FINISHING LARGE SBQ DIAMETERS WITH HIGHEST QUALITY AND ECONOMY [1]

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Abstract
Since the automotive industry approached the manufacturers of rolling mills in the seventies with increased demands for the tightest tolerances in SBQ bars and rods, the KOCKS Reducing & Sizing Block (RSB) was successfully established in wire rod and bar mills counting up to now with 71 references worldwide. In addition to superb quality of the finished product, the RSB allows the manufacturers of SBQ to operate with the lowest possible conversion costs and the highest flexibility of their mills. However, there is a clear tendency in the last few years to produce larger diameter rounds (bars & round billets larger than 3 inches) in this same kind of quality to serve the forging, large automotive and other markets. Today most of these large-diameter SBQ bars are produced in traditional 2-Hi mills that have many times been adapted to finish this range of products. However, the fierce competition faced by most producers makes it difficult for them to realize conversion costs compatible with accepted market prices. In order to meet those targets, Friedrich KOCKS GmbH & Co KG, Hilden, Germany, has developed several RSB-sizes, which meet the requirements profile of modern SBQ-mills, with respect to increased finished diameter ranges, temperature controlled rolling and difficult to deform material grades. This paper shows the enormous benefits that are brought about for a SBQ rolling mill by implementing the 3-roll RSB technology for sizing larger diameter bar with respect to highest possible yield, rolling with maximum mill availability and offering at the same time unlimited production flexibility. It also addresses the recent development of a new RSB stand that can be adjusted under load, while the bar is being rolled (**A**djustable **U**nder **L**oad Stand - AUL Stand).
Key words: 3-roll technology; Reducing & sizing block (RSB); Improvement of quality; Economy; Utilization and market flexibility.; “free-size" rolling; "one-pass-family" rolling, adjustment under load.

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1 INTRODUCTION

The first 3-roll block generation for long product rolling was introduced in 1954 based on 3-roll stands originally developed for the stretch-reducing of tubes. In the following two decades, the 3-roll block mainly found its application in the field of wire rod rolling. In the early seventies, advanced industrialization and highly developed processes in the downstream machinery especially in the area of automotive increased the demand for bars with very narrow tolerances.
Courage, innovation and persistence were the drivers until the so called Precision Sizing Block (PSB) of which the stands had one input drive went into industrial operation at Krupp Suedwestfalen AG / Germany[(1)] in 1979.
Since then the 3-roll technology, the operational processes and the design of the respective machinery went through a steady evolution following market needs. Several developments in all different fields such as material grades and characteristics, mechanical and electrical components as well as automation and optical equipment have been carefully made to improve the 3-roll technology and its implementation. The result of all these efforts is the current generation of the so called 3-roll Reducing & Sizing Block [RSB].
Since the first start up of the 3-roll RSB at Sumitomo Metals / Japan in the mid eighties there has been a continuous growth in the usage of RSBs applied to the finishing area of bar mills where they often act as pre-finishing mills as well as in combination wire rod and bar mills. Since the beginning of the nineties the market is dominated by the modern 3-roll RSB with stands with three input drive shafts. The latest evolution of this machine is the so called heavy duty block or RSB^{++} which started its successful operation 4 years ago – Figure 1.

Figure 1: First 3-roll heavy duty Reducing & Sizing Block operating at Saarstahl AG

The number of RSBs already installed or under contract execution is currently of 71. Today more than 25 million tons of straight bar, bar in coil and wire rod are rolled world wide by means of the RSB 3-roll technology. Focusing just on the SBQ market, more than 70% of the annual production is rolled through Reducing & Sizing Blocks.

2 ADVANTAGES OF THE 3-ROLL TECHNOLOGY

The main reasons for the success of the 3-roll technology are:
- its differences as compared to the conventional 2-high systems
- its operational philosophy.

