Slab and billet grinding and deburring solutions

BY

Alexander Zeischka*
Stefan Purrer**

SYNOPSIS:

According to the newest trends, continuously cast products require full precise surface treatment or deburring at the front and/or tail ends before next process steps. Based on their experience and know-how with abrasive machining processes (abrasive cutting, high-pressure grinding) over a period of more than 50 years up to now, BRAUN has developed a highly flexible surface grinding and deburring grinding machines for applications which are too difficult for conventional deburring techniques. The subject paper describes the key features and advantages of BRAUN's machine design and the operational results from the first already completed projects

Keywords: surface grinding, high-pressure grinding, deburring grinding, finishing, conditioning, ingots, slabs, blooms, billets, bars, product quality improvement, production process improvement

* Senior Area Sales Manager Asia – Steel Cutting & Grinding Machines Division,BRAUN Maschinenfabrik GmbH, Vöcklabruck, Austria
** Head of technical department, BRAUN Maschinenfabrik GmbH, Vöcklabruck, Austria

1. Introduction

During the continuous casting process, molten metal is solidified and formed into slabs, blooms or billets for subsequent rolling in the finishing mills.
Surface conditioning is required in order to eliminate defects and cracks ahead of down-stream rolling process by subsequent grinding of complete surface or just the corners of the semi-finished materials.
In addition the cast products have to be shortened or secondary cutting has to be carried out for the next production steps whereby the cutting is performed by mechanical or by torch cutting, which leaves slag deposits, known as burrs or beards, on the upper and, in particular, the lower edge of the cut end.
The high environmental compatibility make HP (high-pressure/high-performance) grinding technology or its highly flexible deburr-grinding solution superior to other techniques, such as e.g. scarfing, milling or also rotary hammering.

2. BASIC principles of HIGH PRESSURE AND deburring GRINDING

High-pressure grinding is the most reliable and most effective technology to achieve perfect, fault-free surfaces of work pieces.
Depending on the type, quantity and distribution of the surface flaws, either the entire surface or only certain areas of the work piece must be ground.
The more or less heavy, strong-adhering burr at the head and tail ends of the product to be removed reliably in order to achieve fault-free surfaces is also depending on the actual steel grade.
Hot-pressed grinding wheels (see Figure 1) are tools, used with high contact pressure and high drive power for the grinding and deburring grinding process. In order to meet the requirements of the application with regards to highest removal rates, fully automatic control to reduce labor costs, high reliability and optimum safety, etc., the selection of the proper grinding wheel specification is as important as the utilization of a superior grinding machine.

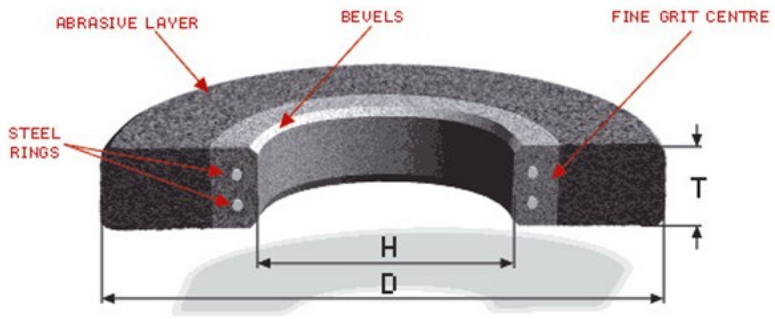

Figure 1. Basic structure of a hot-pressed grinding wheel

The abrasive layer of the resin-bond grinding wheel, compressed under high temperature and high pressure, consists of grain and binder. Both components have to be adjusted in the right proportion to each other. The binder, based on phenolic resins, ensures the greatest distances between grains and thus the lowest grain surface density, which contribute to the formation of very large chips compared to the grinding wheel size.
Hot-pressed grinding wheels operate at working speeds of 80 m/s and are thus exposed to high centrifugal forces. Safe machine and process design and compliance with safety regulations are important.

