54º Seminário de Laminação e Conformação
Anais do Seminário de Laminação e Conformação ISSN 2594-5297 vol. 54, num. 1 (2017)

5-STRAND SLITTING PROCESS: IMPLEMENTATION AND RESULTS - A SUCCESSFUL PROJECT JOINTLY DEVELOPED BY BSRM STEEL LTD AND DANIELI & C. OFFICINE MECCANICHE SPA*

Andrea Zanon[1]
Sunil Kumar Das[2]

Abstract
Slitting processes have been used for many years to increase the productivity of smaller diameter deformed bars, without making major investments in the rolling mill. This technology is used mainly for the production of reinforcing bars (7-20 mm diameter), but successful applications exist also for round bar production. The multi-slitting process enables to produce up to 5 bars starting from one billet, thus increasing the productivity of the smaller products. Danieli Morgårdshammar, world leader in the supply of rolling mills for long products, has been a front-runner in slitting technology since its first applications and has recently developed, first in the world, the technology to produce 5X8mm rebar. This process has been recently applied in BRSM steel, a company based in Bangladesh which is a worldwide benchmark for slitting technology performances. This paper presents the necessary modifications which need to be considered when developing a 5-strand slitting project (and multi-strand slitting projects in general), as well as the results obtained at BSRM Steel when the process was implemented in 2016, the first rolling mill in the world rolling 5X8 mm slit rebars.

Keywords: slitting technology, productivity, roll pass design, guide system.

1 *Danieli & C. Officine Meccaniche S.p.A – Vice President – Service Long Product Mills*
2 *BSRM Group of Companies – Country Director.*

1 INTRODUCTION

Slitting processes is used since many years to increase mill productivity of the smaller products.
Danieli Morgårdshammar, front-runner in slitting technology since its first applications, has recently developed, the technology to produce 5X8mm rebar. This process has been recently applied in BRSM steel, a company based in Bangladesh. This paper presents the necessary modifications which need to be considered when developing a 5-strand slitting project (and multi-strand slitting projects in general), as well as the results obtained at BSRM Steel when the process was implemented in 2016, the first rolling mill in the world rolling 5X8 mm slit rebars, with particular consideration to productivity and reduction of production costs.

2 MATERIAL AND METHODS

Competitiveness of rolling mills is one of the major concerns of mill managers: production cost reduction, improving mill productivity or other metrics are key factors to beat competitors and in some case survive in today's markets.
Excess production capabilities, high volumes of offer and stabilized demand are characterizing steel markets in most of the countries (the so-called "new normal" condition); this has led to an increasing need for a competitive production. However, a similar situation is characterizing also some countries where demand is high, due to imports from other countries or new market players.
In such a scenario, availability for new investments is reduced: only investments with low CapEx and quick return of investment (ROI) are afforded.
The multi-strand slitting technology is one typical example of projects which could improve performances of rolling mills focusing production on small diameter reinforced bars (rebar), as demonstrated at BSRM steel, where 5X8mm multi-strand slitting was introduced in 2016: a premiere in the world!
This process has been developed in Bangladesh where the demand for 8mm rebar is increasing day by day. At BSRM Steel the share in product mix of 8mm rebar was only about 4% in 2010, while it reached about 8% in 2016: it was therefore strategically important to increase the productivity of 8mm rebar. We will see how this process, even if firstly focused on increasing productivity, also resulted in an increase in plant competitiveness, since it led to reduce the cost-per-ton of the final product.

