THE NEW ROLL SURFACE INSPECTION SYSTEM RSIS[1]
AUTOMATIC QUALITY CONTROL OF GROUND ROLL SURFACES

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Abstract

As the present time is characterized by increasing automation and faster production cycles, automatic process inspection of technical processes becomes more and more important. The quality demands and the productivity are increasing, simultaneously. Due to this conflict of aims, it is necessary that also quality inspections – today often carried out manually – become integrated in the widely automated production process. This affects the processes in modern roll shops and service centres as well. Today's production technologies respectively today's demands on quality and productivity require fast, precise and repeatable test procedures. An important target of an innovative inspection system has to be the independence from the manual-visual surface inspection. For the inspection of sensitive, high-precision surfaces such as ground roll surfaces, non-contact systems are required, accordingly. The integration of an inspection system within the automatic program cycle of a roll grinder and the fast feedback of the inspection results lead to decreased scrap rates and advanced product qualities. Future developments should include automatic correction grinding programs. In the following the article deals with Today's situation in modern mills and roll shops; the solution RSIS for modern roll shops; the RSIS basics; he evaluation and display of the inspection results.

Key words: Quality; Surface; Rolls; Automation.

O NOVO SISTEMA DE INSPEÇÃO DA QUALIDADE SUPERFICIAL DE CILINDROS
Controle de qualidade automático de superfícies retificadas de cilindros

Resumo

A importância da automação da inspeção e do controle de qualidade dos processos técnicos cresce dia a dia na esteira da automação e do aumento da velocidade dos ciclos de produção. A produtividade e as exigências de qualidade crescem concomitantemente. Devido a este conflito de objetivos, se torna necessário que também as inspeções de qualidade – atualmente ainda largamente executadas manualmente – se tornem integradas no processo produtivo já amplamente automatizado. Essa tendência afeta também aos processos nas oficinas de cilindros e centros de serviço de retificação, texturização e cromagem. As tecnologias aplicadas e qualidades exigidas nestes processos demandam procedimentos de testes rápidos, precisos e de repetibilidade garantida. Um objetivo importante em um sistema inovador de inpeção deve ser portanto, a independência de uma inspeção superficial "manual". Outra característica importante na inspeção de superfícies de alta sensibilidade e precisão, como às encontradas em cilindros retificados, é um sistema de medição de "não contato". A integração de um sistema de inspeção no cíclo automático de uma retífica de cilindros e a rápida resposta dos resultados da inspeção da superfície resulta na diminuição dos regeitos e elevação da qualidade do produto. Desenvolvimentos futuros devem incluir programas de correção automáticos.

Palavras-chave: Qualidade; Superfície; Cilindro; Automação.

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TODAY´S SITUATION

To guarantee the high quality demands of rolled flat products, sophisticated camera systems are required to scan 100% of the fast moving strip (Figure 1). But with these camera systems the defects on the finished products can only be detected, not avoided.

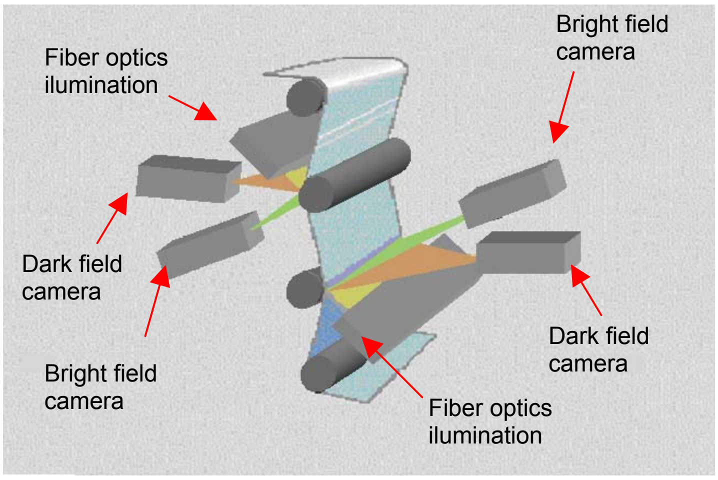


Figure 1: Principle sketch of a strip inspection camera system[1]

However, a defect detected in the rolling of the strip is an irreparable damage and a financial loss. A great amount of the surface defects on strips is caused by work roll surface defects. Consequently, it is necessary to check the roll surface quality prior to the roll is placed in the mill, that means immediately after the grinding process, preferably before the roll is unloaded.[2,3]

Today's roll grinders are more and more operated in automatic roll shops. The automation includes the roll transportation system, the roll cleaning system, the roll storage system as well as loading- and unloading-devices for the roll grinders and the roll grinding process itself. Consequently, the whole material flow from the roll stand to the roll shop and back is automated (Figure 2).[4] As the rolls are ground without operators presence an inspection of the roll surface quality is not carried out, generally. Therefore defective rolls will not be identified and will be used in the mill unseen.