3 Specific designs for SLAB grinding

For grinding of extra-wide steel slabs, BRAUN offers HP grinding machines equipped with 1 or 2 grinding units, a main (top surface) grinding unit for grinding the large top surface of the slab and - if required - an auxiliary (side surface) grinding unit for grinding the side surface of the slab. For the largest HP grinding machines, the main grinding unit is equipped with a pair of grinding wheels with 915 mm diameter and 125 mm width each and can be steplessly adjusted to any desired angle between 90° and 65°, whereas the auxiliary grinding unit is fixed at an angle of 90° and equipped with a max. 125 mm wide grinding wheel of max. 635 mm diameter. The horizontal slide of the main grinding unit is moving overhead, on a heavy-duty gantry structure across the entire width of the slab.

Table 1. HP Grinding Machines

Machine type	Grinding wheel size	Grinding angle	Grinding power
HP 6	max. 635 mm x 102 mm (610 mm x 76 mm standard)	90 ° to 65 ° (steplessly adjustable)	max. 315 kW
HP 7	max. 760 mm x 102 mm	90 ° to 65 ° (steplessly adjustable)	max. 315 kW
HP 9 P	2 x max. 915 mm x 125 mm (main grinding unit for top surface only)	90 ° to 65 ° (steplessly adjustable)	max. 630 kW
HP 9-6 P	2 x max. 915 mm x 125 mm (main grinding unit for top surface)	90 ° to 65 ° (steplessly adjustable)	max. 630 kW
	max. 635 mm x 102 mm (auxilliary grinding unit for side surface)	90 °(fixed)	max. 200 kW

Figure 2. Grinding machine, type HP 6, for titanium ingots and slabs

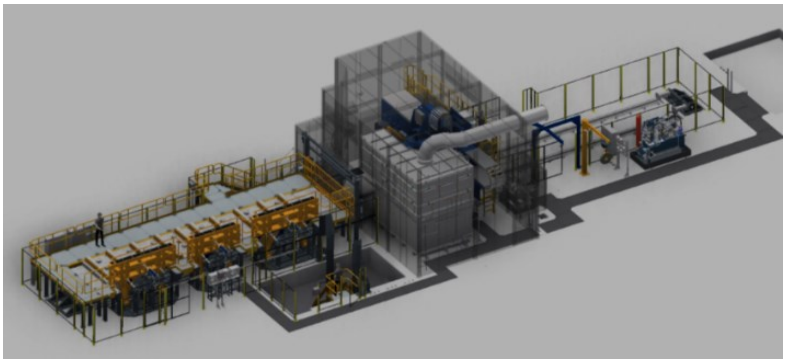

Figure 3. Overall layout of grinding machine, type HP 6 P, including material handling gear for grinding slabs

Probably the most important special features of BRAUN's HP grinding machines are the sensitive, fast reacting grinding pressure control (this ensures a uniform material removal, a smooth grinding process and a perfect grinding result) and the high-performance grinding spindle with specifically designed gearbox. The oil lubrication system developed by BRAUN ensures a reliable and proper lubrication of all bearings and gears, as well as a permanent cooling by means of an oil recirculation and re-cooling system. By this means, a long service life of the entire grinding spindle can be achieved.

BRAUN developed a new design of a grinding carriage, which ensures a perfect grinding of bended slabs with a temperature up to 400°C. The slabs, which can be directly loaded by the overhead crane on the grinding carriage, with a bending of max. 300 mm are supported with an individually defined numbers of liftable support plungers. Therefore also bended slabs are perfectly supported and cannot move or tilt during grinding. To prevent damages due to the direct loading of the slabs on the grinding carriage, a special mechanical damping system was developed.