2.1 Advantages of 3-Roll Passes

2.1.1 Spread

Figure 2 shows a schematic comparison of spread depending on reduction in 2-high versus 3-roll passes. As can be seen from that figure, the deformation efficiency in the 3-roll pass is much higher than in the 2-high pass. Thus with the 3-roll passes the deformation capacity will be converted more into elongation rather than spread by means of roll forces acting from three sides concentric onto the bar. As less spread occurs during rolling, less energy will be wasted for undesirable deformation and converted into heat that could affect the material. This is particularly critical in temperature controlled rolling processes.

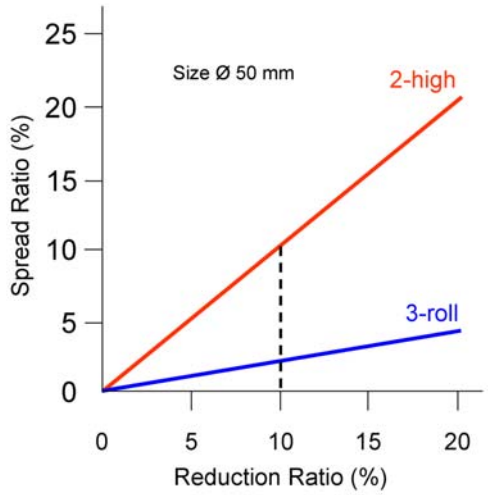

Figure 2*:* Comparison of spread depending on reduction ratio for 2-high and 3-roll passes

The more the spread behavior of a material is controlled, the better the results will be with regards to the tolerances that can be achieved. The spread behavior is different for each material and it also depends on:
- the rolling temperature (temperature distribution of the bar head-to-tail and/or bar-to-bar)
- tension between stands
- cross sectional variations (heavy ends) entering the stands.

The 3-roll technology assures a significantly reduced influence of the spread and is, therefore, able to minimize also the influences of all of the a.m. effects leading to an excellent, more consistent and repeatable product tolerance. In addition, thanks to the homogeneous deformation of the 3-roll pass across the section of the product, very homogeneous structural properties with regard to grain sizes will be achieved.

2.1.2 “Free-size” range

Another significant advantage of the 3-roll pass is the capability of using a wide "free-size" range as opposed to the 2-high pass. By using a certain 3-roll pass geometry, an almost unlimited number of finishing diameters can be produced within the free-size range of 9% of the finished diameter or maximum 3 mm out of the same entry section just by adjusting the roll gap. The “free-size” ranges depending on the finished bar diameter range are shown in Figure 3. Of course this is achieved maintaining the same tight tolerances for all finished dimensions. Many bar sizes even in small lots can be rolled without decreasing mill utilization. The economical effects as a consequence of the reduced number of passes by using the 3-roll technology with regard to rolls and guides along with changing procedures is enormous, especially when rolling a high number of bar sizes with very small diameter increments. The capacity to respond to market needs with great flexibility is another important issue of this rolling method.

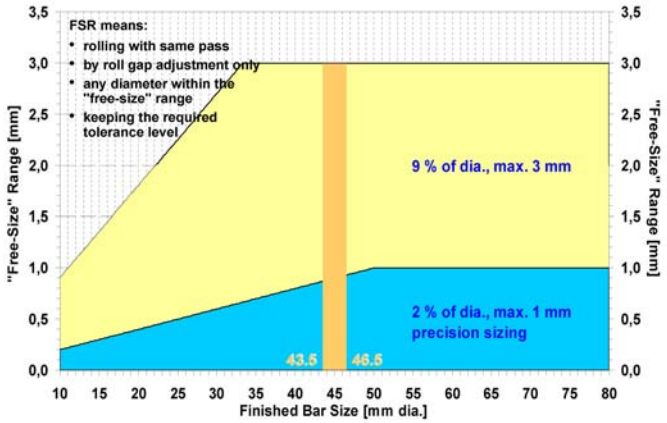

Figure 3 .“Free-size” ranges depending on finished bar diameters

2.1.3Speed differences between rolls and rolled stock

When comparing the roll / bar contact of a pass with two rolls and three rolls it can be seen that the speed differences between the center of the pass and the shoulder is quite low for the 3-roll pass. This not only results in better bar surfaces but also in much lower pass wear. If we on top take into consideration that 3-roll passes use smaller roll rings instead of rolls with roll necks we conclude that the plant will experience much lower specific roll costs (dollars per rolled ton).

