



# LATEST DEVELOPMENTS IN HIGH-PRECISION ROLL GRINDING FOR COLD ROLLING MILL APPLICATIONS MILLS<sup>1</sup>

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## Abstract

Presenting developments for the cold rolling mills applications based on the 100 years of quality and excellence. Development of state-of-art roll grinders for high-tech roll shops, Monolith™ technology, and measure systems for profile, Eddy Current, Ultra-Sonic and Surface Measurements, all integrated to the operation control KPM 10. Complete roll shops with management tools supplied by Herkules as Roll Shop Manager and Roll Works. Modernization and Revamp in old machines and from different suppliers

**Key words:** Roll grinder; Roll shop; Cold rolling mill; Monolith, Measure system.

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## 1 INTRODUCTION

With the new developments for the grinding process the cold mill roll shops are investing in machines with CNC, integrated measurement systems, crack and bruise measurements of rolls, surface inspection systems and avoiding the consume of manual process. With the experience of 100 years Maschinenfabrik Herkules is developing and providing devices and tools for state of the art roll shops. This paper describes the many improvements of the last years made by Herkules and in special for the roll grinders of cold mill roll shops and the use of special measure devices for a complete roll data after grinding process.

## 2 MODERN ROLL SHOPS WITH STATE-OF-THE-ART ROLL GRINDERS

In order to fully take advantage of complete CNC operated machines, integrated measurement and management systems, it is required to have state of the art roll grinders in your roll shop. This applies for all kind of roll shops within cold, hot and plate steel rolling mills and within aluminum hot, cold and foil mills. The Fig. 1 shows a modern Herkules roll grinder installed in a Cold Mill Roll Shop.



**Figure 1.** Cold Mill Roll Grinder with integrated shape measurement system.

### 2.1 Properties of Modern Roll Grinders

- Robust and proven mechanical design capable for running in a heavy industrial environment for decades 24 hours per day
- Trouble-free and low maintenance grinding wheel system
- Integrated shape measurement system for a truly “grinding on the fly” function (measuring and grinding at the same time)
- Super-fast CNC hardware and special grinding software for optimum grinding results in terms of form accuracy, surface finish and grinding times in an automated mainly operator-free mode.
- Inspections systems integrated to the CNC for grind process quality and safe assurance as Eddy Current, Ultra-Sonic and Surface Inspection
- Able to connect and communicate with the roll shop manager and mill manager.
- Full remote access in case of any intervention from the manufacture plant

## 3 HERKULES ROLL GRINDERS DEVELOPMENTS



Based in his 100 years old experience Maschinenfabrik Herkules has developed many technologies to attend the demand of the roll shops and the high production and quality requested by the rolling mills. These are some of the Herkules developments:

### **3.1 Monolith™ Grinder**

The Monolith™ roll grinder, a new generation of roll grinding machine, represents a quantum leap in technology. The design of the Monolith™ grinder isolates the machine from vibrations and save the cost of intensive foundation works, with a huge concrete block. The polymer quartz material separates the cast iron top from the steel plate bottom. Due to the excellent damping properties of polymer quartz, vibrations created on the machine from the grinding process are deadened without exciting the machine structure.

Depth studies show that not only the vibration coming from outside are much better dampened but also the vibration from the machine itself. The result is a much better performance with improved accuracies.

The capability and efficiency of this revolutionary machine design has been proven under actual production conditions since 2003. Up to the beginning of 2010, in total 124 Monolith™ Roll Grinders have been delivered to mills all over the world; In Brazil we have 3 roll grinders already installed with this concept, at ArcelorMittal Tubarão (hot mill), Usiminas and Usiroll (cold mill).