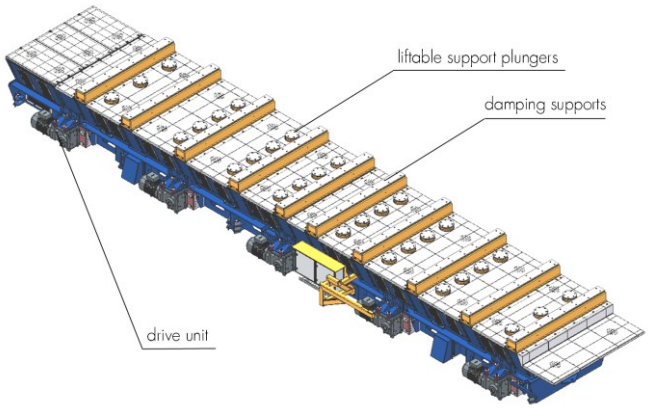

Figure 4. Grinding carriage

Additional to the new grinding carriage a 3D laser slab dimension measuring system has been developed. This system measures the position, cross-section dimensions, vertical bending and horizontal bending of the slab and is directly connected to the PLC of the slab grinding machine. With the detailed measurement information of the slab two, new functions of the slab grinding machine could be developed to meet the customer's requirements. The first requirement is plain grinding (evenness of 3-5 mm) for multilayer rolled plates and the second requirement is chamfer or gutter grinding, both in automatic mode. With this new function, called 3D surface grinding, during each grinding track, BRAUN is not only able to move the grinding pressure cylinder to compensate the height difference furthermore also the movements of the horizontal and vertical axis of the grinding machine can be directly controlled and adjusted during grinding. Therefore, also a constant chamfer can also be ground on slabs that are vertical and horizontal bended at once.

Figure 5. Grinding surface

With BRAUN's multi-functional HP grinding machines for slabs, the following grinding programs can be performed:

- Skin grinding: bright grinding of the complete rolling (and - if desired - also side) surfaces of the slab
- Spot grinding: controlled grinding of partial surface flaws on slab's rolling surfaces
- Pattern grinding: bright grinding of a pre-determined area of the rolling (and side) surfaces of the slab
- Plane grinding: Plane grinding (evenness of 3-5 mm) of the complete rolling surfaces of bended slabs
- Longitudinal corner grinding: grinding of the long corners of the slab
- Traverse corner grinding: grinding of the corners at the face & tail ends of the slab

BRAUN's HP grinding machine design does basically allow to run all of these grinding programs automatically. For an automated spot grinding, it is possible to interface the PLC of the grinding machine with an automated surface inspection system or to download the coordinates of the detected surface flaws from a level 2 system into the grinding machine PLC.

4 Specific designs for deburring grinding

The torch cutting process required during and after continuous casting results in firing slag deposits on the upper and especially the lower cut face edges, and on the cross-sectional surface of the cast product.
In addition to burner settings, burr and beards formation are strongly dependent on the steel alloy and are particularly noticeable in the case of stainless steel alloys, since steel powder is added during the torch cutting process to reduce material losses. Steel powder residues adhere to the slab surface after torch cutting.
The following characteristics of burrs and beards have been noticed in practice by different customers (see Figure 6):

- Moderately adhering burrs on the top and bottom of the slab with a slurry of approximately 25 to 50 mm and a length up to the respective slab width.
- Strongly adhering metal powder incenses at the slab top side over entire slab width

- Strongly adhering slag reflow at the slab top and bottom over the entire slab width
- Strongly adherent local slag baths, usually occurring at the entry and exit points of the cutting burners, at the slab top and bottom

Burr strips | Metal powder incenses

Slag reflow | Local slag baths

Figure 6. Beard and Burr Formation on Slabs

The methods used so far for deburring slabs, billets, and ingots, are either the shearing-off of the burr by means of a shear knife or the removal of the burr by a deburring machine with rotating hammers. Deburring shears machines only remove the bottom side burr, leaving the top side burr to be manually removed. The disadvantages of rotating hammers deburring machines are especially evident for stainless steel alloys, where strongly adherent burrs are not removed and are instead deeply fused into the slab substrate.

4.1 KEY DESIGN FEATURES OF BRAUN'S DEBURRING GRINDING MACHINE

BRAUN's main goal was the development of a deburr grinding solution to rapidly and reliably remove burrs from the front and the rear ends of the slabs at both the lower and upper edges, or, if necessary, to grind the cut end surfaces. Furthermore, customers also expressed the desire to grind up to 70 mm in length direction of the slab on the upper and lower rolling surfaces (see Figure 7).
The limited space conditions in the outlet area of a continuous casting plant, the requirement for easy retrofitting of the system between two consecutive outlet table rolls, and the requirement for a 360° rotatable grinding head (see Figure 8) were the reasons for a gantry-type design of the deburr grinding machine.

