

PROCESS DEVELOPMENTS FOR PRODUCING TIGHTER TOLERANCE SBQ BAR*

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Abstract

During the ABM Conference of 2015 the latest design and process features of the new 3-roll RSB® generation were presented together with a unique Size Control System SCS® for a real time closed loop control to produce an extraordinary quality SBQ – day in, day out. In the past two years, Kocks has focused on improving the repeatability of the rolling process and developed technology to enhance the performance of its equipment. These developments include Fast Remote Control (FRC), Stands Adjustable Under Load (AUL) implementation of closed loop Size Control System (SCS), and finally a state of the art laser Gauge (4D Eagle) that pulls all of these developments into a complete package of quality. Gauges used in the past generally operated with the “shadow” measuring system. The latest gauge developments are based on the “light section” method. This method is more suitable to provide real time measurement parameters of the rolled bar. Placed close to the last rolling stand, the “light section” gauge is capable of measuring around the complete diameter with a clear definition of the bar stage in relation to the axes of the rolls. It is also capable of making these measurements using a very high measurement frequency. Following requirements of the market, requiring the highest gauge measuring frequencies which display the bar in the most accurate way even at the highest rolling speeds, the “4D Eagle” gauge was developed. This paper describes all the process features and parameters of this impressive and unique newly developed gauge as well as the other described technical improvements.

Keywords: Long products; Gauge; Size Control System; Closed-Loop Control; Reducing & Sizing Block; RSB®; SCS®; SBQ Products.

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1 INTRODUCTION

The latest design of the new 3-roll Reducing and Sizing Block (RSB®) is a product of decades of steady development and innovation by Friedrich KOCKS GmbH & Co KG. Its business philosophy of striving for improvements, made the brand “KOCKS” a renowned and reliable supplier to the SBQ market. More than 33 million tons per year of straight bars, bar in coil and wire rod are rolled each year on over 89 blocks with the KOCKS 3-roll RSB® technology.

It is understood that due to today’s increasing competitive pressure, steel producers are forced to improve both the quality of their products and the profitability of their production facilities.

With the new generation of RSB®, SBQ producers are well prepared for existing and future competitive challenges by allowing enhanced bar quality, improved productivity, mill availability and economy as well as a simplified, safe and environmentally friendly operation with a high automation degree.

One key feature of the new RSB® is the implementation of the Size Control System (SCS®), a real-time closed-loop control system for product optimization. Due to this process development, it is possible to react within milliseconds to variations of the incoming bar profile and/or temperature variation. These variations, caused by different mill setups and different material grades affect the characteristic deformation resistances and spreading behaviors.

Nevertheless, the reliable performance of any size control system depends on the technological capabilities of the respective gauging system: the higher the measurement accuracy and frequency of the size gauge, the higher the quality of the information to be processed by the SCS® and, as a consequence, the better the quality of the finished bar.

“W + R Automation” is an expert in supplying high precision profile measuring and surface inspection devices for the automotive industry. Their reputation for precision measuring solutions led KOCKS to promote a cooperation to develop a product suitable for the SBQ Industry. The result of this cooperation is a stand-alone measuring system that utilizes the most advanced technologies currently available on the market.

This new measuring gauge “4D Eagle” operates with the “light section” measuring method, and has the highest measuring rate known in the field of long product rolling mills.

2 KOCKS 3-ROLL TECHNOLOGY IN BAR AND WIRE ROD MILLS

Main technologies to enhance the performance and product quality in bar and wire rod mills are described below.

2.1 The new Reducing & Sizing Block (RSB®) with SCS®

The RSB® has long been known as a workhorse in SBQ steel bar production. “First bar in tolerance” and “fastest start-ups” are known and understood catch phrases when discussing KOCKS bar sizing equipment.

Nevertheless, constant improvement is required in order to fulfill the market requirements of today and tomorrow. To further improve quality, increase production and lower the operating costs, KOCKS has made changes that have reinforced its image as market innovator.