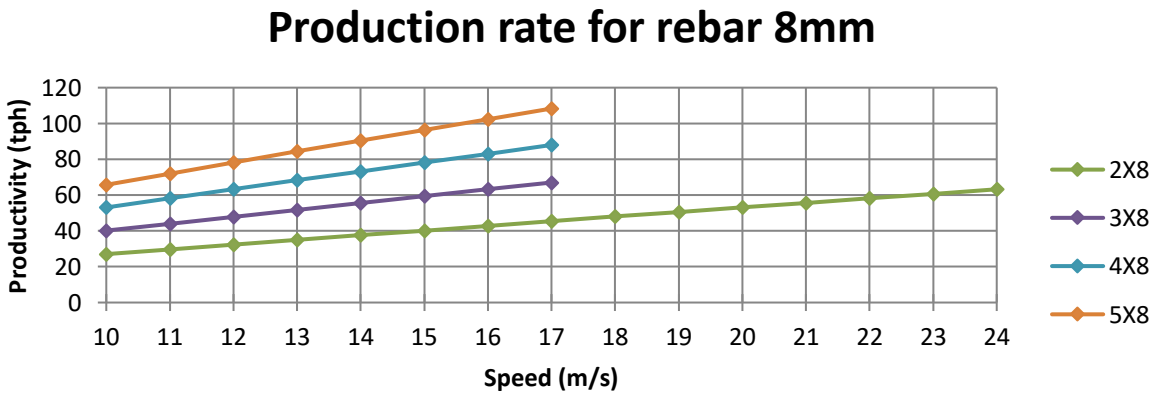

Figure 1. Mill productivity for rebar 8 mm for the different slitting processes

Figure 1 shows the productivity for a rolling mill as a function of the final speed with different slitting technologies. The data are calculated considering a square entry billet 150X150X12000 (2066kg), 5 s interbillet time and 97% yield. It is clear how the introduction of multi-strand slitting can increase productivity for smaller diameters, in order to get closer to the mill productivity.
Considering the typical nominal speed of 13 m/s and keeping the 8mm rebar by way of example, with the 5-strand slitting process productivity can reach 84.3 tph, while with the 4-strand slitting process productivity reaches 68.3 tph; as a result productivity is 23.5% higher.
Similar improvements can be reached also with bigger products, until the mill's full capacity is reached and is as much as possible in line with the furnace capacity.

In order to keep the process stable and reliable, different aspects need to be kept into consideration from the engineering, mechanical and labour point of views.
In particular, when introducing a slitting process, the following aspects require particular attention:
-Productivity of reheating furnace.
-Starting billet dimensions
Mill layout and stand and drive train characteristics (roll diameter, motors, gear boxes, spindles, distances…).
-Rolling sequence including pass geometry, power, torque, speed.
-Guide equipment and setting devices.
-Vertical looper and conveyors.
-Pinch roll and dividing shear
-Bar surface quenching and tempering (water-box suitable for 5 strands).
-Cooling bed
-Bar counter, cold shear and other equipment on the finishing area
-Training, learning curve and know-how transfer

Roll Pass Design

Particular attention has to be paid to the development of the roll pass design, considering in particular the mill layout, available motors and gear boxes, temperatures and existing rolling parameters. The support of dedicated software like Wicon helps the customer make all the relevant and necessary calculations for setting up the mill, designing or simulating rolling conditions with new passes and evaluating if some of the available motors or gear boxes need to be replaced.

Figure 2 shows a typical sequence for the slitting technology, being able to produce two to five strands starting

