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Automation Tool for Quality Assurance of Long Products

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Abstract. The 3-roll Reducing and Sizing block RSB® has been known as reliable instrument for the economic production of SBQ and wire rod. By continuous development of the RSB® technology in the past decades, KOCKS clearly contributed to meet high availability, efficient production, fast dimension change and tightest tolerances to secure a rolling mills' existence. The repeatability of tightest tolerances is an enormous challenge due to the constantly changing basic conditions of a mill. The operator needs to precisely adapt the process parameters reacting to smaller lot sizes made of different material grades with partly strongly varying spreading and shrinkage behavior or yield strengths. It is KOCKS' objective to meet this challenge by an automated tool, the Size Control Systems SCS®, thus lifting the quality assurance of long products to a new level.

Introduction

Since its introduction on the market, the 3-roll Reducing and Sizing block RSB® has been known as reliable instrument for the production of SBQ and wire rod. [1] In the past decades, KOCKS' innovations [2] clearly contributed to meet the following necessities to secure a rolling mills' existence:

- efficient production with fast/quick ramp-up curves by reliable equipment
- more availability by, for example, shorter stand changing times using a dynamic stand changing concept [1] or
- faster dimension change by introducing the Free-Size Rolling design [3] and
- the demands mainly required by the automotive industry for even tighter tolerances.

The repeatability of tightest tolerances is an enormous challenge due to the constantly changing basic conditions of a mill. The operator needs to precisely adapt the process parameters reacting to smaller lot sizes made of different material grades with partly strongly varying spreading and shrinkage behavior or yield strengths.

It is KOCKS' objective to meet these challenges by an automated tool, the Size Control Systems SCS®. [4] The SCS® is a real-time closed-loop control system designed for a modern RSB® with single stand drive aiming to achieve and maintain smallest tolerances and ovality of the rolled product over the production period. Implemented for the first time in 2012 at Georgsmarienhütte GmbH (Germany) in the course of an upgrading and the introduction of stands adjustable under load (AUL), KOCKS is equipping more and more customer with this innovation.

System Structure/Architecture

In the mill line (Fig. 1), there are two hot metal detectors each upstream and downstream of the RSB®. They are used for bar tracking in the SCS®. The two sensors closest to the RSB® are directly mounted to the RSB®.

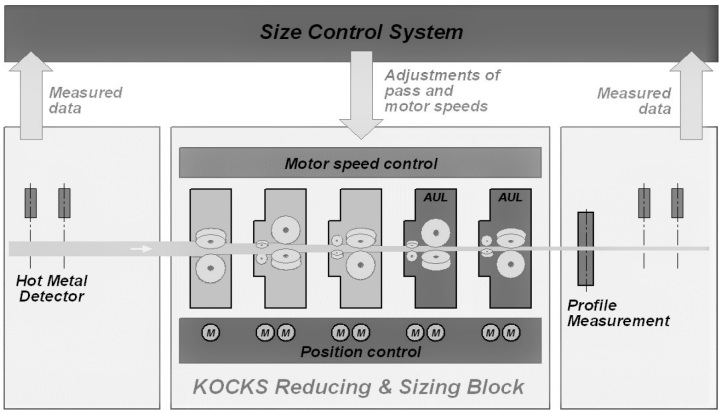

Fig. 1. Schematic presentation of main hardware components of the Size Control System.

Directly downstream of the RSB®, a profile measuring system is positioned, which detects the current profile of the rolled product online. This system has the task to measure the profile of the hot rolled product and to immediately transmit the results as cold data to the SCS® at high frequency. The tighter the tolerance target, the more important it becomes to store the correct shrinkage behavior in this system, which nobody knows better than the operator who deals with the product material every day.

A remote control in the hood of the RSB® carries out the automated adjusting corrections on demand of the SCS® for the stands and guides. An adjusting correction is made during a rolling gap or preferably at the bar when using stands adjustable under load (AUL). There are two types of remote control, a hydraulically controlled one and an electrical one. [1]

A fieldbus connection from the SCS® to the control of the main motors (PLC of the customer) allows acceptance and application of speed changes for the RSB®. Hereby, a quick and effective reaction to changing mass flows in the RSB® during rolling under load is possible.