By improving the productivity and availability of the mill when operating with the RSB®, a higher production is achieved. In addition, conversion and operating costs / ton are greatly reduced. This is realized with:

- *New drive concept*, which results in smaller footprint, less gears overall, less spare parts, less maintenance efforts and drastically reduced oil-lubrication volume.
- *Dynamic new stand changing system*, that allows stand changes in as little as three minutes from mill stop to mill start, therefore guaranteeing the best possible mill utilization factor.
- *New Fast Electric Remote Control*, to make adjustments of the pass up to 3 mm within milliseconds either under load using stands adjustable under load (AUL) or within a billet gap. There is no need to stop the production anymore to make adjustments, which in consequence guarantees reliable and repeatable top tolerances together with the highest mill utilization.

The highlight and the core function of the new RSB® however is the new Size Control System (SCS®), which is why the new generation was named “RSB SCS®” (Figure 1).

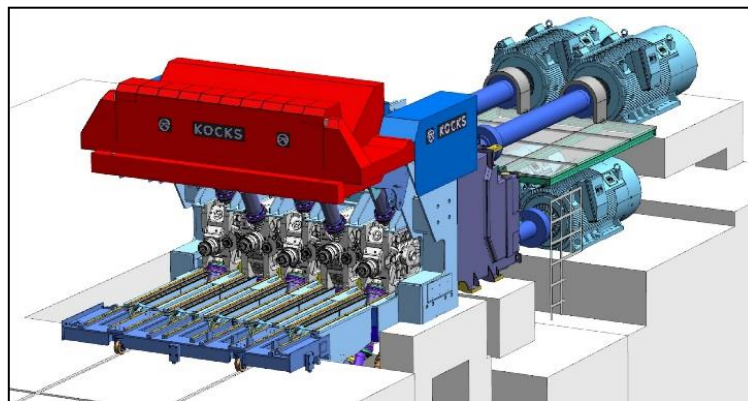


Figure 1. Design of new RSB SCS®.

Increased Production and lower Operating Costs

By adding features that allow higher production, while conversion and operating costs/ton are greatly reduced. By improving the productivity and availability of the mill when operating with the RSB® all of these benefits are achieved.

The level of mill availability and productivity has been greatly enhanced on the new RSB SCS® by means of a dynamic new stand changing system. This system allows stand changes in as little as three minutes from mill stop to mill start. Mill delays for size change or pass wear can be reduced to almost negligible levels. The resulting production increase can justify significant investment as a standalone line item.

In addition to a fast stand change, many size changes are accomplished using only stand adjustment. The new Fast Electric Remote Control can adjust the pass for size or pass wear in milli-seconds. Now small adjustments or free-size adjustments up to 3 mm can be accomplished in the shortest billet gap. This allows precise operation of the mill. No question of whether to stop to make an adjustment. Quality is enhanced with zero resultant decrease in production.

Optimization of the stand design has led to an increased radial roll adjustment range, with the maximum variation in radial position being doubled from 10 mm to 20 mm. Roll consumption, and consequently operating costs, will be reduced drastically, since the number of possible re-dressings of the roll caliber can be doubled.

Making Tolerance Repeatable

The requirement to produce a consistent superb finished quality is the result of a push to reduce handling effort, as well as time-consuming sorting. With today's highly automated machining and forging processes, there is no room for variability.

The RSB® technology is capable of producing at tolerance levels that can achieve 1/7 DIN or better. The challenge of this ability is to make the process repeatable regardless of operating variables. The result of this drive for consistency has resulted in the development of the Size Control System SCS®.

2.2 Size Control System (SCS®)

SCS® is a real-time closed-loop control system meant to achieve the best possible quality of the rolled products by monitoring, maintaining and optimizing the operating parameters of the RSB®.

Besides the large number of different steel grades rolled in a modern and flexible SBQ mill, different rolling philosophies with varying process requirements influence the conditions of the rolled product entering the RSB®. The SCS® aims to compensate these variations by either adjusting the roll gap (position control) or by fine-tuning the inter-stand tension (speed control).