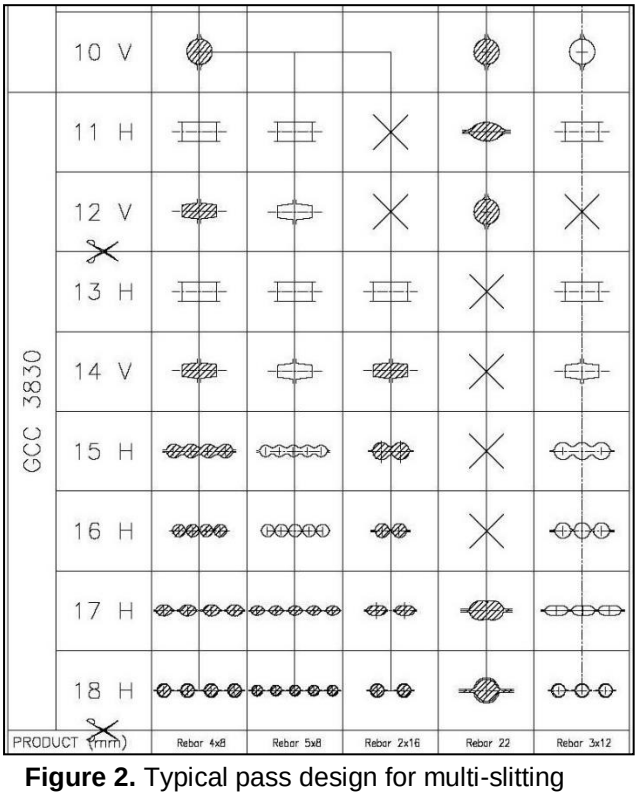

Figure 2. Typical pass design for multi-slitting process

from one billet in a rolling mill with 18 stands.
When introducing the 5-strand slitting, the rolling sequence is usually unchanged up to the intermediate mill. It is anyhow important to foresee dedicated passes to prepare the material on the slitting pass; these passes are critical to ensure the quality of the final product. Among these passes the flat-edging sequence can be noticed, which keeps control of the rolled stock size entering the former and slitter pass.
The last two passes are unchanged if compared to standard rolling, but in this case we have more strands on the mill and this will make the operation more complex. Moreover, for 3 strands and more, the last four stands need to be kept in horizontal configuration; therefore, bar twisting will be necessary between finishing and pre-finishing stands.
With 5-strand slitting a further complication can be linked to the roll barrel length. The pitch between different strands is reduced to allow proper groove distribution and changing: this may lead to utilize dedicated thinner guides, which anyhow need to be strong enough to fulfil the dedicated heavy duty conditions.

Guide System

The guide system is a key factor to obtain optimal mill performance and mill managers have clear in mind which is the impact guides directly have on product quality and rolling mill stoppages (either scheduled for guide/groove change or unscheduled due to cobbles). This is particularly true when referring to multi-slitting processes: therefore, guide equipment and set-up need care and competence.
As indicated, the rolling sequence of the roughing and intermediate mill is usually not changed and therefore the existing guides can be used.
A dedicated guide configuration is necessary for the finishing mill to cope with new pass design, ensuring a precise guiding of the stock, maintaining a reliable process and guaranteeing the balance of the different strands. In particular:
-static guides with replaceable wear parts are used both on the entry and exit sides of flat passes.
-the material is then guided with a standard two roller entry guide SR type into the edging pass. On the exit side a twisting guide CTR type is installed with the main function of stabilizing the