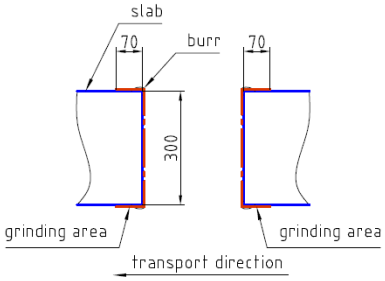

Figure 7. Deburring area

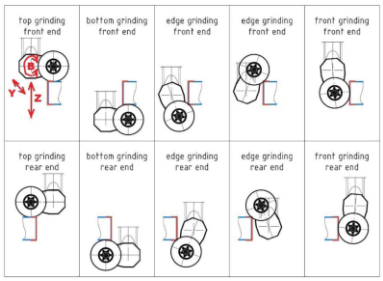

Figure 8. 360° Rotatable grinding head for different deburring tasks

Slab surface temperatures up to 900°C in the deburring area necessitate heat shielding (F) for the gantry frame (A) above the roller table (see Figure 9). The vertical slide (C), into which the grinding spindle motor is integrated and the horizontal slide (B) move on a linear guide system. At the lower end of the vertical slide, the swivel-mounted grinding head (E) is positioned on a swivel drive (D), which allows the required continuous and endless rotation.

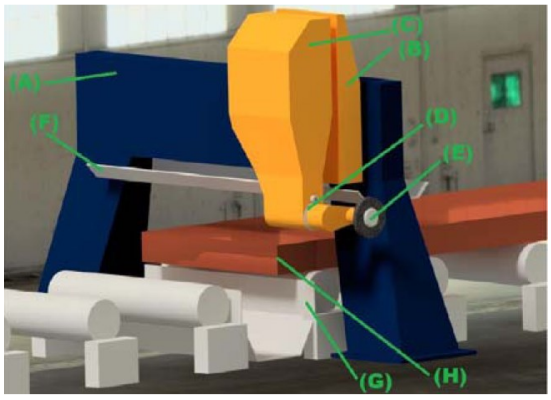

Figure 9. Schematic drawing of a deburring grinding machine

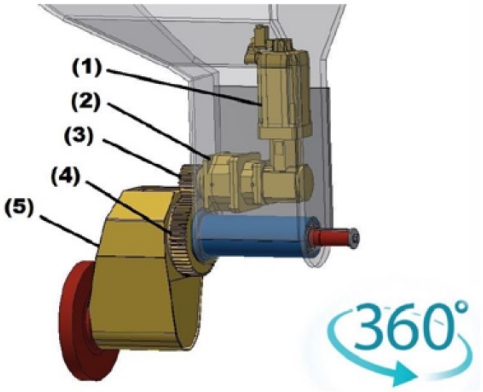

Figure 10. Schematic drawing of swivel-mounted grinding head

The slab positioning and recognition system (H) locates and positions the slab on the roller table. The chip discharge (G) below the slab ensures a reliable discharge of the abraded material.

4.2 PROCESS DESCRIPTION & TECHNICAL DATA OF DEBURRING GRINDING

Deburring grinding of the slabs after the continuous casting can take place either inline or offline.
When the slab is arriving into the area of the deburring machine, the slab head face is recognized by a laser measuring system. Next, the slab is slowed down and positioned via the roller table control. After the slab has been stopped, the position of the slab on the roller table, its thickness and width, as well as its lateral position are automatically determined before the deburring cycle starts.
The following grinding cycles are possible with the deburring grinding machine:

- Two grinding passes on the slab bottom side, adjacent to the cut face
- One chamfering pass at the lower cut face edge, across the entire width
- Two grinding passes on the slab top side, adjacent to the cut face

- One chamfering pass at the upper cut face edge, across the entire width

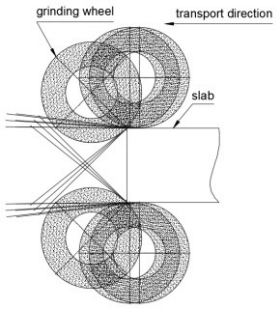

Figure 11. Possible grinding positions

Deburring process:	dry, hot
Motor power:	50 kW, 1 500 to 3 000 rpm
Wheel position	90° to grinding direction
Wheel diameter:	406 mm
Grinding pressure:	up to 4 kN
Infeed Speed:	80 m/s
Grinding depth:	abt. 1 mm
Total cycle time:	4 min for lower and upper edge

