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The intelligent ultra-wide caster for high-quality slabs at Rizhao Shandong

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The single-strand caster is designed for an annual production of up to 1.5 million tons of steel slabs with widths of up to 3,250 mm and a thickness of 150 mm. This means the plant is able to cast the widest slabs in the world. Structural steels as well as micro- and low-alloy steel grades are produced on the caster, and peritectic grades make up approx. 45 percent of the overall production output. The slabs are then processed to sheet metal plate and hot strip in the Steckel Mill using the hot charging technique.

The jumbo caster is equipped with smart and proven technologies, such as HD moldTC/FO, X-Pact® Level Control, X-Pact® Width Control, X-Pact® Solid Control, which are implemented assuring high-quality slab production. In the maintenance shop the digital aligning assistant HD LASr (High Definition Laser Aligning System remote) gets segment and mold alignment performed easily and perfectly. The PQA® (Product Quality Analyzer) system documents, monitors and secures the entire production process in the continuous casting plant.

The plant is also equipped with Industry 4.0 technologies, they provide the smart processing of plant data and automation of processes. Based on the steel grades to be produced, the X-Pact® Tech Assist automatically selects the optimal technological parameter settings for the metallurgical process.

KEYWORDS: SLAB CASTING, ULTRA-WIDE CASTER, HIGH-QUALITY STEEL GRADES, DIGITALIZATION, INDUSTRY 4.0 TECHNOLOGIES;

INTRODUCTION

Shandong Iron & Steel Group set up a new green field production base producing prime quality steels in Rizhao, Shandong Province in China.

The steelmaking plant consists of 4 x 210 t BOF, 2 x 210 t ladle furnace, 3 x 210 t RH, 2 x 2 strand slab caster, 1 x 1 strand ultra-wide slab caster (#3), 2 other relocated slab caster.

#3 is an ultra-wide medium thickness slab caster. The format range of slabs is 150 mm thickness and 2,000 – 3,250 mm width.

Steel grades being produced are mainly structural steels, micro- and low-alloy steels. The slabs are hot charged to the SMS group supplied Steckel Mill, which rolls them to sheet plate and hot strip. The single-strand caster is designed for an annual production of max. 1.5 million tons of steel slabs.

After intensive technical negotiation and market investigation SDIS Rizhao Base finally chose SMS group as the supplier of the jumbo caster.

Basing on its successful jumbo caster projects and rich experience, advanced mechanical design, technology

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know-how and latest electrical and automation X-Pact® packages, SMS group supplied SDIS Rizhao Base one jumbo continuous caster including Industry 4.0 technology for its high-quality steel grades and high output production.