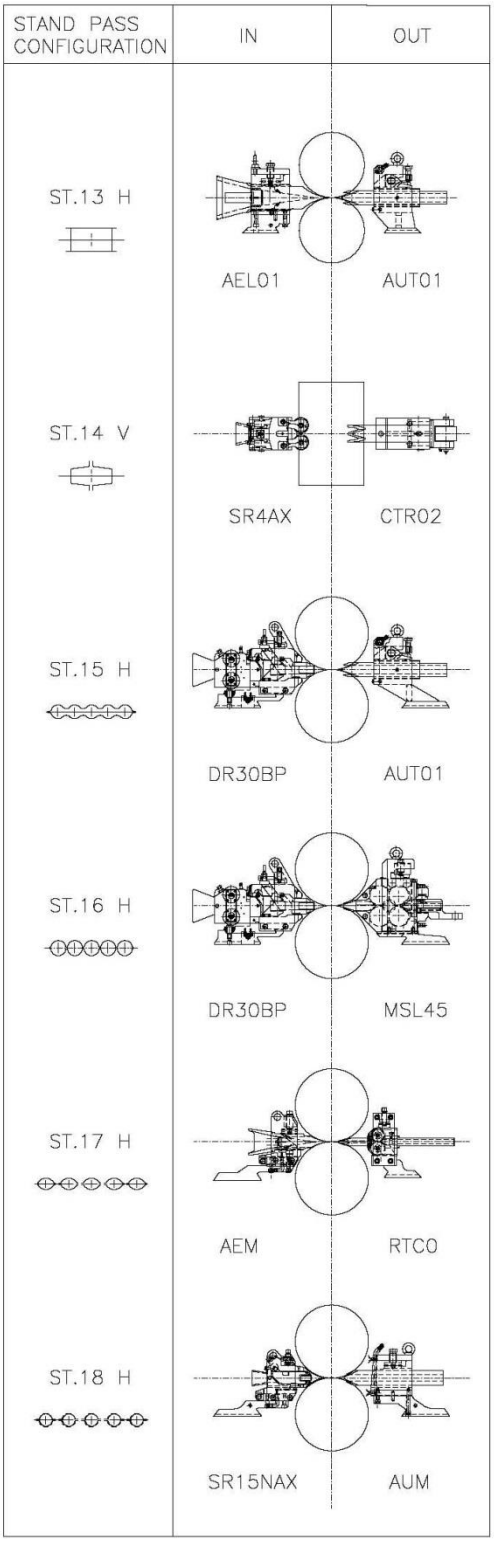

Figure 3. Typical guide configuration

rolled stock.
-on the forming pass, which is the most critical for the complete process, a new 4-roller guide with stabilizing unit has been developed. The new DR guides will ensure precision and rigidity during rolling conditions. The fine adjustable pass base will further improve guide setting in case of minor on-line adjustment. On the exit side, a simple static guide with interchangeable strippers is enough for operation.
-the entry side of the slitter pass requires the utilization of the same DR guide like in the previous stand. The slitting guide is installed on the exit side. Danieli Morgårdshammar requires the utilization of CTD or MSL guide series, according to the application.
CTD guides are used for two and three strands slitting. The cantilever design enables the utilization of bigger rollers and bearings, while the possibility of installation in upside down position maximizes utilization of the barrel length.
On the contrary, MSL guides are used when severe operating conditions are requested (like for example the production of five strands or big slitting stock). MSL guides are equipped with two or four slitting rollers, according to utilization.

The pre-finishing stand is equipped with static guides on the entry side. The static guide will have replaceable inserts and adapt to the different roll diameter due to redressing. On the exit side each strand requires a twisting guide RTC-RS to twist the oval (for two strand slitting it is possible to use a horizontal-vertical configuration for pre-finishing and finishing passes, and in such case twisting is not necessary). All the twisting guides are installed on the same base.
-the finishing stand requires the installation of a roller guide on the entry side, while on the exit side a static guide is used. The roller guide is typically a two rollers SR guide, with central point adjustment and fine adjustment on the base. On the exit side the exit pipes are equipped with replaceable inserts to further increase precision and reduce cobbles originated by material sticking on the roll.

