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LATEST IMPROVEMENTS TO INCREASE RELIABILITY AND PRODUCTIVITY ON MULTI-SLITTING PROCESSES[1]

DESCRIPTION OF THE NECESSARY EQUIPMENT AND STEPS TO OBTAIN OPTIMAL RESULTS WITH MULTI STRAND SLITTING TECHNOLOGY

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Abstract
Slitting processes have been used for many years to increase the productivity of rolling mills, and at the same time to reduce the overall production costs. This technology is used mainly for the production of reinforcing bars, but successful applications exist also for round bar production. Without making major changes on mill layout, multi-slitting process make it possible to produce up to four bars starting from one billet. Danieli Morgårdshammar, world leader in the supply of rolling mills for long products, has been a preeminent provider in slitting technology since its earliest applications. In order to deliver a smooth start-up and increase the reliability of multi-slitting processes, in particular for four-strand slitting, Danieli Morgårdshammar has developed different solutions and improvements to be applied along the mill. Starting from process designing, the Danieli Morgårdshammar package includes a dedicated guide system, loopers, conveyors, alignment devices, water-cooling manifolds and other equipment. Special training and start-up assistance can be provided with the intervention of specialized process, mechanical and automation engineers. This paper will present the modifications that Danieli Morgårdshammar has determined to be necessary to improve multi-slitting processes, and the results of the latest applications realized during the latest mill start-up.
Keywords: Slitting technology; Productivity; Pass design; Guide system.

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1 INTRODUCTION

Steel bar rolling mill managers are continuously challenged to increase the productivity of their plants in order to compete successfully with the changing market conditions. For many years, slitting technology has been one of the preferred solutions used to maintain high mill output during the production of small bars, keeping low capital expenses and thus enabling a quick return of investment.

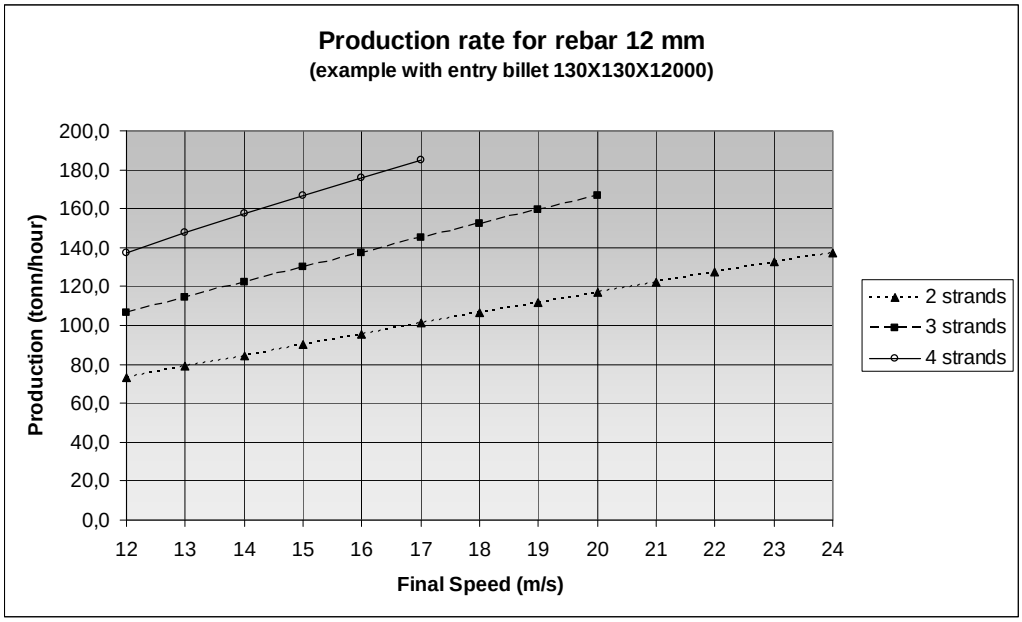

Figure 1: Production table for reinforced bars 12 mm.