In consequence, the following advantages are achieved with the SCS®

- Automated monitoring of finished dimension.
- Immediate reaction to deviations on the bar profile.
- Minimization of tolerance by roll gap adjustments or inter-stand tension optimization in the RSB®.
- Optimization of ovality by roll gap adjustments or inter-stand tension optimization in the RSB®.
- Repeatable operation values independent from rolling staff.
- Fast acquisition of operational process data.
- Shortened ramp-up curve for optimum rolling operation.

Figure 2 schematically shows the general system architecture of the Size Control System and the use of rolling stands adjustable under load (AUL) as an example. Depending on the finished dimension to be rolled, this stand type is used on the last two stand positions, to be able to adjust the roll pass during the rolling process against the rolling force.

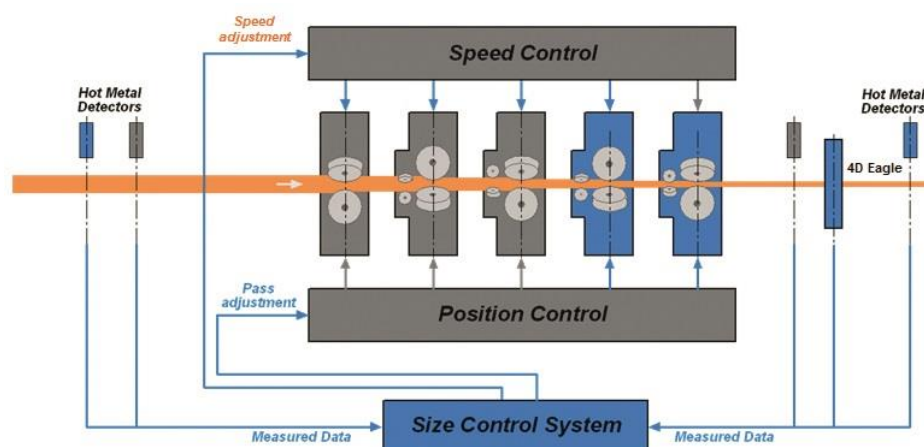


Figure 2. System Architecture of Size Control System (SCS®).

Hot metal detectors and the 4D Eagle, the newly developed measuring system, are positioned at the exit side of the RSB® in order to record the speed and the dimensional accuracy of the finished bar as the basis for subsequent control.

Based on the measured profile deviations of the finished round, SCS® creates a correction for the parameters 'pass size' and or 'motor speed' for the stands in the RSB®.

Pass adjustment can be performed immediately during rolling for stands with "Adjustment Under Load" (AUL) or with conventional stands during billet gaps of less than one second.

Speed Control done through the modification of the tension factor can be applied to improve the size tolerance immediately while the bar is being rolled. Roll wear can also be easily compensated by SCS® without interrupting the production, maintaining the optimum tolerance level all the time.

2.3 Stands Adjustable Under Load (AUL)

SCS® operates either with stands adjustable under load (AUL) or with conventional stands.

The stand adjustable under load (Figure 3) is able to adjust the roll pass during the rolling process against the rolling force. The three rolls move concentrically against the rolling force to achieve the optimum pass size.

By taking closed-loop feedback from the SCS®, the stands are opened or closed to achieve tight tolerance or to reduce the effects of pass wear on the bar. These stands, based on the proven 3-roll heavy-duty stands, can be inserted into an existing RSB®.



Figure 3. Stand Adjustable Under Load (AUL).

2.4 Fast Pass Adjustment

Without an extremely fast remote control, the proven benefits of SCS and AUL would be greatly limited. For this reason, the newly developed Fast Remote Control was integrated as an integral part of the new RSB® generation. The well-proven remote control of stands and guides was re-designed and further optimized in order to cope with the need for faster size changes.

Free-size adjustments can be done without stand change in a traditional billet gap of less than five seconds. With AUL stands, these adjustments can be undertaken immediately against the rolling force in milli-seconds, maintaining excellent finished tolerances with absolutely no break in production.

These adjustments are made individually for every stand and roller guide. This is accomplished by means of a set of servo-motors, situated inside the safety cover of the RSB®. The coupling of the remote control drives occurs automatically when the safety cover is closed (Figures 4 and 5).