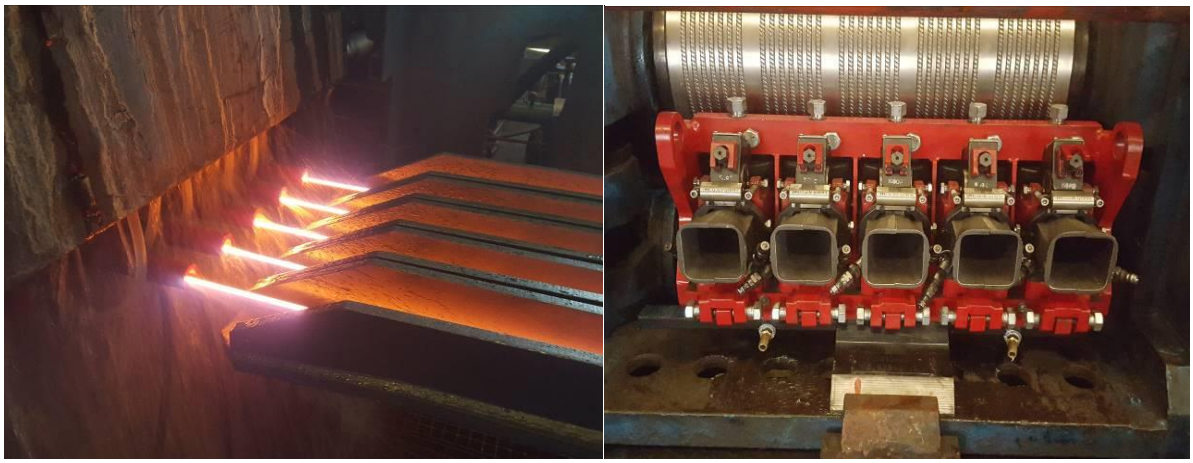

Figure 4. Exit twisting guide RTC and entry guide SR type

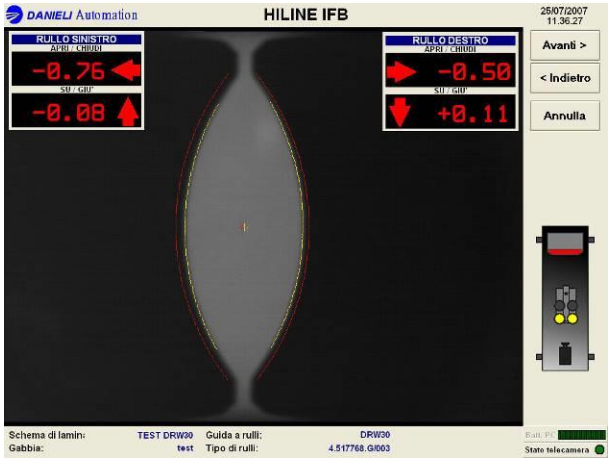

Figure 5. Hiline® screen-shot

It is very important to have the above guides properly maintained and prepared before any utilization. That's the reason why special tools have been specifically developed for guide setting and alignment. Different type of devices can be provided, according to requested accuracy degree and customer experience.
When the target is to assure the best accuracy degree, computerized systems like Hiline are used to obtain repetitive setting independently from human eyes, with tolerances that are impossible to reach with the standard tools.
As an alternative optical devices may be used: an optical bench will be used to set up the guides on the workshop, while an optical collimator is used to align the guides on the mill.
For standard applications good results are also obtained by means of mechanical devices. Templates are used to check the shape of the guide rollers and to set the guides in the workshop. Once guides have been properly prepared, they are aligned with the cylinder grooves by utilizing dedicated setting gauges.

Stands, rest bars and rolls

Finishing mill stands have to be properly maintained to ensure proper groove dimensioning during rolling. Furthermore, the drive chain has to prevent flattering from being transmitted to the rolled stock, creating cobbles or vibration problems; in particular spindles and spindle supports may require to be replaced if they are old or not properly designed.
A proper guide positioning is assured by rest bars, which are therefore key equipment in getting good results from multi-slitting processes.
On all stands, but in particular on the former and slitter passes, rest bars should:
-ensure stability and rigidity of the guide cursor holder.
-prevent rocking-torsion of the guides during rolling.
-enable an easy, repetitive and precise guide alignment.
These features should be maintained throughout the rest bar life and therefore rest bars should be easy to maintain and design tolerances should be recovered after use.
All the above features have been taken into consideration in designing the Danieli square rest bars which are equipped with replaceable sliding pads