Figure 1 represents the productivity for a rolling mill in terms of finishing speed with different slitting technology. The data are calculated considering a square entry billet 130X130X12000 (1540kg) and the interbillet time of 5 sec. To get the same productivity, final speed of two strands has to be doubled compared with four-strand production.

Together with the increase of productivity, further advantages of slit technology can be evaluated both for existing and new mills. In particular:

- Possibility of increasing the billet size or using fewer rolling stands to produce a specific size;
- Reduction of exit speeds, simplifying operation and eventually shortening the finishing area length.

First industrial applications with slitting process have been developed for the production of 10, 12 and 14 mm reinforcing bars (two-strand slitting) and date back to the 1980s. Today, slitting technology is commonly used to produce a wider range of products (from 6.3 up to 24 mm) with a number of strands increased up to four. Of course rolling conditions and difficulties are completely different if we compare 2X14 and 4X8 production. In order to keep the process stable and reliable, different aspects need to be considered from the engineering, mechanical and personnel points of view.

In particular, the following aspects need to be considered when introducing a slitting process:

- Reheating furnace productivity;
- Billet sizes;

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- Mill layout and stand characteristics (roll diameter, motors, gear boxes, distances …);
- Rolling sequence, including pass geometry, power, torque, speed;
- Guide equipment and setting devices;
- Vertical looper, conveyors between stands and after the last pass;
- Pinch roll and dividing shear;
- Bar surface quenching and tempering;
- Cooling bed;
- Bar counter, cold shear and other equipment on the finishing area; and
- Training and know-how transfer.

2 PASS DESIGN

Particular attention has to be paid to the development of the pass design, taking in particular consideration the mill layout, available motors and gear boxes, temperatures. Typically, on an existing mill, the rolling parameters are calculated on the basis of the existing conditions. This verification will help to determine if some of the available motors or gear boxes need to be replaced.

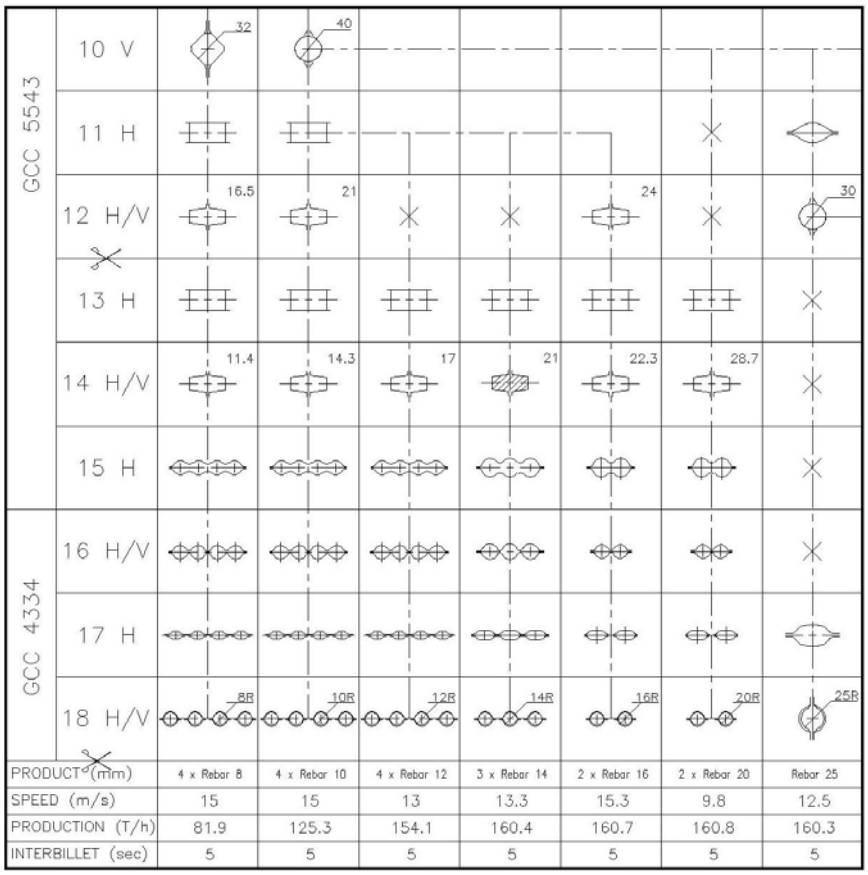

Figure 2: Typical rolling sequence on a modern rolling mill.