Figure 12. Deburring grinding machine technical specifications

4.3 SOLUTION FOR LONGITUDINAL DEBURRING GRINDING OF SLABS

Torch cutting is not the only source of burrs on continuously cast products. Traverse grinding of slab rolling surfaces by certain types of slab grinding machines can cause burrs at the longitudinal slab edge. These strongly adhering burrs can be particularly difficult to remove. For their reliable removal from longitudinal slab corners, BRAUN has developed a different deburr grinding unit comprising two grinding robots (Figure 13) situated at the slab surface grinding machine exit.
As soon as the head end of the slab is detected by a roller table light barrier, two robots equipped with grinding wheels (one robot located on each side of the roller table) automatically grind upper and lower longitudinal edges of the slab alternately while the slab continuously moves forward on the roller table (see Figure 14). Preset grinding pressure is automatically maintained throughout the process. The abraded burr (swarf) removed from the longitudinal edges (corners) of the slab is collected in a moveable spark box. The slab transport speed is supervised by a laser measurement system, which provides the information required for control of the robots. When the tail end of the slab passes the light barrier, the two grinding robots are automatically retracted.
The required grinding wheels for the two robots are stored in a vertical chain conveyor-type tool magazine with an automatic tool changing device. This ensures that all four longitudinal edges (corners) of the slab can be ground with interruptions for tool changes. The unloading of the worn grinding disc and loading of the new grinding disc will be safely done by an operator in a separate loading area without disrupting the deburring process.

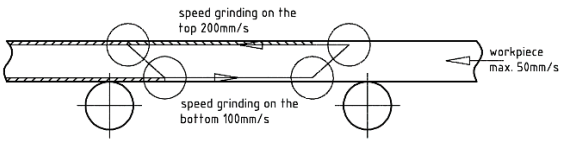

Figure 13. Industrial robot with grinding wheel

Figure 14. Grinding processes on lower and upper edges

Figure 15. Industrial robot in operation

Figure 16. Longitudinal deburring grinding results

4.4 SOLUTION FOR DEBURRING/CHAMFERING OF ROUNDS

Electrodes and remelt ingots used for manufacturing special steel products are in most cases separated by means of an abrasive cut-off machine in chop-stroke or index cutting processes.
Even though almost no - or only a very light burr - remains at the edge at the end of the product after abrasive cutting, some customers require an additional chamfer of 45° in order to ensure perfectly burr-free product ends. For these requirements BRAUN developed a deburr grinding unit, which can be retrofitted on existing abrasive cut-off machines. This deburr grinding unit consists of a grinding robot, which is mounted on the abrasive cut-off machine (see Figure 17). Depending on whether the edge of the front or the rear end of the product is to be deburred/chamfered, the grinding robot is situated either on the left or right side of the abrasive cut-off machine spark box. This deburr/chamfering grinding machine is equipped with a tool magazine with automatic tool changing device.
After cutting off the head or the tail crop, the electrodes or ingots are rotated with by means of a material turning device which is integrated in the transport roller table and lifts the round product off the roller table. At the same time, the grinding wheel mounted on the robot arm is positioned at an angle of 45° from above and the chamfer is ground on the edge (Figure 18). The deburring process is completed after one revolution of the electrode or ingot.
By means of a special force control, grinding wheel contact pressure is automatically adjusted in real time.

Figure 17. grinding robot in operation

Figure 18. electrode with a 45° chamfer

5 CONCLUSION

HP grinding machines allow skin, spot, controlled pattern and plane grinding, as well as longitudinal corner grinding and traverse corner grinding of the corners at the face and tail ends of the slab and billets.
The deburring solutions as described for semi-finished slabs, blooms, billets, and electrodes are feasible and adaptable to specific products requirements. Based on flexible design concepts, deburr grinders can be retrofitted on existing continuous casting lines, hot grinding plants, or abrasive cut-off machines, with relatively low investment costs.
Building on the company's specific know-how and experience in grinding, and coupled with targeted R&D of flexible, integrated solutions for deburring slabs, blooms, billets, or electrodes, BRAUN has developed robust new abrasive deburring and chamfering solutions for the metals industry.

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