The Working Principle

A common setup provides the operating data for the rolls, guiding rollers, funnels, gear settings and motor speed of the RSB®. For the SCS®, an internal pass design analysis provides additional target values for the characteristic rolling parameters DT (diameter of the rolled side at the bar) and GT (diameter of the gap side at the bar) (Fig. 2).

DT and GT are the main diameters, which are determined by 3-point measuring. When looking at the finished product, DT and GT are considerably influenced by the pass position of the last and last but one stand position. However, the tension-pressure ratio between the stands plays a role, too. It is possible with appropriate modifications of the roll speeds to act on the contour of the bar.

The quantity of pass adjusting corrections or speed modifications results from as parameterized functions stored in the SCS®. Among others, it depends on the size of the finished dimension, the pass shape, the number of entry sections, the reduction of the material to be deformed per pass in the RSB®, the actual spreading behavior of the material rolled and the actual mass flow in the RSB®.

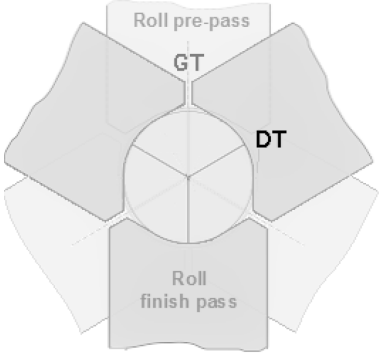

Fig. 2. Definition of the common 3-point diameter DT and GT.

The profile measuring system measures the actual DT and GT diameter at a high frequency and transmits them to the SCS®. Of course minimum and maximum diameter of every measured cross-section have to be transmitted by the profile measuring system as well. Tolerance and ovality are determined by these values. The measuring data are collected, verified, arithmetically averaged and evaluated in a measuring window. Since the closed loop control is based on the measuring data of the profile measuring system, it is of essential importance that the profile measuring system has an excellent measuring accuracy and transmits high quality data to the SCS®.

A suitable measuring window is necessary to reduce the effect of possible variation of data. Its use avoids that the system reacts too sensitive to single values and works unsteadily. However, the larger the measuring window, the more inert the system.

The basic target of the control is to determine the deviation between the specified and the actual value, the target value and the actually measured diameter, and to reduce the deviation to a minimum by means of integrated algorithms.

Operating Modes

The SCS® functions in three different operating modes:

- the conventional operating mode where no stand under load is adjusted
- the hybrid operating mode where two AUL stands are used on the last two rolling stand positions and are adjusted under load or
- the full AUL-operating mode where an AUL stand is used on every stand position and all stand positions are adjusted under load.

The SCS® is designed in such a way that the dimension corrections at the finished product are mainly achieved by adjusting corrections at the stands under load. Customers who are still using conventional stands, which cannot be adjusted under load, can make an adjustment in the subsequent rolling gap. The dimension of the gap side of the bar can be influenced under load by modifying the rolling speed of many finished sizes. Hereby, it is possible to influence the ovality on the bar. [5] If necessary, the rolled dimension is corrected by adjusting the stands in the rolling gap subsequently.

Insight into Practical Operation

Production with stand adjustment under load (AUL). By using stands adjustable under load on the last two rolling stand positions (hybrid operation), the SCS® can make a dimensional correction of the finished product by means of roll gap adjustment directly on the bar. Fig. 3 shows an example of an application from the test phase with an incorrect setting of the roll gap adjustment at the bar head. The nominal dimension of the product is 40.00mm. At the beginning, the profile measurement shows an average of 40.20mm; the ovality of the product is 0.30mm. Immediately after the evaluation of the first integration interval, the SCS® issues an adjusting correction for both AUL stands, which the remote control carries out.