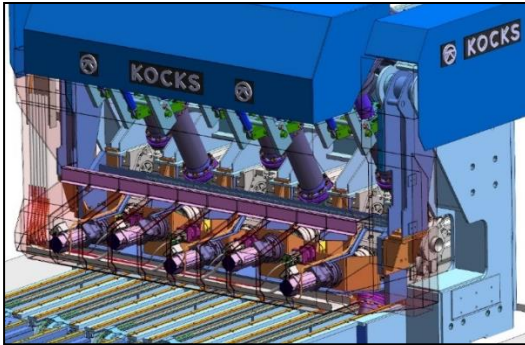


Figure 4. New Fast Remote Control (FRC).

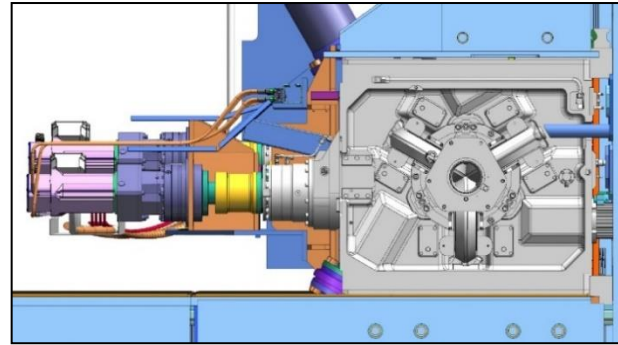


Figure 5. Cross section of the FRC.

In addition to fast pass adjustment, no modern mill could operate with less than the fastest stand change time. An integral part of the new RSB® generation is an innovative stand changing concept, which allows a complete size change in less than 3 minutes.

2.5 Fast Stand Changing

This fully automated system allows each stand to be individually pulled out or pushed into the pass line by an electrically operated chain system, which is integrated in the stand base. The stand cars are equipped with a toggle operated safety bar, which assures that the stands are positioned correctly on the car (Figure 6).

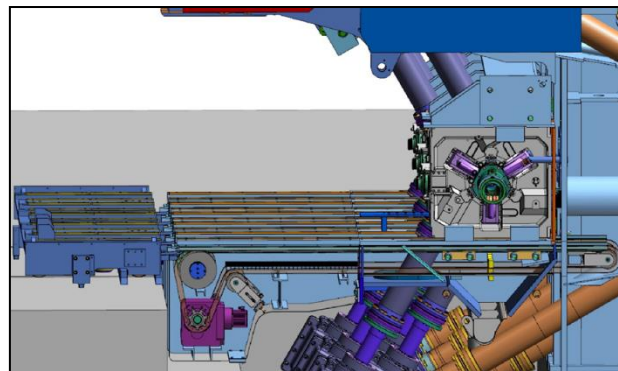


Figure 6. Fast stand changing concept.

No other sizing system can offer such a quick stand changing system. This new leap forward, like the others described above, lead to high mill availability and corresponding increased profitability.

2.6 4D EAGLE

Since KOCKS considers itself a provider of integrated automation and software solutions for long product rolling mills, the need for the development of a trendsetting measuring gauge as a perfect supplement to the SCS® system and in addition as a stand-alone product was identified.

KOCKS found with W+R AUTOMATION an excellent partner in order to develop a new measuring gauge that meets the high requirements of modern rolling mills for highest precision and measuring frequency.

W+R AUTOMATION is a well-known and reputable company which has decades of experience in providing profile measuring and surface inspection systems for the most demanding customers in the automotive industry.

The result of this cooperation is a high-end measuring gauge, named 4D-Eagle, which integrates the newest technologies and has the highest measurement frequency known so far for this type of solution.

In this sense, the 4D Eagle is not only a measuring system that is used together with the KOCKS Size Control System (SCS®). It can also be applied as a stand-alone device in all other long product mills. The 4D Eagle can be used as independent state-of-the-art measurement system for round bars, wire rods, hexagons, rebars, square, tubes and other long product applications.