Operating Philosophy

The basic target of the RSB operating philosophy can be summarized as follows:
"Minimize any mill down-time to an utmost extent by shifting all operations interrupting the production from the mill line to the roll shop."
Therefore, all activities like roll ring changing, roll adjustment, guide preparation, guide adjustment and stand and guide assembly are performed in the roll shop while rolling with another set of stands. The most important effects of this operating philosophy are a significantly increased mill flexibility (rolling different finished sizes at any time) and the highest level of mill utilization (almost no down times).

4 THE HEAVY DUTY RSB GENERATION

The most recent development of the RSB is the heavy duty RSB. This development was fueled by the ever changing market needs that showed customers aiming to finish large diameter bars with tight tolerances while at the same time achieving a one-pass-family through roughing and intermediate mill applying thermo mechanical rolling in an extended dimensional range. The key component of the new development is the heavy duty 3-roll stand in combination with the heavy duty C-module^{++} drive system.
In order to fulfill those demands the RSB has to handle much higher roll separating forces and rolling torques.

4.1 Development of the Heavy Duty stand and C-module

The largest RSB stand available when this development started was the 370 (nominal roll diameter in mm).
The easiest solution in order to respond to the new market needs and reach a higher deformation capability would have been to develop a larger stand size with a respective larger roll diameter. The big disadvantage of this idea, however, would have been a higher investment and corresponding operational costs for such an RSB. Also the larger roll ring diameter would have negatively influenced the spread behavior in the deformation process as well as the specific roll costs.
The challenge of the new development became to keep the roll diameter as small as possible but reaching maximum rigidity of the stands. Innovation and over 50 years experience in the field of 3-roll technology were the key to meet the a.m. demands while keeping the minimum roll ring size. The new 370^{++} Heavy Duty stand was born.
As a consequence 370^{++} heavy duty stands have the same outside dimensions as the conventional stands of the same size and can be inserted in the same stand support as used for the conventional stands.
The main characteristics of the new stand and its outstanding capabilities in comparison to the conventional design are summarized in Figure 4.

Figure 4: Comparison of basic data of conventional and heavy duty 370^{++} stand

In order to increase the allowable rolling forces and torques as well as to roll bigger finished diameters it was necessary to change the roll fixing method from the axial clamping type by flanges – see Figure 5 (a) – to an oil pressure shrink fit type – see Figure 5 (b). This was creating sufficient space to use bigger/stronger radial bearings (allowing for the higher roll forces and torques) and also to insert wider rolls (to roll bigger finished diameters).

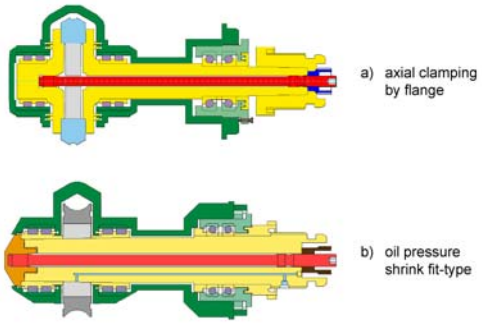

Figure 5:Roll shafts of the conventional (a) and the $^{++}$ type (b) stands

Besides the new 370^{++} stand design a new and reinforced C-module^{++} as shown in Figure 6 was also created.