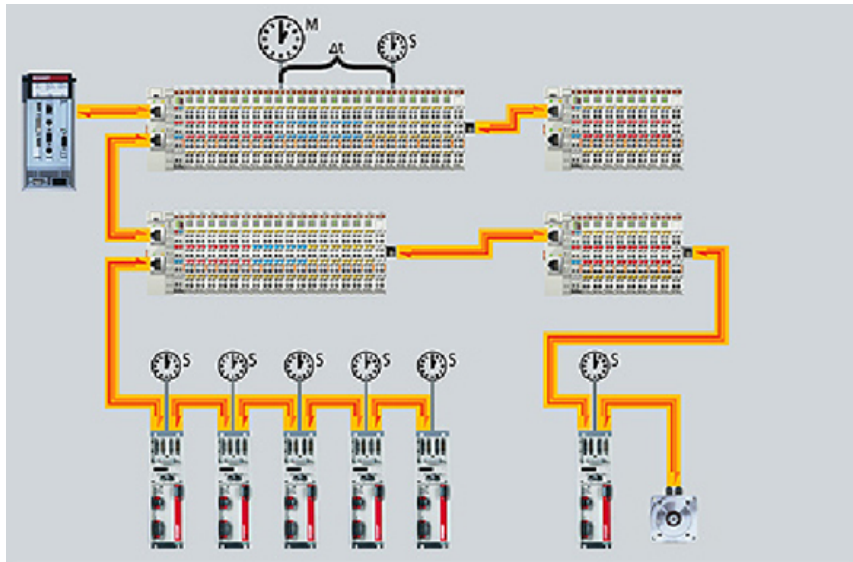
### **3.2 KPM 10 CNC**

Since 1998 Herkules has decided to develop its own control system. The company Beckhoff is a partner of this development with the necessary hardware. The control is based on an IPC with a software PLC – no hardware PLC is necessary which improves the reliability of this control. Since 2006 Beckhoff is going in new directions with the eXtreme Fast Control technology.

The control is based on an IPC, with high performance real time motherboards. The software is built on TwinCAT, the extreme Fast real-time control software, which allows cycle times of down to 50µs.

The complete connection of all I/Os is executed via EtherCAT. Also all standard Ethernet components can directly be connected without any loss.

Advanced real time features based on distributed clocks with EXACT synchronisation (100 axes can be synchronized in 0.1ms). Motors and Drives are also connected in extreme fast and reliable as it is executed also via EtherCAT. The example of the Beckhoff system structure and the communications between the components is indicated below in the Fig. 2:



**Figure 2** Extreme fast real time system.

The necessity of an extreme fast control system comes from the grinding process. For a roll grinder it is necessary to have a process controlled control system – which means the control needs to get the feed-back of the grinding process. Today all Herkules roll grinders are equipped with modern measuring systems which check the geometrics of the roll during the grinding process. There is a tremendous no. of data which needs to be accomplished by the control computer. Also the reaction time of the motors and drives needs to be limited to a min. otherwise the grinding wheel reacts always too late as the roll is turning.

With this control the machine is able to receive data from another devices integrated to the grind process and actuate after measurements of cracks, bruises and other surface faults, this is made automatic and on-the fly, avoiding manual interventions on the machine. In the following, the integration of these measurements into an automated grinding process are being described.

### 3.3 Laser Measurement of Rolls – the RSIS

To a high extent, the quality of the finished flat rolled product depends on the roll quality. In order to avoid possible quality defects, the rolls should be free from any surface defect.

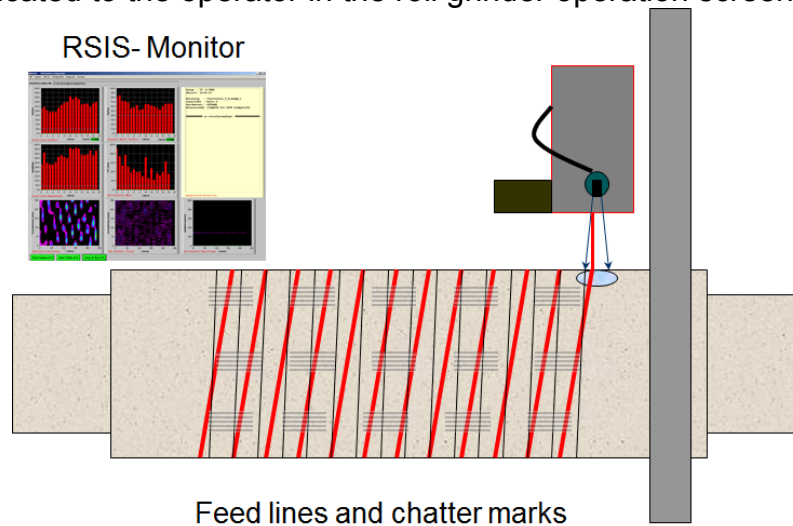
Current standard steel strip inspection of flat rolled products use sophisticated camera systems. With this system quality defects can be detected, but not avoided. It makes sense to check the quality determining components prior to the rolling process additionally.

Besides that, more and more roll grinders are being run with no or minor operator interference as parts of an automatic roll shop so that roll surface defects, if any, are not detected before running in a mill. Increasingly, roll shops are being run as Service Centers requiring a documentation of the delivered roll quality.