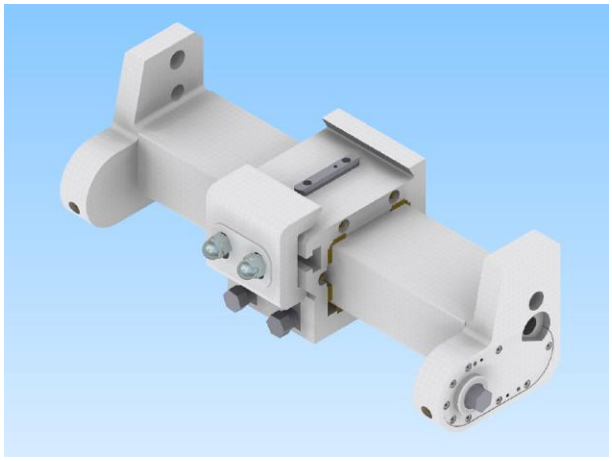

Figure 6. State-of-the-art rest-bar

and utilize a specially designed screw thread to simplify guide alignment, while the "scraper" shaped nut keeps it clean.
Rolls are another equipment which usually requires particular analysis. To increase rolling time and keep grooves with proper shape, rolls of finishing mills are usually changed; instead of using standard cast iron rolls, composite tungsten carbide rolls or high-speed steel rolls can grant longer groove lifetime (thus reducing mill stoppages) and improve rolling stability (the rolled stock is more uniform). Typically, the utilization of carbide rings requires also to upgrade roll cooling, since each groove requires approx. 25 cubic meters per hour of cooling water at 4 bar (or more, according to roll supplier), with minimum 125 cubic meters per hour in case of 5-strand slitting in the finishing and pre-finishing passes.
In such conditions, also guide rollers are made of long-life materials, like titanium carbide (TiC) or sintered steels.

Conveyors, loopers and quenching box

When considering the installation of multi-strand slitting, to get reliable performances it is important to pay the right attention to conveyors and vertical loopers, to ensure smooth rolling without risks of obstacles, avoiding the chips or splinters which are originated in the contact points between conveyors and bars, which tend to accumulate and cause cobbles.

Figure 7. Vertical looper during rolling

In most countries, smaller deformed bars are manufactured with the utilization of a quenching box. In such cases, in particular for smaller products, we have to prevent bar head cobbles due to impact with the water present inside the cooling elements: the waterbox design foresees treatment on the first part of the box, while dedicated conveyors are installed towards the following pinch roll and dividing shear, moving the different strands closer and parallel to each other. The waterbox design also requires a simple and repetitive alignment of the internal elements.
All the equipment described above is designed taking into consideration that in any case cobbles may happen: it is important to reduce their impact, preventing damages, simplifying cleaning activities and shortening the start-up time. Different expedients are used for the above purposes, like leaving space for cobble outlet, install dedicated protections or keeping the slitting guide not fixed but capable to be expelled in case of cobbles).

Cooling bed and cold shear

Another critical area which can typically originate troubles when rolling smaller diameters is the cooling bed run-in roller table. Excessive steps between rollers and tables, or excessive roller wear can lead to the so-called "bar flying" problem and the whole process will not be under control any more. This area, in case of multi-slitting application, is therefore analysed thoroughly and optimized. Rollers could also be replaced by high-performance materials, reducing problems originated by wear conditions.
Furthermore, to simplify the bar delivery to the cooling bed, it is important that the different strands be as much as possible of equal length. Regarding this aspect, it is

really important to tune-up the mill software with a specialized automation engineer. The same bar length means simplified bar alignment and cut-to-length process optimization.
Attention has to be paid also to photocell and sensors positioning, protecting them from light, water and steam. It is suggested to foresee a dedicated cleaning air flow to keep them clean in particular from steam. As regards light, it is important to consider all the different directions during the day.

Technical assistance and start-up

As already indicated, even if it can improve the mill performances, multi-strand rolling requires greater attention to details and preparation of the equipment; it is important to foresee a dedicated training and learning period side-by-side with Danieli specialists. Such activities should cover the different shifts to balance know-how and performances. Involvement of people is a key factor to ensure success and at least team leaders should be involved in the development of this project, as they will then spread the necessary information to all the team members.
A typical Danieli start-up team is composed of four specialists with the following tasks:
-rolling specialist: take care about rolling and the performance of the slitting process, in particular for the rolling mill area, coordinating the activities of the other people.
-mechanical specialist: the task of the mechanical specialist is very critical on existing mills where all the main equipment needs refurbishment to guarantee the necessary accuracy and stability requested by the multi-strand slitting process. During the rolling process he will assist the rolling specialist mainly for the finishing area equipment.
-guide specialist: prepare all the guide systems and make sure that all the guides be ready to be installed. He can also help the rolling specialists during groove changing to speed up the activities and reduce mill stoppages.
-drive and automation specialist: optimize the rolling conditions, keeping under control the motor utilization and the sequences of the different machines (motor cycles, shear cycles…).
According to the customer's experiences and capabilities, these specialists can be integrated with other technicians.

