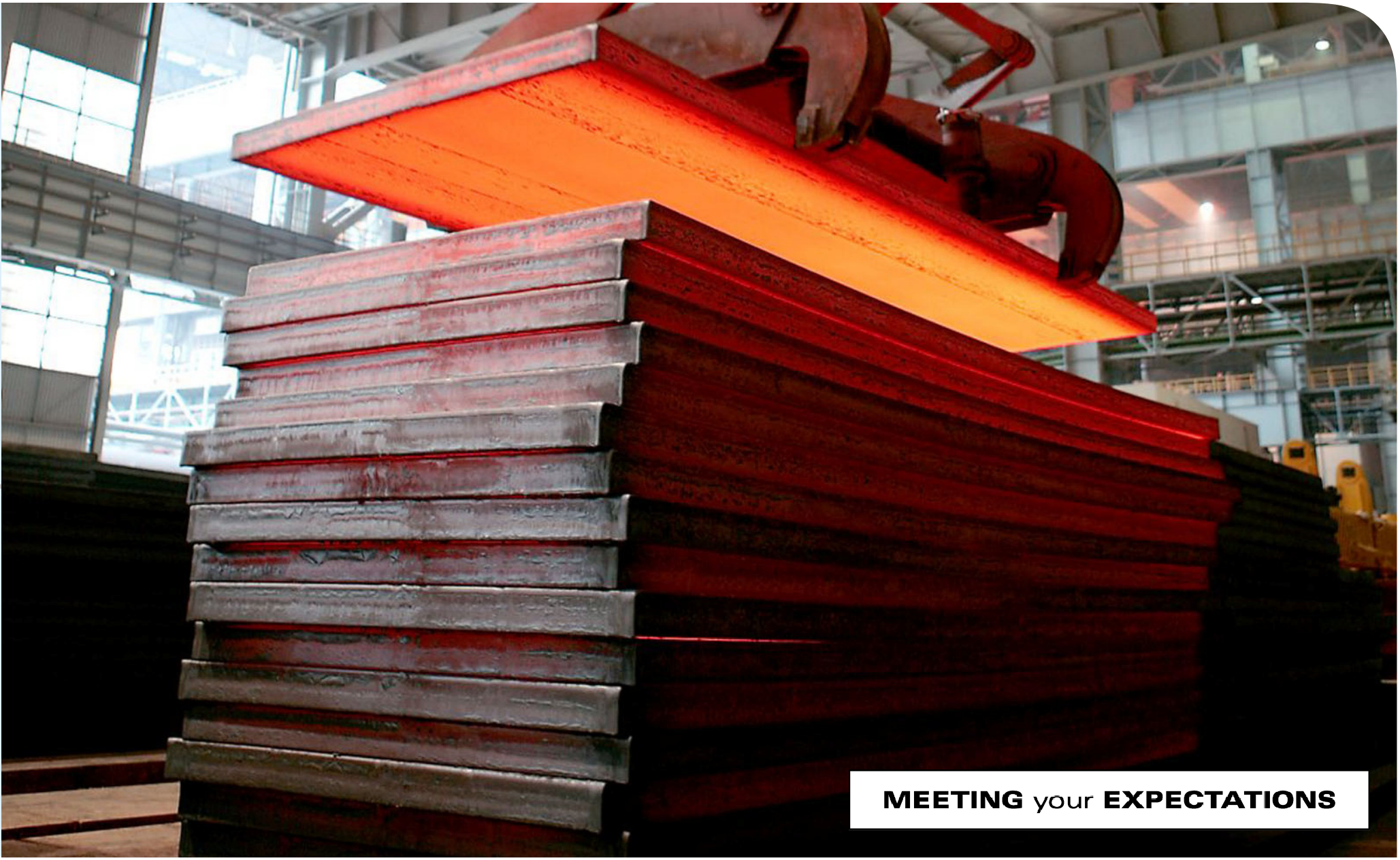
>120 µm in diameter



Pipes and heavy plates – Continuous casting solutions for value-added grades

The bow-type caster is the preferred solution in comparison to the vertical bending caster