Figure 2: Example for an automated roll shop [4]

Recently, roll shops are more and more operated as independent or integrated service centres. Particularly the documentation of the roll surface quality is a critical part but for customers an important part of the quality management process.

SOLUTION RSIS

The automatic **R**oll **S**urface **I**nspection **S**ystem (RSIS) was developed by WALDRICH SIEGEN for automatic detection and evaluation of roll surface defects caused by grinding faults. The inspection can be carried out during and after the grinding process.
As several roll surface defects can appear on the roll surface simultaneously and overlaid, the different surface defects are detected and classified by the RSIS. The inspection cycle is integrated in the CNC grinding program. Every ground roll is inspected and no roll can be used in the mill unseen. The evaluation is objective and not operator related. Furthermore the results don’t depend on roll material or application.
During the first phase of development, the RSIS provides a warning signal to the operator in the case that an out-of-tolerance surface defect appears. Known surface defects are classified and threshold values are set for various defect characteristics, based on the required roll surface quality aspects. During the coming second phase of development an automatic correction grinding, depending on the classification and evaluation of the detected surface defects shall be computed and performed by the machine control automatically.

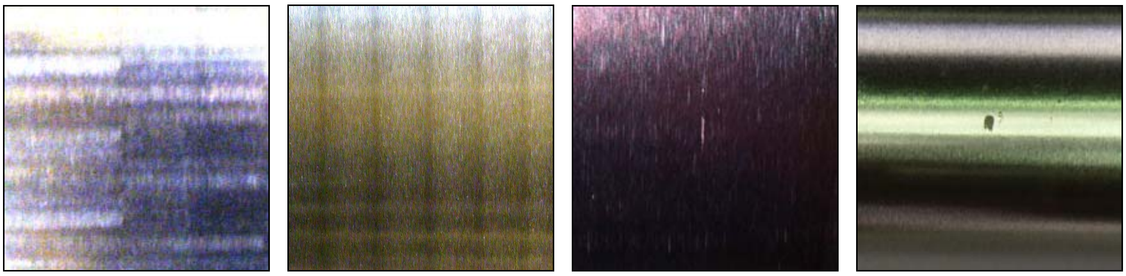
RSIS BASICS

Generally, the assignments of measurement technology comprise the following applications:

- Layout of the device control
- Layout of the interfaces
- Application of mathematical methods
- Recording of the inspection data and results
- Visualisation of the inspection data und results
- Documentation of the inspection data and results

The measured values have to be detected by a sensor and are to be transmitted to a computer, failure-free. For the computer internal further processing, the data have to be digitised. Thereafter, the detected data are passed on to the process- and visualisation-systems.[5]
Consequently, the RSIS consists of the sensor head, the front end processor unit (FEPU), an analysis and diagnosis PC and an accordant software for evaluating data.
The sensor head consists of the laser module, adjustable mirror and laser optics and the main sensor device. The laser module is realised as a focused laser diode. The laser is a category 3R laser. The radiated power amounts less than 5mW, the wave length is 650 nm. The adjustment of the mirror and the laser optics is carried out automatically prior to each surface inspection cycle. Accordingly, the operation of the RSIS-sensor is nearly maintenance-free. The dimensions of the sensor head amount to 56 mm x 80 mm x 148 mm (L x W x H). The weight including all components and modules is less than 1 kg.

The FEPU is an independent and scalable processor unit. It consists the RSIS system software and is equipped with the interfaces to the sensor head and the machine control. Analysis, diagnosis, visualisation and archiving of the inspection data is carried out by the RSIS PC.
The RSIS is programmed to detect and evaluate axial and radial surface defects as well as single defects (Figure 3). This means, that chatter marks, feed lines and spirals as well as scratches and indents can be detected with the RSIS.



a) b) c) d)

Figure 3: a) Chatter marks b) Feed lines c) Scratches d) Indents

The inspection device is installed at the measuring caliper of the roll grinder. During the inspection, the gap between sensor head and the rotating roll has to be kept at a constant distance. Therefore an inductive displacement sensor is installed. An air nozzle keeps the roll surface clean from coolant and dirt (Figure 4).