The above figure represents a typical sequence for slit technology, being able to product two-three and four strands starting from one billet in a rolling mill with 18 stands.
Usually, roughing and intermediate mills are unchanged if compared to the traditional single bar rolling.

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Thereafter, some passes are foreseen to prepare the material on the slitting pass; these passes are critical to achieve the quality of the final product. Among these passes the flat-edging sequence can be noticed to keep control of roll stock size that will enter the former and slitter pass.
The last two passes are un-changed if compared to standard rolling, but in this case we have more strands on the mill and this will complicate the operation. Moreover, with at least for three and four strands, the last stand needs to be kept in horizontal configuration and therefore bar twisting will be necessary from the previous stand.
Together with the support of the process specialists, dedicated software have been developed to help mill technicians to make their evaluation on pass design. For example, using Wicon will help the customer to make all the relevant and necessary calculations for setting up the mill and designing or simulating rolling conditions with new passes or with different equipment.
It is of fundamental importance to use, in conjunction with this special pass design, some special roll guides to achieve precision guiding of the stock during rolling conditions, maintaining a reliable process and guaranteeing the balance of the different strands. Particular attention has to be paid while guiding the bar into the forming slitting passes.

3 GUIDE SYSTEM

During the slitting process, guiding represents a key factor for attaining optimal mill performance. Therefore, particular attention has to be paid to guide equipment and set up.
On the roughing and intermediate stands standard guides are used. Usually two roll guides are foreseen to guide the ovals, while on the other passes static guides are installed.
On the other hand, special guides are needed for the finishing stands, where the following guide configuration typically is used:

- Static guides for both the entry and exit sides of flat passes.
- Then, the material is guided with a standard two- roll entry guide, SR type, into the edging pass. On the exit side a twisting guide, CTR type, is installed with the primary function of stabilizing the rolled stock for the former pass, which is the most critical step of the complete process.
- On the forming pass, a new four- roll guide with stabilizing unit has been developed. The new MDR guides will grant precision and rigidity during rolling conditions. The use of such guides, usually equipped with a fine adjustable pass base, also will maintain the centerline thanks to a patented adjusting system in case of minor on-line adjustment. When long rolling campaigns are requested guide rolls can be made of titanium carbide (in particular this configuration is chosen when carbides rolls are installed on the finishing mill). On the exit side a static guide, with interchangeable strippers, is used.
- The entry side of the slitter pass using the same MDR guide as in the previous stand.