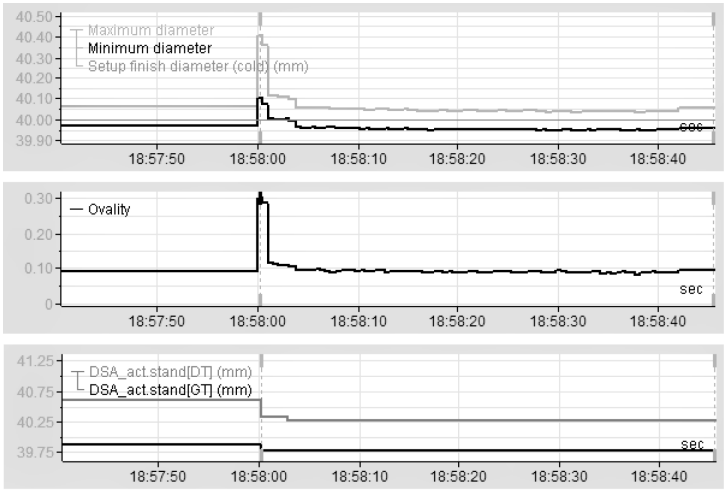

Fig. 3. Adjustment of stands under load in a test for SCS® in "hybrid" operating mode with an incorrect setting at the beginning. DSA describes the operating adjusted pass diameter.

The lower diagram of Fig. 3 shows the change of the pass adjustments (DSA = adjusted pass diameter). In a second pass adjustment of the last stand, the ovality is lowered to a minimum of approx. 0.10mm and remains stable up to the end/tail of the bar. No further corrections by the SCS® are required.

A dimensional correction can become necessary, for example when the operator makes a quality change within one setup and the hot dimension is thus changed by a different shrinkage behavior or yield strength. After the first information from the profile measuring system, the adjusting corrections are determined and implemented by the remote control so that not only the ovality on the bar is adjusted but also the rolling dimension of the last rolling stand position. In comparison with the conventional operating mode, SCS® can reach even tighter tolerances.

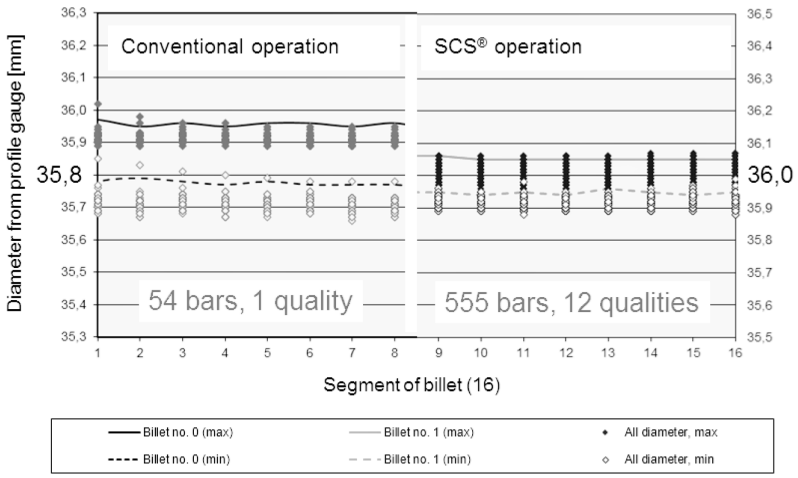

Fig. 4. Comparison of achieved tolerance in conventional (left) and hybrid operating mode (right) with stands adjustable under load.

In this context, Fig. 4 shows an example of two adjacent finished sizes from a mill production. The average values of the minima and maxima is formed on the basis of 16 segments of the respective bars. Segment 1 describes the bar head, segment 16 the bar tail. Thus, on the left you see the tolerance range resulting from conventional SCS® operating mode for 54 subsequent bars of the same quality. The right side shows the result of 555 bars achieved a day before using AUL stands and the SCS®. It is remarkable that 12 different steel qualities/grades were rolled at very different rolling temperatures in this campaign.

Pilot control. The rolling temperature changes the yield strength. If the rolling temperature planned for the setup is not reached in a process, the target dimensions of the product are not achieved at the first go. The SCS® operating modes presented up to now can correct these

dimensions only later on. If the operator knows the changed material temperature before the bar arrives at a station in the deformation chain, corrections of the operating parameters of this station (e.g. the RSB®) in advance can compensate these effects. This is called pilot or feed-forward control.