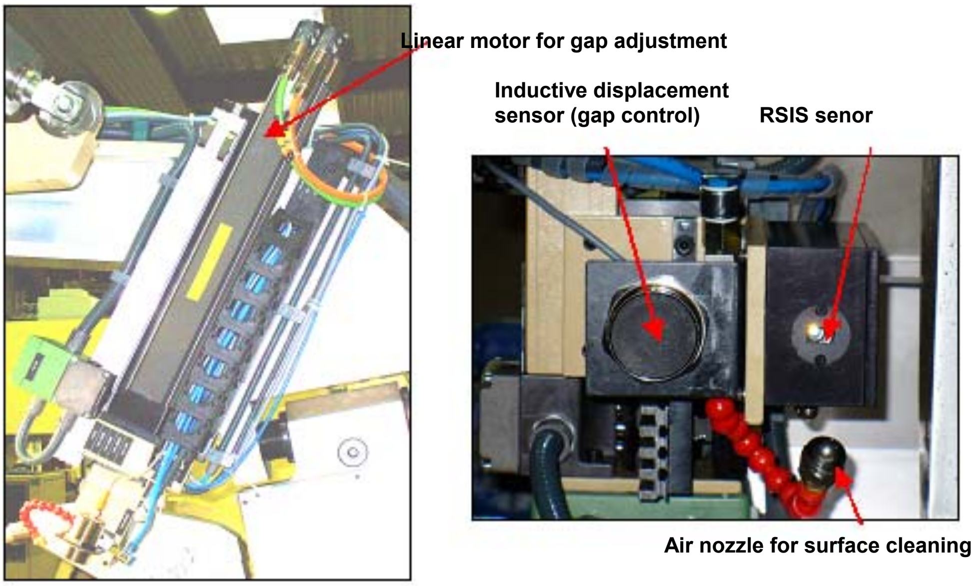


Figure 4: Systems installation at measuring calliper

The measuring principle is based on a measurement of the scattered light. If the laser beam contacts a zero-defect surface, the beam will be reflected according to the law of reflection. The angle of incidence and the angle of reflection are the same. If the laser beam contacts a defect surface, the beam has a diffuse reflection. The form of this diffuse reflection shows certain characteristics for every different surface defect. However, not only geometrical deflections of the surface causes the characteristical light reflection, but also dark and bright respectively dull and shining points on the surface. Such defects are detected by the RSIS as well.

The evaluation of the reflected light is effected by different photo diodes, which are arranged inside the sensor head. The characteristically reflected light is converted into a characteristical current progression (Figure 5).

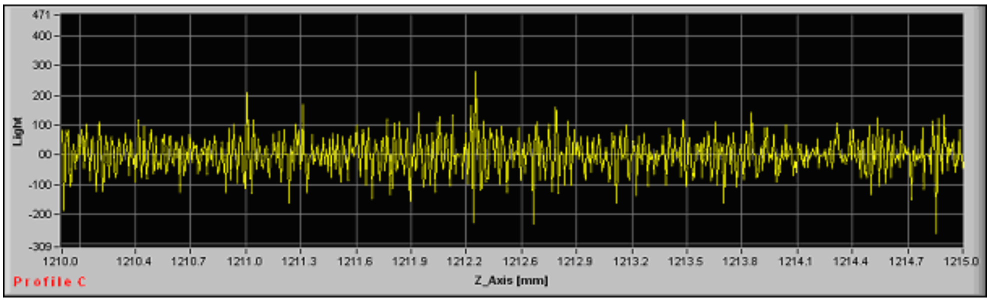


Figure 5: Scattered light converted in a current progression

This current progression is analysed and filtered by the RSIS to classify different surface defects. In principle, the differentiation is carried out on the basis of the frequencies of the detected light signals and the resulting current progression. Axial formed defects are causing high-frequency signals, whereas radial formed defects are characterized by low-frequency signals. Different low- and high-pass filters are used, accordingly.

Before the progression is filtered, it gets digitised. The result of this analogue-to-digital-conversion is a temporal sequence of discrete current values. The inspection data is described in the time domain, consequently. However, for the above mentioned analysis of the inspection data, that means the searching and classification of periodicities and frequencies, the data has to be described in the frequency domain. In principle, this translation is carried out by using Fast-Fourier-Transformations (FFT).