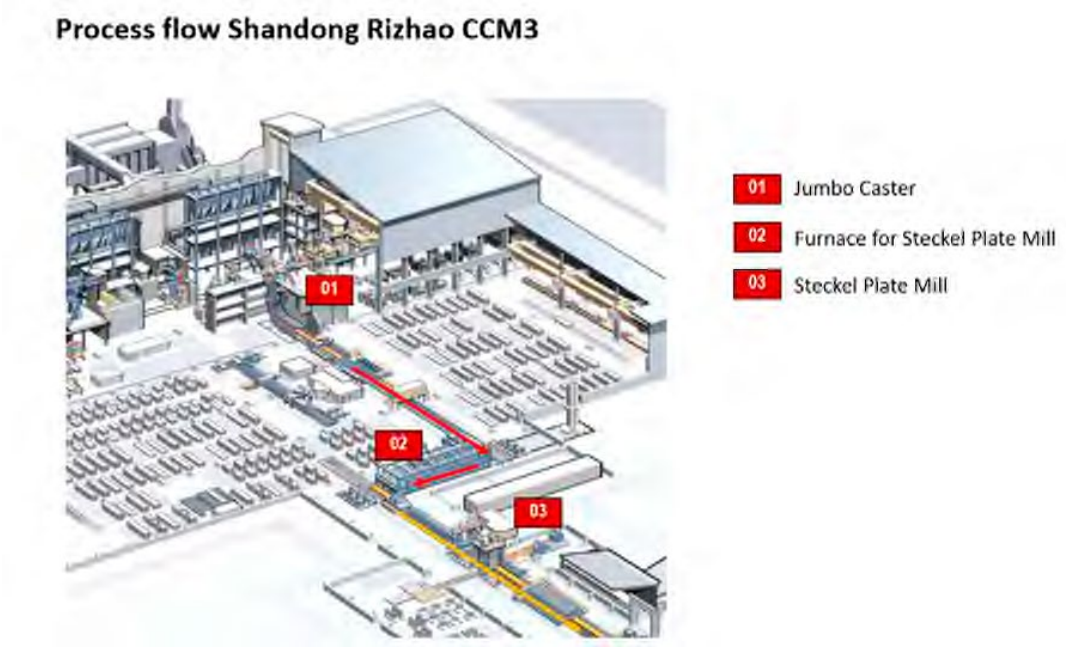

Fig.1 - Production line at continuous casting plant, in particular: the ultra-wide caster, furnace for Steckel mill, Steckel plate mill in SDIS Rizhao Base.

The caster project scope comprised the design, manufacture and supply of core mechanical parts, the electrics and automation, and the supervision of erection and commissioning.

SDIS Rizhao Base, Shandong province in China, has awarded SMS group the final acceptance certificate, following the successful commissioning of the new continuous caster for ultra-wide slabs 6 months after the first cast.

Fig.2 - Jumbo caster in production.

Fig.3 - JThe widest slabs cast by caster # 3 at SDIS.

PLANT DESCRIPTION AND MAIN DATA

The single-strand ultra-wide caster is designed for the production of qualified steel slabs in flexible formats, which match the 3500 mm Steckel mill production mix in SDIS Rizhao Base.

The range of grades produced comprises structure, micro-alloyed, alloyed steel grades, which are used in large buildings, bridges, ships, pipelines, ocean platforms, boiler and pressure vessels and machinery, provided in thicknesses of 150 millimeters for Steckel mill. During casting, the width can be steplessly set from 2,000 to 3,250 millimeters.

Tab.1 - Main technical data.

DESCRIPTION	MAIN DATA
Type of machine / no. of strands	Vertical liquid bending (VLB) / 1
Steel meltshop	BOF, LF, RH
Nominal heat size	210 t average (240 t max)
Slab width	2,000 - 3,250 mm
slab thickness	150 / (180 provision) mm
Metallurgical length	18.7 m
Machine radius	6.67 m
Vertical length	2.5 m
Number of segments	9
Strand bending and unbending	both, as multi-point
Production speed (for low carbon @150mm)	2.0 m/min
Annual production capacity	max. 1,500,000 tpy

The caster features a vertical length of approx. 2.5 m thus accounting for uniform strand solidification and for centering segregation bands in the slab. The strand guide is composed of 9 segments with a smart roller configuration for optimum strand support minimizing tendencies for bulging or cracking. The strand bending as well as the straightening within one segment are performed each over several points enabling minimum bending / unbending strains for best internal and surface quality.

Fig.4 - 3D caster design.

SMS group's intelligent slab casting modules are linking design, process, technology and automation.

INTELLIGENT MOLD

The mold, being of compact type and featuring a length of 900 mm enables the casting of 150 or 180 mm thick slabs as a future extension. The narrow sides can be online set and controlled according to individual tapers by X-Pact® Width Control. A soft clamping function during the width change results in reduced adjustment forces and less wear of the copper plates. The electromechanical narrow side adjustment featuring upper and lower high-precision spindles cares for exact taper and slab width adjustment.

The X-Pact® Width Control is equipped amongst others with:

Delta Speed Adjustment serves to adjust bigger width changes within shorter transition length. It allows lower compression (width decrease) or reduced gap (width increase) during adjustment.

The width and taper adaption function ensures an optimized width and taper setup of the mold. Thus, it optimizes the slab width and the heat flux on the narrow sides, which sustains the casting process by uniform melting of casting powder in this sensitive area.

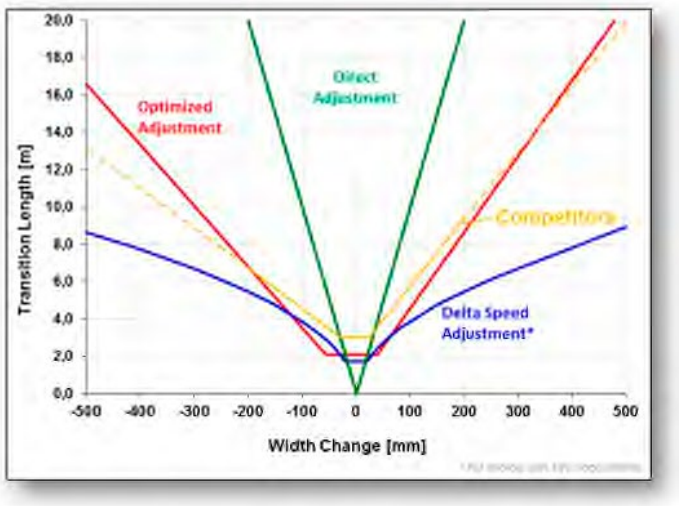

Fig.5 - Delta speed adjustment with considerably reduced transition lengths.