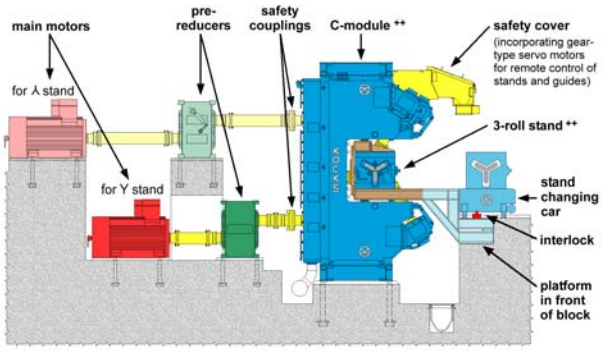

Figure 6:Heavy duty C-module drive system with pre-reducer and motor arrangement of the RSB^{++}

All advantages that are well known for the conventional design RSB are valid for the heavy duty RSB as well.
These are:

- Pass design with a combination of reducing and sizing in one block (RSB)
- one-pass-family rolling throughout the roughing and intermediate mill feeding the RSB
- "Free-size" pass design
- Remote control adjustment of rolls and guides (in mill line)
- Quick stand-changing system (in mill line)
- Quick roll-changing system (in roll shop)
- Computer-aided adjustment system for stands and guides (in roll shop)

Remote control as well as the computer-aided adjustment of rolls and guides will be explained in more detail in sections 3.3 and 3.4 of this paper.

4.2 Pass Schedule Comparison for a Conventional and a Heavy Duty RSB

The consideration of temperature controlled rolling is part of almost any current project whether it is a mill revamping or a complete new mill. It is becoming more and more common practice in modern long products mills to roll at reduced temperatures in order to improve the metallurgical and mechanical properties of the material of the bar, thus simplifying or eliminating subsequent heat treatments and drastically reducing corresponding post-processing costs.[(2)] This process is generally called thermo-mechanical rolling (TMR). In addition to that, more and more customers are

aiming to use the 3-roll technology and its flexibility also for larger finished bar dimensions while still rolling at reduced temperatures.
A typical pass design example demonstrates the advantages and the capabilities of the new heavy duty RSB. This project belongs to a project that initially considered rolling thermo-mechanically from Ø 16.0 – Ø 43.4 mm and conventional finishing rolling for sizes bigger than Ø 43.4 mm and up to Ø 76.9 mm using of a 5-stand 370 RSB. As it can be seen in Figure 7 the pass design in the roughing and intermediate mill is composed of a one-pass family plus one additional feeder. In other words, using 7 feeders it is possible to roll any diameter at any time although two of these feeders would have to be rolled out of stand # 10.

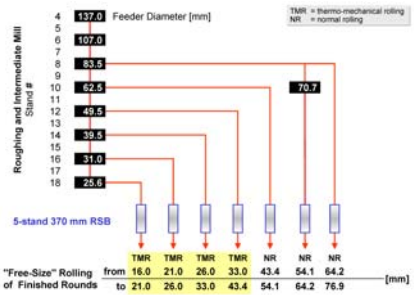

Figure 7: Pass design with RSB and conventional stand design

The maximum permissible roll separating forces and torques of the conventional 370 mm stands limit the maximum size for thermo- mechanical rolling to a finished size of Ø 43.4 mm if we want to roll out of a one-pass-family. Needless to say, additional feeders would make TMR possible for larger dimensions than Ø 43.4 mm, but the mill availability would be affected.
Based on the same overall considerations, the newly developed heavy duty RSB is capable of rolling with only 6 feeders out of a pure one-pass-family in the roughing and intermediate mill (instead of 7 in the case of the conventional RSB) the complete finished range from Ø 16.0 – Ø 76.9 mm as shown in Fig. 8. The thermo-mechanical rolling capability of the block can also be increased up to a range of Ø 57.0 mm from a feeder of Ø 62.5 mm. In addition the finishing range out of the heavy duty RSB can be even increased with an additional feeder of Ø 107.0 mm up to Ø 100.0 mm still enjoying the benefits of rolling with a pure one-pass family. Taking into consideration all the mentioned advantages of the new heavy duty design its positive impact on the operational characteristics of the mill and on the capability of serving the market with greater flexibility are more than obvious.