Shadow Measuring Systems

Gauges used in the past generally operated with the “shadow” measuring method. In this type of measuring system, a light source is directed onto the bar. On the other side of the light source, a positioned sensor detects the light and the area that is shadowed by the product (Figure 7).

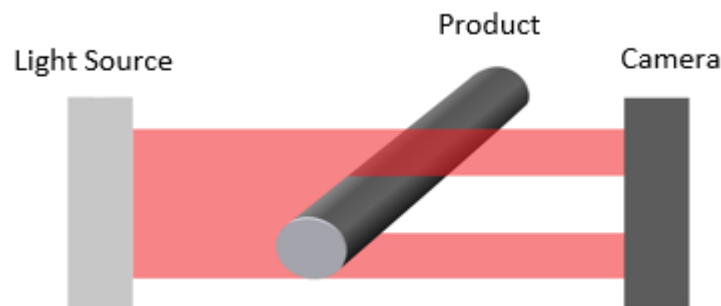


Figure 7. Shadow Measuring Method.

The downside of this type of measuring method is that it only measures two points on the product. Except the measurement of those two points, the dimensions of the rest of the product is unknown. By adding more axes, and thus more light sources and sensors, the amount of measured points is increased accordingly.

Additionally, the frame containing the measuring devices can rotate, to measure different angles of the product.

However, the initial problem of not having the whole circumference of the rolled product measured remains the same. Even with a rotating frame, the “shadow” measuring systems will never be able to measure the real shape of the rolled product, due to the nature of the rolling process, where the products are conveyed with a certain speed through the measuring systems. Instead, those systems use estimations by extrapolating and interpolating the missing information. Consequently this also means, that for any closed loop control system (e.g. SCS®), very important information like ovality and cross sectional area are just estimations.

Light Section Measuring Systems

The latest and best method for hot steel measurement, using “light sectioning” is the principle of the laser triangulation.

A laser source projects a laser line onto the product, which is reflected and captured by a CCD-camera. The 4D Eagle, which also uses this technology, is equipped with four of these sensors, each scanning 90° of the circumference of the product (Figure 8).

All the results of the 4 sensors are evaluated by the processing unit. This allows a complete surface profile to be portrayed, which means that the results of the measurements are not points, but a real and full circumference visualization.

The result is true and distortion-free display of ovality, diameters, and deviations from the optimum.

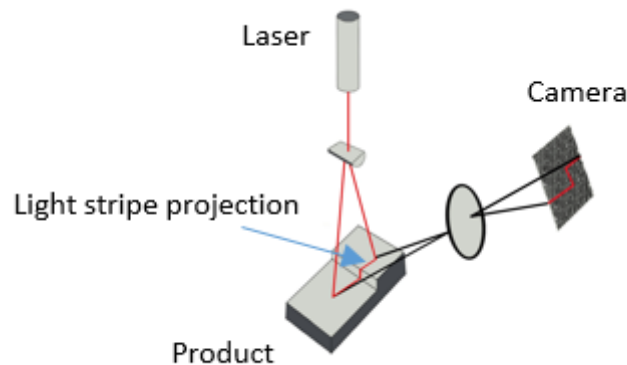


Figure 8. Light Sectioning Method.

Features of the 4D EAGLE

State of the Art Design

Inline hot measurement during the rolling process exposes the measuring gauges to material at rolling temperatures higher than 1000°C. This requires a rugged sensor housing to protect any sensitive especially optical components. The 4D Eagle uses a stainless steel housing to ensure reliable long-term operation. The measuring cell is fully sealed and resistant against scale, water and dust according to Industrial Protection class IP 65 (Figure 9).