EVALUATION AND DISPLAY OF THE RSIS RESULTS

The roll is scanned spirally. The filtering and evaluation of the digitised sensor data is carried out as an one-dimensional vector along the inspection spiral.

The surface visualisation is generated by the machine's feed signal, the evaluated sensor signals and a trigger signal of a rotary encoder, installed at the machine's headstock (Figure 6).

In principle, the visualisation is a display of the local current value in a x-z-coordinate system (x-direction = circumference; z-direction = barrel length). The scanned surface is shown as the unwound roll.

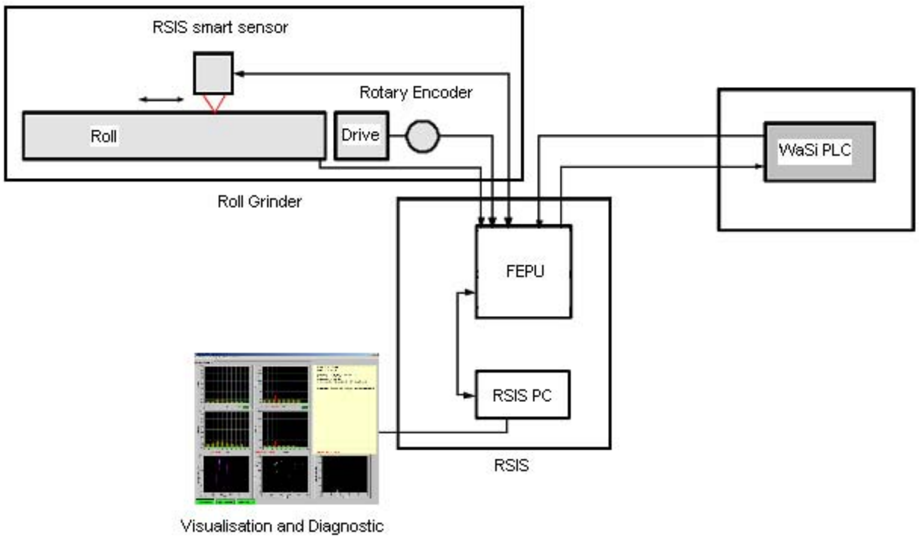


Figure 6: Signals for generating the RSIS visualisation

The local current values respectively the difference of the values is characterised by different colours and contrasts. Surfaces with just slight or without defects are characterised by homogeneous, single-coloured, low-contrast displays. Stronger defects are shown based on a colour code and the defect characteristic (direction) in a typical contrast pattern (Figure 7).

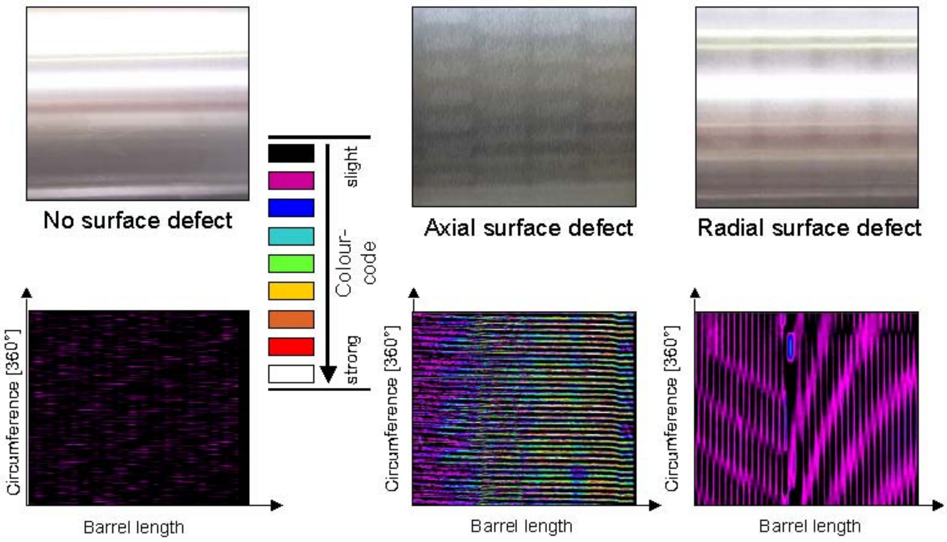


Figure 7: RSIS-Visualisation of different roll surfaces

To estimate the results more differentiated, additional histograms displays show the current profile of the roll surface, compared to a sectional view. The histograms describe the standard deviation referring to the analysed data of each single revolution (Figure 8). Further it is possible to show the maximum defect value per revolution.