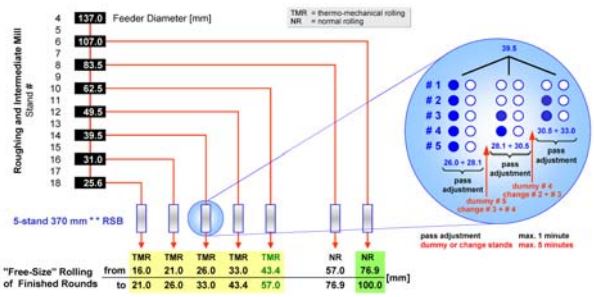

Figure 8*:* Pass design with heavy duty RSB

3.3 Computer Aided Adjustment System for Rolls and Guides

In order to reach excellent tolerances that would lead to obtaining always the “first bar in tolerance” it is necessary to adjust the rolls in the 3-roll stand very precisely. This adjustment is made by using the Computer Aided Pass Adjustment System (CAPAS). CAPAS is a computer-aided optical device[3] which works with two light sources and two CCD-cameras, having thus two adjusting stations. Stands and roller guides can be adjusted at the same time on this system.
A specially created computer program evaluates the signals coming from the CCD-cameras automatically while the radial and axial roll adjusting values are displayed on the monitor.
The described roll and guide adjustment is carried out with high maximum precision of 0.02 mm with which human errors are completely avoided.

3.4 Remote Control for Rolls and Guides

In order to change from one bar size to another within the “free-size” range – see the examples of the 3 “free-size” ranges between Ø 25.0 to Ø 33.0 mm in Figure 9 – it is necessary to adjust rolls and guides in the mill line as accurately and as quickly as possible.
This is done by means of a remote control integrated in the RSB. The adjusting units for the stands and the roller guides consisting of servomotors and gears are integrated in the safety cover of the RSB. When the cover is closed the adjusting shafts of stands and guides are automatically engaged with the servomotors and gears.
A specially developed program called Bar Mill Configuration (BAMICON) [4] calculates the adjusting values for the rolls and guides depending on the required finished product size. The corresponding adjustment is carried out during a billet gap in a maximum of 1 minute and with an accuracy of max. 0.02 mm. BAMICON also includes a roll management tool that allows the user to follow up the sets of rolls through its campaigns as well as a module that determines the motor RPM settings for any of the products to be rolled.
With all of the described adjustment systems it is possible to operate the RSB with the highest accuracy but at the same time in the most efficient and economic way avoiding at the same time any possible human errors.

4 SUMMARY OF ALL AVAILABLE 3-ROLL STAND TYPES

The 3-roll stands with 3 input drive shafts in operation until today are the types 215, 300, 370 and the heavy duty version 370^{++}. A new 435^{++} type and 490^{++} type are just on order. Further targets are the heavy duty versions 215^{++} and 300^{++}. Figure 9 contains all available 3-roll stand types together with the respective finished diameter ranges.

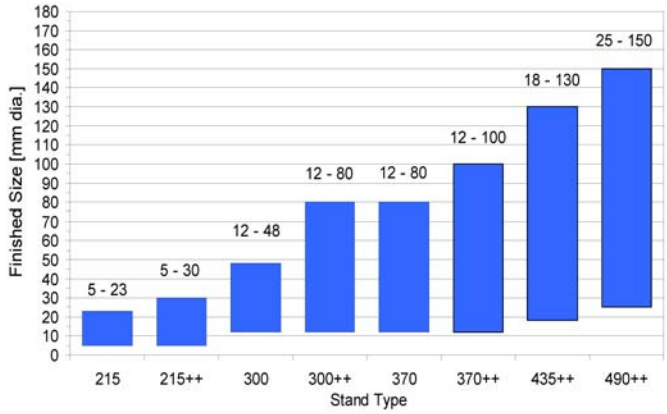

Figure 9*:* Summary of 3-roll stand types

5 THE NEW RSB STAND WITH ADJUSTMENT UNDER LOAD (AUL)

This type of stand, developed in parallel with the Integrated Size Control System (ISCS), leads to an improved level of operation by allowing the shortest possible heavy ends, more precise compensation of differences in the entry section to the RSB and also the capability of monitoring and controlling the rolling force in real time. As all stands used in the RSB, the new stand Adjustable Under Load (AUL) meets as well the extremely high requirements with regards to stand adjustment and finished product accuracy while still allowing the end user to achieve the highest operational efficiency.