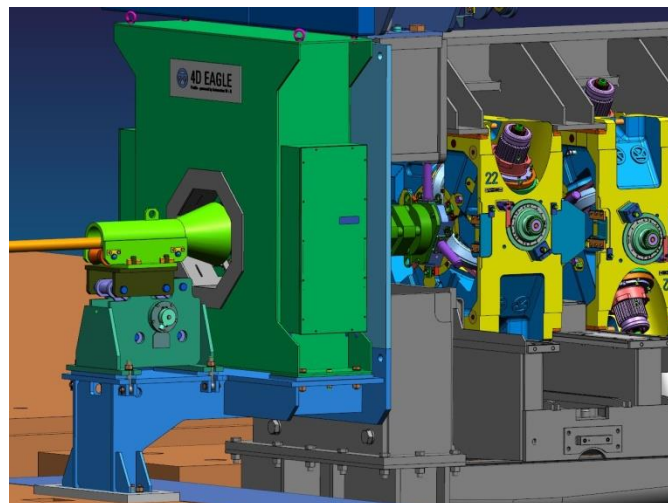


Figure 9. 4D Eagle in an Executed Order.

The measuring cell is a self-contained unit that contains all electronics and evaluation equipment. It is not necessary to have an external electronic cabinet. The only required connections to the gauge are the power supply and a fast Ethernet connection for the operator and maintenance stations. The system offers an interface

for an optional external encoder for measurement of material speed. Profinet and EtherCAT can be used for signal exchange.

This means that all the equipment for measurement and evaluation is on-board, eliminating the need for additional cabling and connections. The internal equipment of the measuring cell is cooled by a closed loop water chiller and an air conditioner unit.

Highest Measuring Rate Known in the Industry

With the advancements in the field of optoelectronics in the recent past, it is possible to get exact measurements along the whole product length at constantly increasing measuring rates. The 4D Eagle has a much higher measuring rate than any other system on the market. In consequence, the 4D Eagle is able to monitor the finished bar with a much tighter profile definition as compared to other system.

During the rolling process, the 4D Eagle scans the whole surface around the circumference of the product (of any shape) in real time, and thus it provides a full surface profile of the product. This is done without any mechanical movement of the sensors.

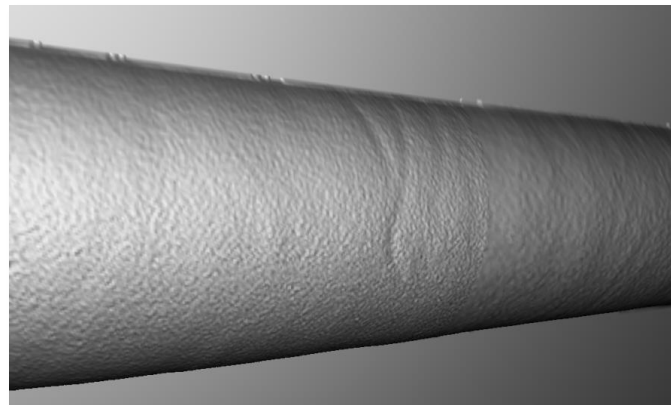


Figure 10. Bar Surface, Scanned with Laser Triangulation (4D Eagle).

The monitoring and the subsequent display of the complete surface of the bar allow the optional automatic detection of local and periodic defects (caused by roll cracks for example) or dimensional variations of the rolled product. Instead of detecting the surface defects of the rolled products at the final quality control station, the 4D Eagle will identify them immediately and countermeasures can be taken in the shortest possible time. This drastically reduces the amount of faulty products, and in consequence increases the mill profitability.

All data from the measurements will be stored in an integrated SQL Database that allows offline analysis of historical data. All measuring results are referenced by length along the as-rolled product, which allows for easy reviewing of all points of interest.

Based on the measurement results, the 4D Eagle can optionally calculate the weight-per-meter and the cold finished size (in combination with a pyrometer).

The advantages of the new developed 4D Eagle are:

- Highly accurate measuring system based on the light section principle with the highest measuring frequency known in the long product market.
- 4D Eagle is available for any type of long product.
- Monitoring of the full circumference of the product with automatic detection of local and periodical defects and dimension variations. In case of defects, just in time counteractions are possible, leading to higher yield, higher mill economy and

profitability, as well as avoidance of time consuming manual inspections (less personnel).

Stand-alone measuring gauge, or in combination with the Size Control System (SCS®) where the excellent measuring results serve to optimize the performance of the RSB.