With X-Pact® Level Control, using an eddy-current measuring system, a stabile mold level is achieved. A hydraulic actuator system consisting of a rapidly moving hydraulic cylinder with integrated position transducer actuated by a control-valve moves the tundish stopper rod to keep constant mold levels. The stopper mechanism features high thermal stability and tight tolerances in order to translate the rapid hydraulic movement onto the desired stopper rod movement.

The intelligent mold comprises also the HD mold$^{TC/FO}$ (TC = Thermocouples or FO = Fiber Optics) enabling an undisturbed casting process for increased plant availability. Based on a reliable thermocouple or the fiber optical installation in the mold, the system allows detecting stickers thus predicting and minimizing breakouts.
Further, the heat flow over the mold width and height is measured and the temperature distribution in the mold is displayed as a map.
Summing up HD mold$^{TC/FO}$ visualizes the processes in the mold, helps for optimizing the mold taper settings, cares for minimizing sticker breakouts and permits the optimization of casting powder for an improved slab surface quality.
One set of HD mold^{FO} narrow side is supplied in the project. By a much higher density of measuring points compared to thermocouples, it can prevent gutter formation for best slab quality.

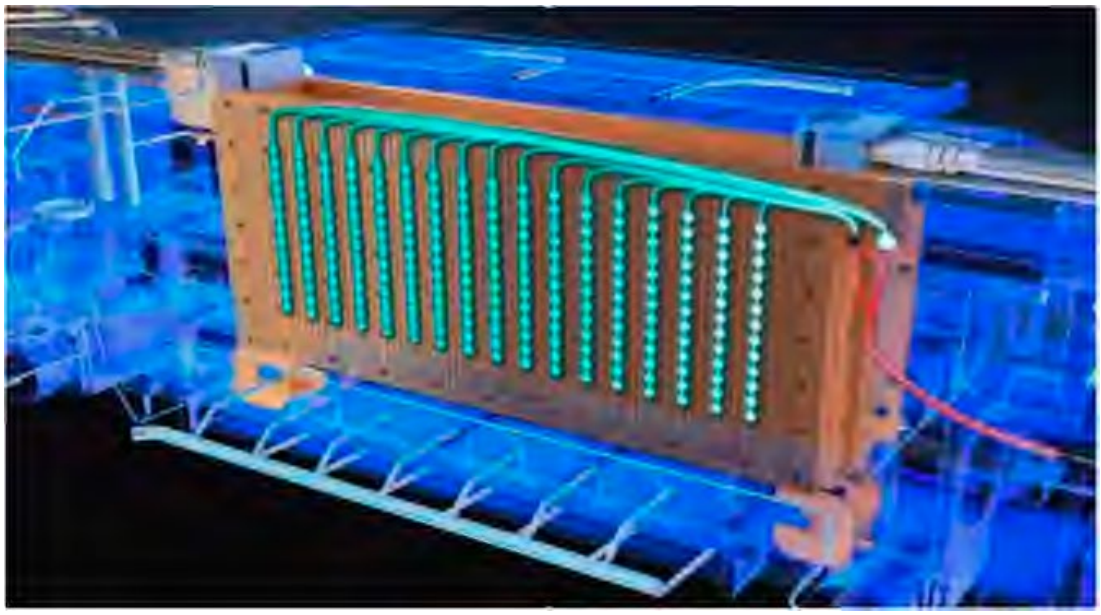

Fig.6 - example of broad face HD mold^{FO}.

Copper plate coating plays an important role in the quality of highly sophisticated steels sensitive to cracking at high temperatures. Without coating or following the wrong coating philosophy pinches can form close to the meniscus zone and grow up to longitudinal cracks in the edge zones of the solidifying and shrinking slabs.
UNIGUARDTM metal-ceramic coating from SMS group leads to higher copper plate surface temperature at stabile casting speed compared to e.g. the formerly coating concept with NiCo. Contraction of the strand shell is thus decreased and the heat flow through shell and mold powder into the mold is kept more homogeneous.
Copper plate life time can be increased using the UNIGUARD™ concept with 1mm full face coating by factor 2.5 for broad faces and 3.5 for narrow faces [2].