Thus, while maintaining all the well proven advantages of the Heavy Duty Stands,

- Knock-out shaft design with oil pressure fit and resulting quick roll change
- Defined axial and radial adjustment of the stands in the roll shop by the CAPAS system
- Highest rigidity of the stands

that result in a greatly improved rigidity, the new stand Adjustable Under Load (AUL) brings several improvements of its own. Compared to other designs the new RSB stand Adjustable Under Load (AUL) offers,

- Rolling forces that are absorbed exclusively within the stand and are not transmitted to the block frame
- Radial adjustment of the rolls that is carried out by eccentric sleeves with a friction-free bearing arrangement
- Quick and very precise adjustment of all three rolls that occurs simultaneously with one hydraulic rotary actuator
- Each stand has one dedicated hydraulic rotary actuator for adjustment
- The hydraulic rotary actuators are situated in the movable protection hood of the block
- A highly sensitive sensor shows the exact position of the eccentric sleeves
- The axial adjustment of the rolls is not influenced by the radial adjustment and can be carried out separately

Figure 10 shows a photograph of the new stand Adjustable Under Load (AUL) inserted in stand position # 5 in test operation at a German steel plant.

Figure 10*:* View of the new Stand Adjustable Under Load (AUL) in operation

To safeguard the capabilities of the RSB at all times while operating with the new stand Adjustable Under Load (AUL), it also incorporates a mechanical brake that fixes the position of the eccentric sleeves until the pressure of the hydraulic actuators is established.
This design characteristic essentially means for the operator that,

- In case of problems with the hydraulic system, a brake system automatically guarantees locking of the adjustment and the continuation of rolling with the highest quality, and
- If there is no hydraulic pressure because the stands were taken out of the block, the rolls remain in position and the current pass can be checked against the desired standard

6 CONCLUSION

A constantly growing demand for high-quality steel bars finished with tight tolerances, excellent surface finish and adequate metallurgical properties, produced with high mill flexibility (any size and grade at any time to reduce inventory) and at the same time showing best operational economy (maximum yield, high mill utilization, low operating costs) has influenced the development of modern rod and bar mills considerably. Carefully watching the global market and the needs of the customers is the driver for new concepts and innovative technology.
The innovative stand Adjustable Under Load (AUL) when utilized grants the shortest possible heavy ends, a more precise compensation of differences in the entry section to the RSB and also the capability of monitoring and controlling the rolling force in real time. Likewise, the new heavy duty RSB represents the latest generation, and combines more than 50 years of experience with numerous innovations.
This generation of heavy duty RSBs made its first successful start-up at SAARSTAHL AG / Germany, Voelklingen Works in 2004. Shortly after that the same company decided to install a second heavy duty block at its Neunkirchen Works that started up in 2006. Two more heavy duty blocks have been commissioned in 2006 in Seah Besteel in Kunsan / South Korea and Jiangyin Xing Cheng Special Steel Works in Jianying, Jiangsu Province / P.R. of China continuing the path of success of the RSB technology. The fifth heavy duty block was put into operation this year at Ascometal in Hagondange / France and the sixth and seventh will be installed in 2009 at Henan Jiyuan in China and in Republic Engineered Products in Lackawanna,

NY – USA respectively. Finally, recently received orders will increase the total number of heavy duty RSBs installed or on order to 9, including the first 435^{++} as well as the first 490^{++} RSB.
The demands of the market for the capability of finishing even larger diameter SBQ with tight tolerances while enjoying the advantages or the RSB in terms of the use of the 3-roll technology coupled with lowest conversion costs and high market flexibility, gave way to the creation of other RSB types that would be stronger than the already developed 370^{++} RSB: The 435^{++} and the 490^{++} RSB. Theses new 435^{++} and 490^{++} stands and equivalent C-Modules are designed to finish bar sizes up to Ø 130 mm and Ø 150 mm respectively with SBQ tolerances.
Thus the RSB technology is finally also available to large-diameter / heavy-products SBQ mills.

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