3 ROLLING RESULTS WITH SDC® AND AUL

All of the design updates undertaken over the last years have resulted in a reducing and sizing mill that is capable of greatly improved operations and maintenance. But without resulting improvements in actual production, the accomplishment would be diluted. In order to prove that the technical concepts are sound and reliable, Kocks has undertaken extensive trials with producers who are among the most demanding in the marketplace.

An example of these trials were taken from the reputable German SBQ-producer Georgsmarienhütte GmbH, where the SCS® is successfully in operation since the summer shutdown of 2012.

Making use of the “free-size” pass design it is a daily routine to roll stable and reproducible tolerance and ovality values, which are consistently within 1/10 DIN EN 10060.

The following example underlines the ability of the size control system SCS® (Figure 11).

44 bars with the finished target size of rd. 55,2 mm were rolled at GMH with different material grades, different spreading characteristics and different temperatures.

The results showed a total ovality level better than 1/7 DIN EN 10060 covering all 44 bars and better than 1/12 DIN EN 10060 for individual bars within the rolled lot.

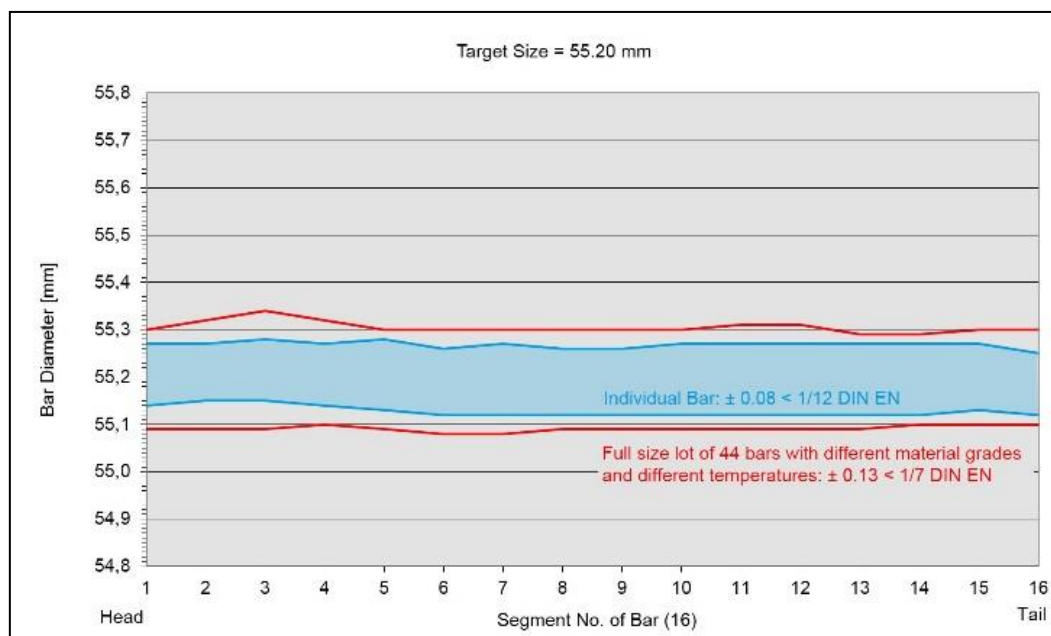


Figure 11. Rolling results at GMH.

These results, achieved when using SCS® and AUL, validate the design principles that Kocks is presenting to the market, producing near perfect quality in increasing volumes.

4 CONCLUSION

The 4D Eagle perfectly suits the requirements of any rolling mill for any long product shape.

With the highest measuring rate, the 4D Eagle provides the complete profile of the rolled product, thus making it possible to detect surface defects with additional evaluation hardware. The advanced design, without any movement of mechanical equipment, guarantee a reliable and precise operation.

Additionally, the 4D Eagle perfectly complements the KOCKS equipment, making it a key component for the closed loop control system of the new RSB SCS®. The results are perfect adjustments during the rolling process, which in consequence ensure an excellent product quality with the highest mill utilization and mill flexibility in the market.

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