A feed-forward closed loop control is not based on the consideration of error deviations. Instead of error analysis, this control is based on the knowledge about the process as mathematical model or on experience of the operator. Both aspects are implemented in the SCS® as two different settings.

The SCS® then is able to consider and control in advance a changed yield strength caused by a change of material quality or a changed temperature.

Willingness to use. In 2015, the SCS® was successfully commissioned at another customer. For this purpose, the already existing RSB® 370/4 with conventionally used stands was modified. Besides the closed loop control system SCS®, the RSB® received a new, hydraulic remote control and stands adjustable under load. Furthermore, the modification measures comprised the new installation and commissioning of a profile measuring system immediately downstream of the RSB® as well as an extension of the stand roll shop for the new stands.

Within only a few days, the operators were made acquainted with the SCS® and since then rolling takes place on a constantly high level. Since re-start of the production in September 2015, the SCS® was active 70% within the finishing size range 13 to 90mm. The AUL stands are used up to 75% as roughing and finishing passes in the hybrid operating mode in rolling production.

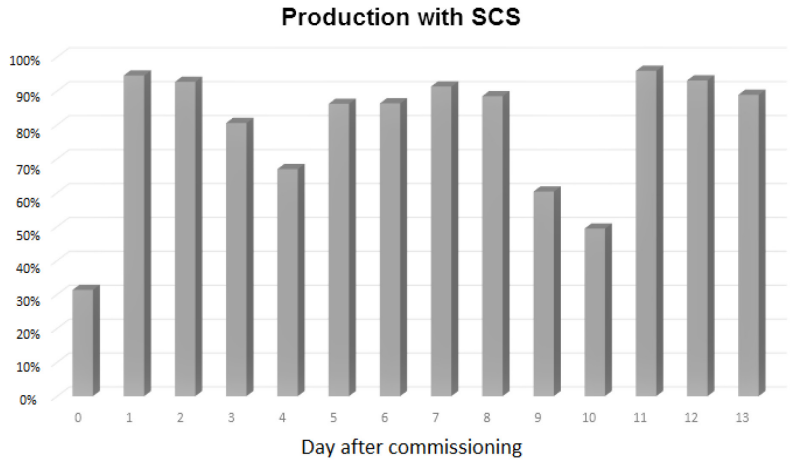

Fig. 5. Production with SCS® after commissioning.

More and more customer appreciate the SCS® having a new installation or an RSB® upgrade to optimize their production with this smart tool independent from the employee. For an exemplary mill, Fig. 5 shows the portion of the production handled with SCS® immediately after commissioning. SCS® is used for more than 80% of the production. Here, only conventional stands, which are not adjustable under load, were used.

Summary

The SCS® consists mainly of a real-time closed loop control system aiming at tightest tolerances and ovality of the rolled finished product, which can be maintained by a 3-roll Reducing and Sizing block RSB® over the total production period. Based on 70 years of experience with mills, pass design and commissioning as well as on reflections of experience made by our customers, a KOCKS' development team developed a highly interesting product, which optimizes process parameters such as pass adjustments and motor speed of a RSB® in an automated way during production.

The control algorithms decide on the kind and size of the adjusting corrections based on the deviations between the target values and the measured actual profile data of the finished product, which are transmitted to the SCS® by a connected profile measuring system. The speed corrections

are applied immediately by the drive motors. Roll gap adjustments are applied by a modern, fast remote control at the AUL stand of the RSB®.

The advantages of the SCS® can be presented as follows:

- Very tight tolerances are assured already for the first bar
- Automated control of finished sizes
- Immediate reaction to process changes
- Constant optimized tolerance
- Minimization of ovality
- Repeatable, best rolling results independent from the employee
- Fast recording of process data
- Faster ramp-up curve

The repeatability of tightest tolerances in the hot rolling process is submitted to enormous challenges due to constantly changing basic conditions. KOCKS accepted this challenge and successfully developed the Size Control System SCS®. SCS® enables the operator of the mill to constantly and reproducibly produce a very tight tolerance level.

Hint

RSB® and SCS® are German trademarks registered by KOCKS.

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