Aspect	Vertical Bending Machine	Curved Machine
Product Quality		
Cleanness / inclusion distribution for API and plate grades	good	good
Risk of surface and sub-surface cracks	low to medium	low
Risk of internal cracks	medium	low
Operational Issues		
Temperature level during unbending > 920 °C	critical	achievable
Casting window / ladle sequencing	medium small	large large
Strand stop	difficult	comfortable
Break-out removal (liquid steel in bow section)	very demanding ≈ 3 – 4 shifts	comfortable ≈ 1 shift
Maintenance		
Alignment of segments	demanding	comfortable
Investment Cost		
Buildings and structures	approx. 110%	100%
Slab thickness	250 / 300 mm	350 / 400 mm



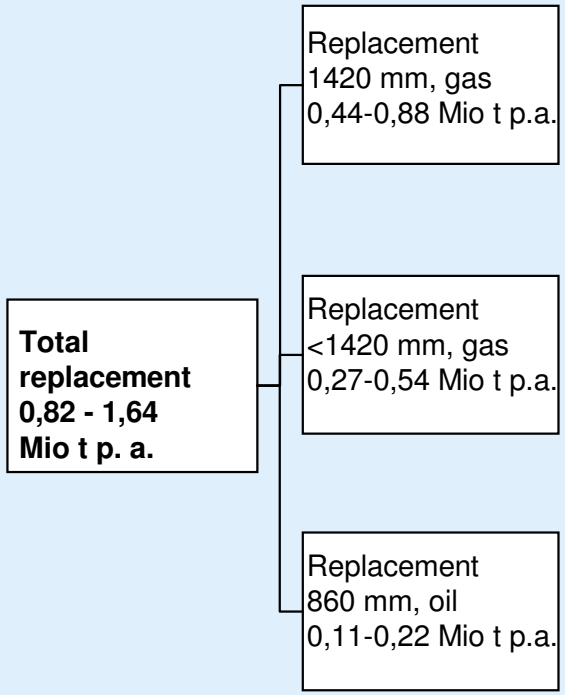
Pipes and heavy plates – Continuous casting solutions for value-added grades

Line pipe requirements from new projects and replacement of existing pipe lines.

Demand from new projects

Project name	Length km	Diameter mm	Volume Mio t
Northern European onshore	900	1420	0,95
Northern European offshore	1 200	1067 - 1220	1,22
Eastern Siberian - Pacific	4 200	1067 - 1220	2,22
Urengoi	600	1420	0,64
Shtokman	2 252	1067 - 1220	1,51
Teriberka	2 840	1420	2,84
Ananiev-Izmail-Turkey	880	1220	0,70
Yamal Center pipeline	2 148	1420	2,30
CPTO Torzhok	1 000	1420	0,60
Total 13,0	**16 020**		**12,98**
Realization factor			**65 – 80 %**

Replacement need per year



From new projects
0.85 – 1.06 m. tpa

Replacement 0.82 – 1.64 m. t
at a repair rate of 0.5% – 1% per year

Source: Clippings; Press; Interviews, SMS Siemag

Pipes and heavy plates – Continuous casting solutions for value-added grades

Product Mix – CC #4 at Salzgitter Flachstahl AG

SALZGITTER AG
Stahl und Technologie

Steel Grade No.	Description	Casting speed for different slab sizes (m/min)	
		250 mm	350 mm
1	ULC Ultra Low Carbon (0,002-0,005%C)	-	-
2	LC / Low Carbon (0,03-0,05%C)	1,25	0.65
3	LC / HSLA micro-alloyed	1,25	0,65
4	Peritectic Steel (0,08-0,14%C)	1,20	0,65
5	Peritectic Steel micro-alloyed	1,20	0,65
6	MC / Medium Carbon, Structural Steel (0,15-0,25%C)	1,20	0.65
7	High Carbon (0,45-0.6%C)	1,10	0,60
8	Ultra High Carbon (0.6 – 1.0 %C)	1,10	0,60
9	Si steels	-	-