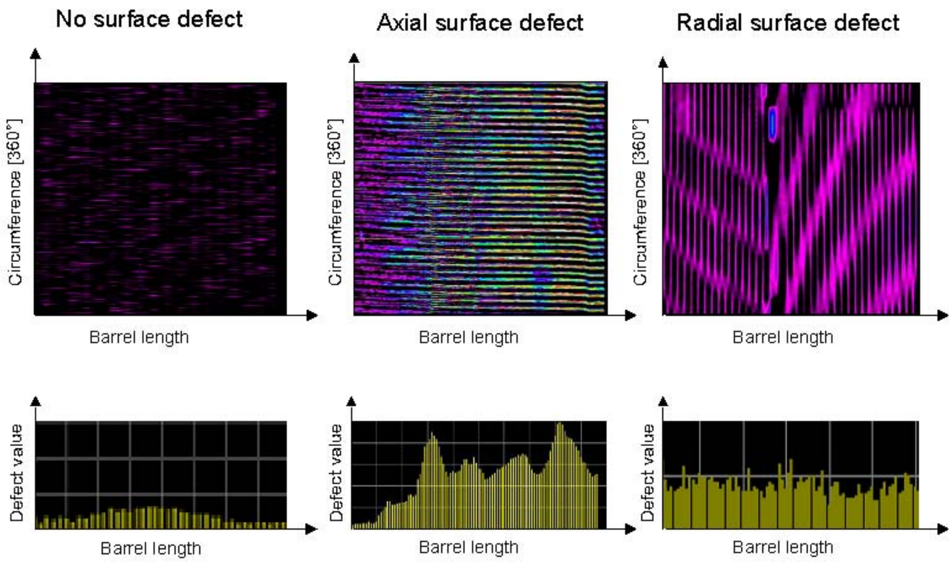


Figure 8: Histogram display of different roll surfaces

As the RSIS-inspection of the roll surface is no absolute measuring method, but a comparative method, it is necessary to set application specific threshold values for each different roll surface quality.

The threshold values depend on customers demands on quality and are set one-time during commissioning of the RSIS at customers site. Every bar above the threshold value is displayed in red as a warning signal (Figure 9).

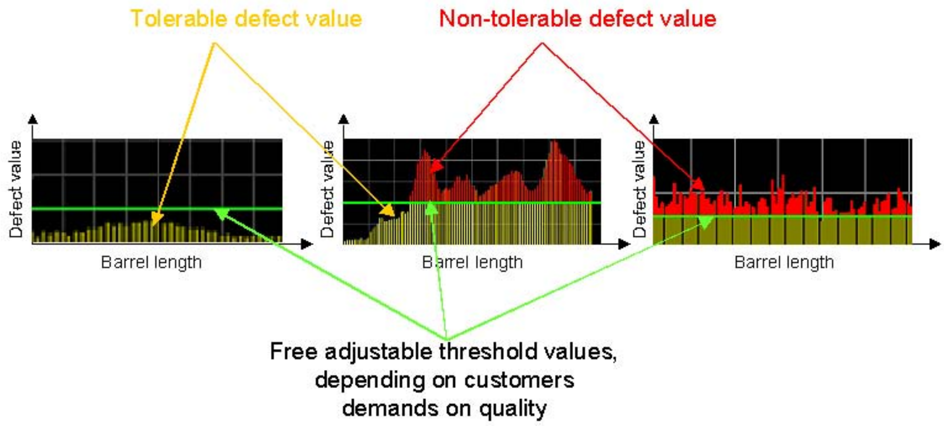


Figure 9: Threshold values for different surface defects

On defective surfaces multiple types of chatter marks appear overlaid and in different frequencies. Accordingly, it is necessary to analyse the chatter distance and the defect value of each single type of chatter marks in a frequency spectrum. The chatter distance is described in mm and degree (Figure 10).