RIGID MACHINE HEAD DESIGN

By leaving the mold's foot rollers the strand is guided smoothly to the first roller of the well-aligned segment 0 and accordingly to segment 1.

Fig.7 - Compact machine head.

During insertion, segment 0 and segment 1 are easily installed as they are self-positioning and self-connecting to the water supply lines by water-connecting plates. Furthermore for quick maintenance, mold, segments 0 and 1 can be removed as a package in one step.

The leaf-spring guided oscillation system is actuated by 2 hydraulic cylinders. With online adjustment of stroke and frequency, the hydraulic oscillation offers complete flexibility. Sinusoidal and asymmetric sinusoidal wave forms are possible. X-Pact® Mold Oscillation controls and monitors reliably the synchronized movement of the cylinders on the left and the right side. The system cares for reduced and very even oscillation marks and a good distribution of casting powder, important for a slab surface quality that enables hot charging.

The smart and well proven leaf-spring guided system reduces the total oscillation weight, is mechanically wearfree and almost maintenance-free. It reaches the best oscillation shape, which is favorable for strand shell and copper plate interaction.

Different oscillation curves are selected depending on the used steel group, suggested by the X-Pact® Tech Assist. It offers real-time displays of measured values of the oscillator like positions, pressures and neg. strip, monitors strand friction forces helping to indicate bad or insufficient mold powder and hydraulic or mechanical problems.

OPTIMUM STRAND SUPPORT AND HANDLING

The strand support and segments are specially designed to assure an optimal strand support, slab geometry and quality of ultra-wide, medium thick slabs.

First, a smaller bow radius is used to lower the machine height and reduce the ferrostatic pressure, which leads to very slim segment frame design for easy installation and removal. Secondly the segment frames are strengthened with heavy and big size plates to bear much higher ferrostatic pressure coming from ultra-wide slabs. The segments built with rigid plate design have very long segments life time as well.

Thirdly the roller bodies of the segments are split into four parts to satisfy the strict requirements imposed on the strand guiding system of ultra wide slabs for minimum roller deflection. All these minimizes segment and roller deflection, which significantly increases with increasing casting width.

In addition, the segment body construction was engineered with the help of the finite-element method (FEM) to achieve proper segment stiffness.

The cold/hot strand is driven on both sides at the upper and lower center roller to ensure exact guiding of all slab sizes and an optimal force transmission on the ultra-wide strand. The drive control X-Pact® Strand Drives provides a high degree of synchronicity between the two electric drives per segment and the interaction of all segments during casting. It ensures a predefined distribution of the total load among the segment motors which
are pressed on the cold/hot strand.

Precise aligning of the strand guide is one of the important keys for producing high-quality slabs.

For caster #3 at SDIS Rizhao Base the reliable, easy, precise and digital measuring system HD LASr (High Definition Laser Aligning System remote) was provided by SMS group. The digital aligning assistant combines the best available hardware laser tracker and the intuitive SMS group software undertaking 3D measurement and automatic storage of data. It perfectly aligns the mold and strand guide and digitalizes the measuring data to increase quality and decrease maintenance costs.

Fig.8 - HD LASr [segment] used for segment alignment.

Perfect edge temperature avoiding corner cracks is realized with width-dependent secondary cooling. Up to five control loops each on loose and fixed side ensure flexible adaptation of cooling media distribution over the ultra-wide slab width in the critical segments. The fix distance of nozzle to slab maintains constant impact and constant heat transfer. An increasing product range is realized by air mist cooling.
X-Pact® Solid Control (replaces the previous DSC®) and includes the well-proven model for temperature control of the secondary cooling. Its extended functionality ensures even and controlled strand shell growth, offers the option of selecting "dry casting" in the horizontal strand guide, improves the edge quality through controlled edge cooling for all slab widths, calculates and precisely regulates the final solidification point and ensures with a homogeneous solidification front for besterformance of Dynamic soft reduction® and safe casting.