As response to the aforesaid said, Herkules has developed the process integrated optical roll surface inspection system (RSIS):

An optical sensor head (laser technology) is positioned in axial direction by an linear motor to the roll surface. The integrated distance control assures a constant distance between roll surface and optical sensor. This allows to cover all roll diameters and common roll shapes, like CVC or tapered shapes. In order to obtain repeatable

measuring results, the roll surface is automatically cleaned by the means of compressed air. After the sensor head is positioned to the preset distance, the optical sensor is moved in longitudinal direction along the roll barrel. During this longitudinal movement the roll rotates and the roll surface is scanned in a spiral shape. The evaluation of the measured data is done on a separate industrial PC located in the control cabinet. Finally the measuring results are presented on roll grinder's CNC screen. In order to reduce auxiliary time, the optical surface scan can be done in parallel with the scan of the optional available crack detection system. The Fig. 3 shows the RSIS system during measurement of one roll and the graphics which are indicated to the operator in the roll grinder operation screen:



**Figure 3** RSIS measurement system.

The following typical roll surface defects can be detected and classified:

- Chatter marks ● Feeds ● Spirals ● Scratch marks (commas)

The RSIS makes it possible to:

- check the roll surface prior to the flat rolled product,
- detect possible defects of ground roll surfaces and compares them with the stored data of typical defects,
- trigger warning signal to operator in case of conformity of detected defects with stored data,
- develop a classification databank of typical roll surface defects.

In a second step Herkules will develop correction grinding software, to automatically modify the grinding process parameters according to RSIS results, e.g. prolog or repeat finish grinding, variation of grinding speed, etc.

### Advantages

- Automatically optical inspection of ground roll surfaces.
- Integration of RSIS within the automatic cycle of a roll grinder.
- Inspection protocol as quality documentation for the customer (rolling mill).
- Evaluation independent from operator and its skills.
- Even defects which are invisible for human eyes can be detected.
- Usage of well known and already proven sensor components.
- Fully automatic distance control (roll surface to RSIS sensor).
- Roll surface roughness does not influence the result.
- RSIS works independently from roll materials (forged steel, cast iron, ...)

- Detecting sensitivity can be adjusted to customer needs.

### 3.4 Integrated Eddy Current Measurements of Rolls

The eddy current inspection system (EC tester) is used for checking the roll surface, detecting cracks and chill cracks up to a length of 3 mm, hardness increases and hardness variations as well as magnetic fields. In order to be able to detect these defects, they have to start at the roll surface.

The eddy current roll inspection can be carried out during the grinding process. The effective width of the eddy current inspection head is 40 mm and with several passes during the grinding process the complete surface of the roll is checked. This means that the total time of the roll in the machine is not prolonged due to the eddy check system. This is an important aspect when considering that modern roll shops are nowadays checking 100% of their rolls for cracks.

The surface defects are shown in a diagram which indicates the criticality of the cracks and hardness increases. Magnetic fields on the rolls are also indicated on the screen in order to avoid wrong decisions.

Surface defects are shown in an "unwound" representation of the roll shell by means of the radial and longitudinal coordinates of the roll. After the inspection the operator directly knows if the roll is free of defects or not. In case there is a defect, its size, surface structure and position on the roll are directly indicated.

#### 3.4.1 System components

Sensor for eddy current scanning, Calibration kit and Portable installed Demagnetizer.

The eddy check measurement is being applied by the steel industry (cold and hot rolling mills) and by the aluminum industry. With the regular control of the rolls and the development of their cracks and bruises during the life time, it is possible to guarantee that no spawling or other accidents will occur during the rolling process. Since the inspection is realized during grinding, the overall grinding time for the hot strip work rolls is not affected by the eddy current measurements.

### 3.5 Ultrasonic Roll Sub-surface Inspection

The ultrasonic roll inspection system (US tester) has been developed for the automatic sub-surface roll inspection. The effective width of the ultrasonic inspection head is 10 mm. The measuring range of the standard sensor is 5 - 240 mm below the roll surface.

The cooling water of the grinding machine can be used to conduct the ultrasonic signals in the inspection head to the roll surface.

The roll inspection with the ultrasonic system cannot be carried out during the grinding process and a clean surface (like after every grinding process) is absolutely required.

Sub-surface defects are indicated in mm depth, calculated on the run-time of the signal. The signal amplitude indicates the size of the defect in the roll interior.

Surface and sub-surface defects are shown in an "unwound" representation of the roll shell by means of the radial and longitudinal coordinates of the roll. After the inspection the operator directly knows if the roll is free of defects or not. In case there is a defect, its size, surface structure and position on the roll is directly indicated.

Especially for the ultrasonic inspection the unwound representation of the roll shell is a very helpful and timesaving method to exactly localize the defect.

### 3.5.1 System components

Electronic card for measuring integrated in the IPC, sensor for ultrasonic testing.