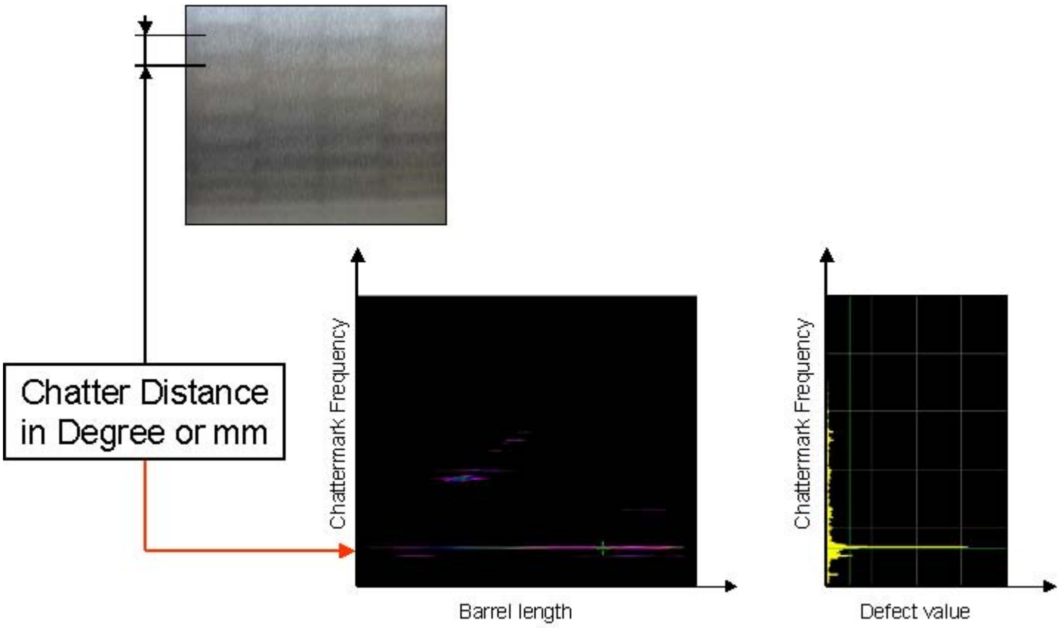
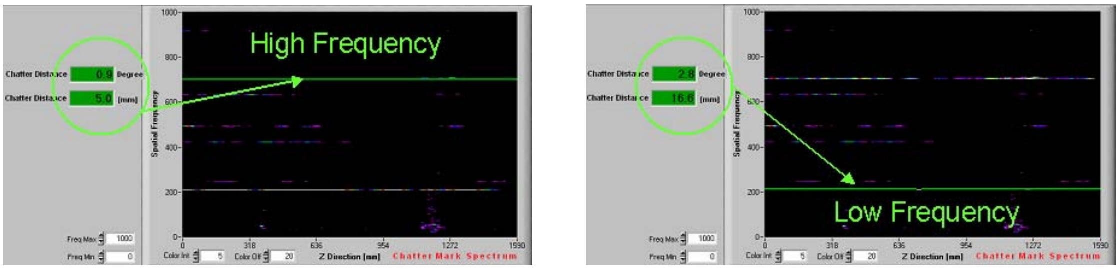


Figure 10: Chatter marks in the frequency spectrum

Figure 11 shows an example of a chatter mark spectrum with two main chatter frequencies on a high defect value and several ancillary chatter frequencies on a lower defect value.



a) b)

Figure 11: a) High main chatter frequency b) Low main chatter frequency

As shown in the picture above, the first main chatter frequency appears in the distance of 0.9 degree respectively 5 mm, whereas the second main frequency appears in the distance of 2.8 degree respectively 16.6 mm.

These results are very important for further analyses of the grinding and the milling process.

It is possible to draw conclusions of potential disturbance frequencies, based on the detected surface defects. Regarding the grinding process the analysis of the chatter frequency on the roll surface and an frequency analysis of the grinder enables the exact localisation of the vibration stimulator. In general high frequency chatter marks are caused by faults in the area of the grinding wheel, where as low frequency chatter marks result from disturbances on the side of the work piece.

SUMMARY

The RSIS identifies even finest surface defects. That means that the RSIS is able to detect defects which are invisible for human eyes. The RSIS classifies the different, and as the case may be, overlaid surface defects, exactly.
The surface roughness does not influence the measuring result.
The surface inspection can be carried out simultaneously with other quality assurance systems such as eddy current and ultra sonic crack detection systems.
To verify the roll's quality a documentation of all inspections is available as a quality protocol. The system automatically provides information about the characteristics and the positions of the appeared surface defects.
Accordingly, the RSIS enables the integration of an quality inspection system into the widely automated production process and bridges a till today existing gap in the quality management systems of mills and modern roll shops, consequently.
Presently WALDRICH SIEGEN develops a software to provide automatic correction grinding based on the detected and evaluated surface data.

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