The X-Pact® Gap Control is designed for segments with position control. Its functions include

- Dynamic soft reduction® to improve the internal slab quality, ensures a well-adjusted taper for each casting situation.
- Intelligent Taper Tracking to avoid negative effects on mold level, prevents segment overload and avoids high withdrawal forces by smooth changing the thermal taper in all casting situations.
- Segment Gauge Control to ensure defined slab geometry, prevents internal cracks caused by imperfect segment transition. It compensates the segment bending and cylinder elongation under load conditions.
- Withdrawal Reduction to prevent high segment forces after strand stop and roll slippage for strand start

by controlling the transmitted torque.

- Slant Control to prevent mechanical damages of the rolls/segments, decreases the failure rate and improves slab geometry.

X-Pact® Cast Optimizer is centrally embedded in the overall automation infrastructure. It features interfaces to the Level 1 and other Level 2 systems of the caster and is connected to other Level 2 systems, the Level 3 and the PQA® (Product Quality Analyzer). Based on data acquisition and administration of the above systems the X-Pact® Cast Optimizer tracks the complete material from arriving at the ladle turret, transport through the caster until leaving the run out area. During this, the system optimizes the complete casting process using several functions beyond the tracking as e.g. casting speed optimization, determination of heat transition, supervision of current steel analysis or cut-length optimization.

Fig.9 - Control pulpit of #3caster.

PQA® AND INDUSTRIE 4.0

The steel grades produced by the steelworks encompass structural steels as well as micro and low-alloy steel grades used in high buildings, bridges, ship and marine, boiler and pressure vessels, machinery, pipelines as per the below table.

Tab.2 - SDIS Rizhao Base steel grade groups.

STEEL GRADE GROUP	STEEL GRADE
Carbon structural steel and quality steel	Q195～Q275, SS330, SS400, SS490, 20, 45, 65Mn
Low alloy structural steel	Q345, Q390, Q420, Q460, Q500, Q550, Q690, S690Q, S890Q, S960Q, SM400, SM490, SM520, SM570, A572, Gr50-65, A573
Building structural steel plate	Q345GJ, Q390GJ, Q420GJ, Q460GJ, SN400, SN490, A572, A573
Bridge plate	Q345q, Q370q, Q420q, Q460q, Q500q, Q690q, Z15-Z35, SM490, SM540, SM570
Ship and marine engineering steel	A/B/D/E, A32/D32/E32/F32, A36/D36/E36 /F36, F40, AH/DH/EH/FH420-690
Boiler and pressure vessel plates	Q245R, Q345R, Q370R, 18MnMoNbR, 17MnNiVNbR, GB713, 3MnNiMoR, 15CrMoR, 14CrlMoR, 12Cr2MolR, GB3531, 12CrlMoVR, 12Cr2MolVR, 16MnDR, 15MnNiDR, GB19189, 09MnNiDR, 12MnNiVR, 07MnMoVR, 07MnNiVDR, 07MnNiMoDR, 06Ni9DR, SB410, SB450, SB480, JIS G3103, A202, A517, A537, A516, P265GH, P295GH, ASTM
High-strength wear-resistant plate for construction machinery	NM300～NM600, S10C～S58C
Pipeline steel including Submarine pipeline steel, HIC pipeline steel	X42 ～ X120, ...
Weathering steel	Q235NH, Q355NH, Q390GNH, Q460NH, Q550NH, JNS

Fig.10 - SMS group smart plant concept.

SDIS Rizhao Base also ordered latest quality enhancing digital solutions for the casting plant from SMS group.
PQA® (Product Quality Assessment & Assurance, also known as QES® Quality Ensuring System) is an integrated product quality system. It covers the essential quality aspects by the acquisition of relevant process data and events from the steel melt shop, the caster up to the slab yard or plate / coil yard in case of direct hot slab charging. The quality-determining variables and process parameters are automatically evaluated at regular intervals. The results are used to improve process control and to create a reproducible setting of the desired quality characteristics. Further benefits of the PQA® are the improvement of quality management and the full transparency of the process and product quality. PQA® helps to assure a superior slab quality and to compare the results for hot or cold-charged slabs. It stabilizes operational performance, enhances confidence in quality decisions and enables the integration of continuous improvement by flexible rule adaption.

Additionally, the plant is equipped with Industry 4.0 technologies developed by SMS group for smart plant data processing and process automation. Based on the steel grades to be processed, the X-Pact® Tech Assist automatically selects the optimal technological parameter settings for the metallurgical process.
X-Pact® Process Guidance provides automatically - whenever needed - all relevant process information and prompts operator screens. All plant control and maintenance functions can be conveniently executed from the operator's station. X-Pact® Business Intelligence combines the data from different systems, enabling interaction with dynamic applications and dashboards.