## 3.6 Roll Shop Management Systems

In order to utilize in an intelligent way all the measurement data from the Herkules CNC roll grinder the next logical step is the installation of computerized roll shop management system. There are different levels of functionality to suit with varying data collection and transmission according customer requests.

Information about roll geometry and surface finish build up the basis of the database of a roll shop management system.

In order to simplify the implementation of linking machines to a roll shop management system (RSMS) the Roll Data Collecting System was developed. This System bundles data from/to machine controls and communicates with the RSMS.

The Roll Data Collecting System (RDCS) receives roll data from the machine control during manufacturing and stores them in a database, the following data items are transferred from CNC to the Roll Data Collecting System:

- CNC Program name and curve number
- Operator ID
- Date and time of program start
- Roll diameter prior to and after grinding
- Roll profile prior to and after grinding
- Crown
- Roundness
- Eccentricity
- Shape deviation
- Out of center line
- Roughness and peak count
- Crack and bruise
- Date and time of program end

An Oracle database is installed on the Roll Data Collecting System to buffer roll data and machine information. All machining cycles of all rolls during the predefined time interval (for example: 3 months) are stored in the database. This part of the roll history is available on the system. Roll data is stored in for the so called "**Production Cycle**". A production cycle represents the period of life time of the given roll. It consists of all process data that is gathered during a turn between mill and roll shop.

For each of the machines linked to the system a dedicated communication session runs in the background. Communication between the CNC control and the Roll Data Collecting System is managed by an event trigger system located on the CNC control.

When a roll is loaded onto machine and operator has entered its roll ID, the CNC control informs the communication program which roll is loaded using a predefined trigger. Upon receiving this information, the communication program scans the database for corresponding roll machining schedule.

If a suitable schedule is found and a CNC program (including its curve ID) is specified inside the schedule, the program ID (and curve ID) will be sent to the CNC.

If no schedule of a target roll is found or if no CNC program is specified in the schedule, the system will select the program according to area code, line code, roll type, roll sub-type and mill production type from the machining program table.

Roll machining results are gathered during the process automatically. In case of a network malfunction, roll data are buffered in the CNC local database. As soon as the

network is recovered, buffered data will be transferred to Roll Data Collecting System.

For the communication to RSMS the system uses TCP/IP stream sockets to communicate with external Roll Shop Management System.

After a roll is machined, operators can check its results using the MMI screen “Grinding Data” and eventually complete manual entry data (for example roughness values if the machine is not equipped with an automatic roughness measurement device). Use the “Send Data” button to trigger the data transmission to external Roll Shop Management System.

In addition to discrete values of grinding results, the Roll Data Collecting System also stores graphic information of:

- Roll profile
- Cross section – Roundness, eccentricity etc.
- Crack & Bruise

### 3.6 Roll Works

*Roll Works* is a software system for automation, quality assurance and optimization of grinding process for rolls in the steel, paper and printing industry.

The basic function of *Roll Works* covers storing, visualization and the possibility of evaluation of essential parameters and measurements for the grinding process.

The data transfer is done using a permanent online interface to the grinding machines.

Visualization – online as well as offline – is done via the application *Roll Works Explorer*, which is the central interface between the system and the operator. Access to the data is generally done using a network interface – thus hardly any local restrictions in regard to principle possibilities for access exist.

The following data is acquired and stored:

- Sequence of automatic programs, sequence of program steps.
- Parameters for automatic programs, such as grinding program, operator, roll number.
- Each last profile measurement to each program steps, in which such measurement is done.
- Each Eddy Current, Ultra Sonic and concentricity measurement.
- Used grinding parameters such as grinding pressure, cutting speed, roll rotation, etc.
- Sequence of many other parameters, like profile deviation, stock removal rate, vibrations (only in connection with optional Vibration Monitoring System VMS)
- Each error (alarm) occurred on the grinding machine.

The following statistical evaluations can be made:

- Machine faults, machine availability
- Grinding performance and roll production performance

With the module *Process Control*, *Roll Works* targets for grinding processes based on the process parameters and measurements known to the system can be configured. This module actively interferes in the sequence of the grinding machine and thus guarantees an automatic grinding under consideration of certain preset conditions.

For example rules for the following subjects are adjustable:

- Minimum and maximum roll stock removal rates, where also the roll history (rolled tons, etc.) can be considered.
- Eddy Current and Ultra Sonic threshold values.