3 RESULTS AND DISCUSSION

The first application in the world of 8 mm rolling with 5-strand slitting process has been jointly developed by Danieli with BSRM Steel (Bangladesh), where the increasing demand for 8-mm rebar, whose productivity was limited by the finishing speed, was the key factor to develop the project.
BSRM set a logical target to increase productivity of 5x8mm by almost 25% compared with the 4x8mm. Since the first day of rolling no special or extra efforts were necessary in the rolling mill, while the finishing area required more manual intervention.
The desired rolling parameters were achieved with the second campaign quite easily. Although no special training was necessary, as BSRM technicians have several years' experience with 4x8mm rolling, Danieli support team provided assistance on site shortening the learning curve.
BSRM started rolling 8 mm in 2009 with 3x8mm: later on the same year 4x8mm was rolled. In 2016 the development of 5x8mm became reality.

The best performance reached in 2016 gave the following results:
-productivity: 82.4 tph
-efficiency: 94.1%
-yield: 97.35%
-electrical consumption: 78.78kwh/mt
-daily production: 1,861 ton
Emboldened by its success, BSRM is now planning to go for 5x10mm rolling in the next few months, to run the mill at a slower speed and still have a higher productivity.

The figures above indicate the gain of 5x8mm rolling over 4x8mm rolling, and this will further improve as BSRM is planning to further increase the finishing speed. The challenges in mill operation can easily be met with better technical discipline during mill setting, following necessary procedures for equipment maintenance, alignment, etc.
There are all-round benefits in terms of productivity, power consumption, fuel consumption. The marginal loss in yield is more than compensated by an increase in productivity and decrease in fuel and power consumption.
This will also lead to reduce production costs for 8mm rebar by more than 2%. The quality of rebars produced in 5x8mm through Tungsten Carbide composite rolls has remained the same.

8mm Rebar Rolling Performance Evolution at BSRM Steels, during start-up phase.

	UM	Rebar 3X8mm	Rebar 4X8mm	Rebar 5X8mm
Rolling Start Date (First Time)	Date	Apr. 2nd , 2009	Nov.15th, 2009	Jan. 12th, 2016
Daily Production	Ton	496	1434	1678
Productivity	Tons. Per Hour	49,2	66,2	80,7
Mill Efficiency	%	57,97	91,95	88,02
Yield	%	94,81	97,31	97,09
Miss Rolling	%	1,45	0,45	0,34
Finishing Speed	Meter per Second	13,00	12,57	12,00
Consumption per ton (gas fuel)	Nm^3/Ton.	38,11	34,02	33,123
Consumption per ton (power)	KWh/Ton.	123,33	94,86	84,317

Figure 8. Results at BSRM Steels

4 CONCLUSION

The introduction of multi-strand slitting has remarkable benefits as regards both mill productivity and cost reduction. Usually rolling mills do not require major changes. The necessary equipment has been described in the previous paragraphs. A strong cooperation with Danieli during commissioning phase will help turn these projects into a success, as demonstrated by the results obtained at BSRM Steels, the first mill ever capable to successfully produce 8mm rebar with the 5-strand slitting process.

1 Danieli Group
Established in 1914, Danieli & C. Officine Meccaniche Spa is one the world's top three suppliers of equipment and plants for the metal industry worldwide. It is world leader in minimills and rolling mills for long products. Throughout its history, Danieli has been a leading pioneer; developing different milestones in metal industry production. In recent years, Danieli has invested more than 150 million Euros each year in research and development. The company is based in Buttrio (Italy) and has a worldwide presence.

2 BSRM Group of Companies
Established in 1952, BSRM Group of Companies in Bangladesh is the oldest and largest group having core interest in steel melting, rolling and marketing, and has remained a market leader with an excellent brand image thanks to its main focus on quality. The group is the first company in Bangladesh to produce Thermo-Mechanically Treated Rebar, Slit Rolling, 50-mm rebar rolling and more recently 5-strand rolling of 8-mm rebar. Headquartered in Chittagong Bangladesh, the group has 3 meltshops and its rebar production capacity is around 1.3 m Tons. Its production includes also small angles, channels and cold rolled ribbed wire rod mostly for the local market..