PRODUCTION & PRODUCTS

After the start of the hot commissioning the caster has shown a stable production curve. As an example: In the last two months of 2019, 904 heats, which means 210,707.00 t liquid steel were cast.
The production of different steel grade groups in these two months has been portioned as per the following graph.

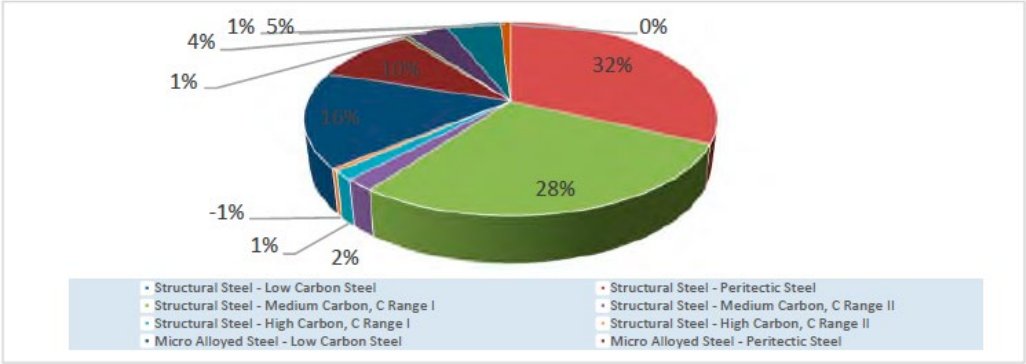

Fig.11 - Production of steel grade groups in Nov. & Dec. 2019.

The slab widths cover nearly the whole format spectrum; however emphasis is on the medium width range of 2,250 – 2,750 mm.

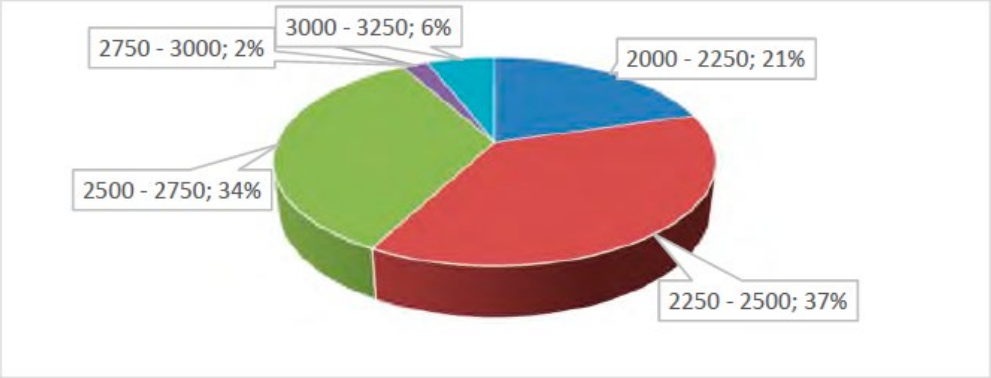

Fig.12 - Produced slab widths in Nov. & Dec. 2019.

The slab surface quality records for Nov. 2019 are only 9 slabs with surface defects (cracks). There are no slabs with surface defects in Dec. 2019.

Fig.13 - Slab piles in slab yard.

The superior internal quality is highly-demanded for slabs to be rolled for plate products in Steckel mill. The macro solidification analysis show that class C internal quality is achieved in the casting process.

Fig.14 - Macro solidification analysis: Class C 0.5 (central segregation, cracks, porosity, holes, ..) according to Chinese Slab Quality Standard YB-T4003-2016.

CONCLUSIONS

SDIS Rizhao Base is a new green field production base producing prime quality steel grades in Rizhao, Shandong Province in China, set up by Shandong Iron & Steel Group (SDIS).

SDIS Rizhao Base is successfully producing high quality ultra-wide slabs comprising of demanding steel grades. The vertical bending caster supplied by SMS group, commissioned in 2019 is equipped with the Industry 4.0 slab casting modules of SMS group. The latest smart and well-proven technologies such as HD modules, various X-Pact® packages and the PQA® system assure the ultra-wide slab quality achieving more than 99% defect-free slabs.

REFERENCES

[1] Newsletter SMS group, no 4 2019

[2] Innovative mold coating technology positively influences strand surfaces, Stahl und Eisen "135 (2015), Vol. 12, Pp 87 – 95