- Structure parameters for Eddy Current measuring values (increase display always on the same surface position yes/no, increased display of cracks and structure measuring values on identical surface position, etc.).
- Diameter threshold values (under automatic consideration of actual counter roll diameter)
- Profile threshold values (under consideration of optionally definable roll border)
- Demand and execution of controlling measurements for checking of measuring devices

## Roll Works - Optimizer

The optimizer automatically detects the most suitable grinding parameter under consideration of maximization of stock removal rate, minimization of dangerous vibrations (only in connection with optional Vibration Monitoring System VMS), minimization of grinding wheel wear and other influences under special consideration of each given conditions (roll diameter, wheel diameter, etc.).

Generally the *Optimizer* will make the grinding process deterministic, means controlled controllable. Only for illustration it is to be mentioned, that due to this a well-aimed reduction of target values is possible – for example a continuous load of machines can be stipulated, which of course will lead to different grinding performances due to variable demand.

Remark:

- *Roll Works Optimizer* uses elements from the field of Artificial Intelligence; it is a learning machine with Fuzzy Logic elements.
- Based on the grinding processes already completed, the system is automatically and continuously learning.
- The achieved parameters will be transferred to the grinding machine automatically.
- By using the optional Vibration Monitoring System VMS dangerous vibrations will be minimized.

Advantages:

- Reduction of necessary men power, grinding times and wheel wear.
- Improvement of roll surface quality and decrease of roll removal

## Roll Works - Network Requirements

Although ways of connection apart of TCP/IP are generally possible, the essential interfaces will be transacted over this.

For the connection of the grinding machine a fast network speed is required, at least 100MBit/s.

For the connection to our RSMS there are no such speed pre-conditions, here 128kBit/s (slow internet connection) would be sufficient.

Also for the connection of the instances of application *Roll Works Explorer* to the data bank resp. the software components of a.m. module a slow network connection is sufficient.

For remote access (Teleservice) via VPN the customer has to provide an Internet access.

## Roll Works - Example Cost-Effectiveness Calculation

The below example shows possible advantages, which have been actually achieved by using the *Optimizers* at Voestalpine in Linz in the area of work roll in hot rolling

mill. 2006 is used as reference year as this was the last calendar year without use of the *Optimizer*.

Achieved improvements: 2008 vs. 2006

Reduction contact time 18,95%

Reduction grinding wheel wear 14,36%

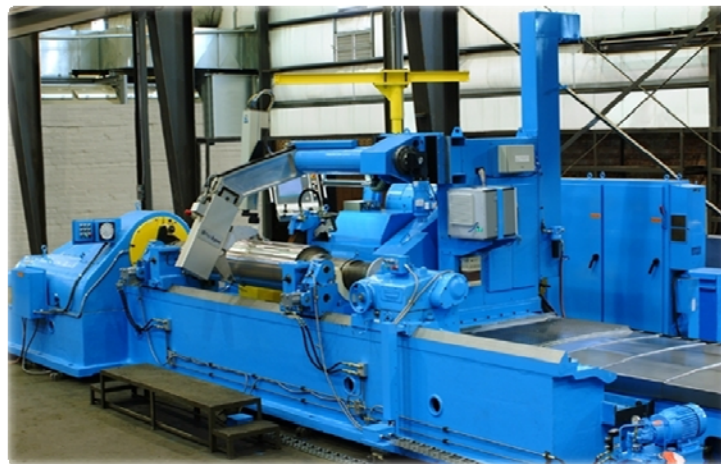
Reduction consumption roll material 1,00%

#### 4 MODERNIZED ROLL GRINDERS WITH COMPLETE ADVANTAGES OF HERKULES DEVELOPMENTS

The above developments are also available for “old roll grinders” after the modernization made by Herkules, even machines made by another manufacturers can be modernized to a complete fully automatic roll grinders. Herkules has the know-how and experience modernizing roll grinder from another manufactures as Waldrich Siegen, Voith, Naxos-Union, Farrel and others. The complete modernization can be carried out at customer site or at our plants in USA or Germany.

The guarantee of a complete modernized roll grinder and his performance tolerances are the same as a new roll grinder.

A complete modernization and addition of high technologic devices makes an old machine not only look as new, but increase his grinding performance, guarantee and assure the quality of the rolls and avoid mechanical or electrical problems caused by old parts that sometimes are out of market and obsolete. The Fig. 4 is the example of one old machine modernized to the state-of-the-art roll grinder:



**Figure 4.** Modernized ROLL GRINDER

#### 5 RESULTS

Incorporating the measurements of forms, chatter marks, cracks, bruises and magnetism of rolls on-line into the roll grinder CNC with automatic and instantly actions during grinding process and using these data in a sophisticated management system, the roll shop operation gains more reliability. Furthermore, the rolls and the grinding process itself have a complete controlled life time with tools for his improvement and to assure the quality of the rolls ground by the roll shop.