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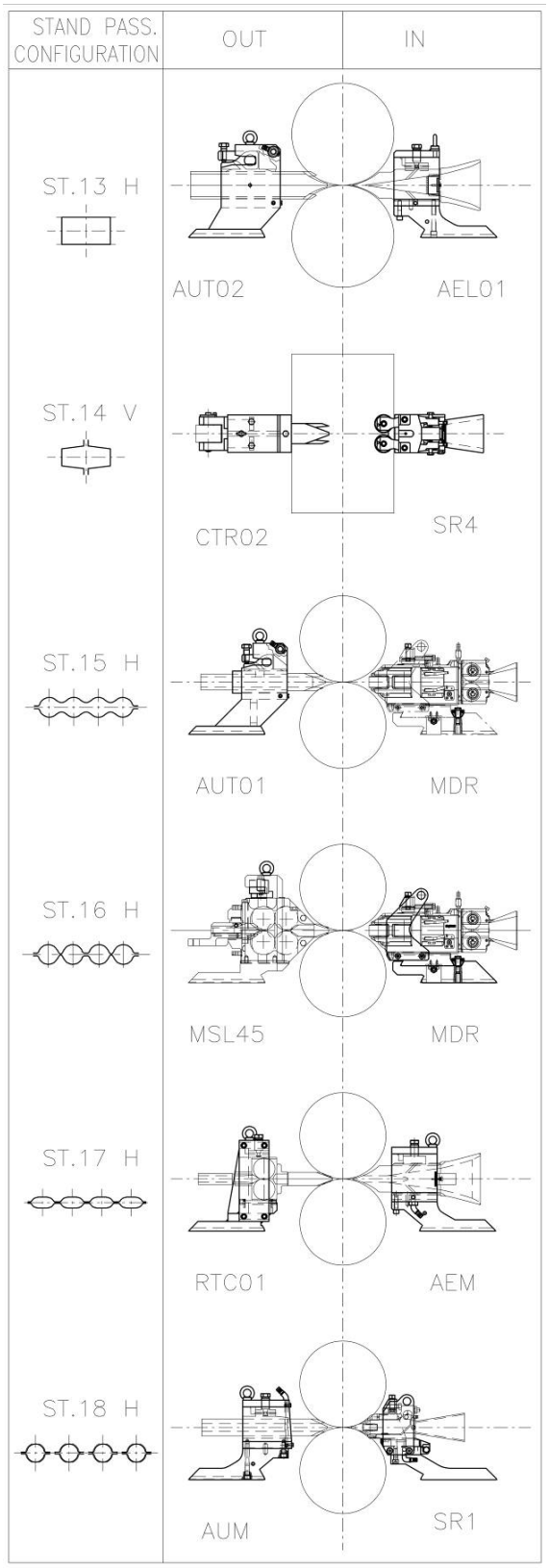

Figure 3: typical guide configuration.

On the exit side, the slitting guide is installed. Danieli Morgårdshammar recommends the CTD or MSL guide series, according to application.
CTD guides are used for two- and three-strand slitting. The cantilever design makes it possible to use larger rolls and bearings, while the possibility of installing it upside

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down maximizes the use of the barrel length. CTD guides mean a reliable guide with low overall operating cost, together with extremely simple utilization procedures.
On the contrary MSL guides are used when severe operating conditions are requested (for example, the production of four strands or big slitting stock). MSL guides are equipped with two or for slitting rolls and can be used for two, three, four strands, and are ready also for the five-strand slitting process.

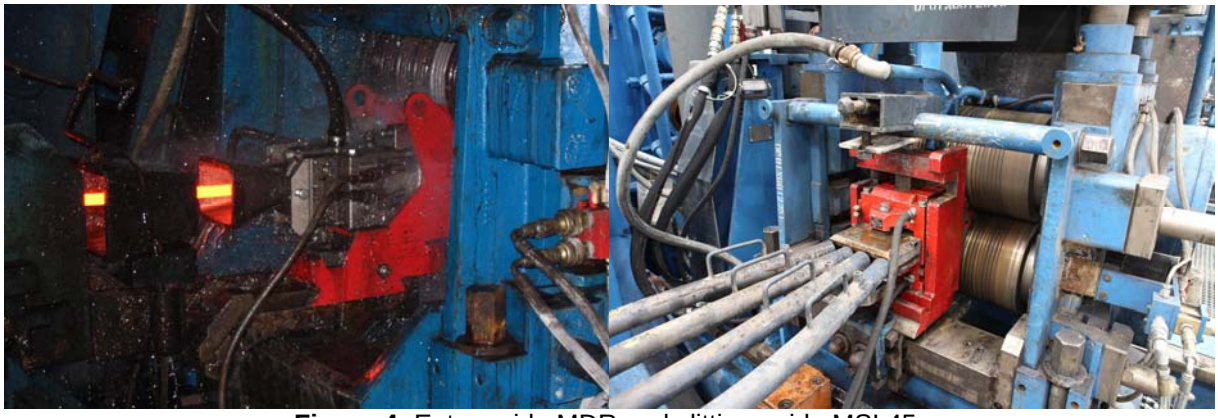

Figure 4: Entry guide MDR and slitting guide MSL45.

- The pre-finishing stand is equipped with static guides on the entry side. The static guide will have replaceable inserts and adapts to the different rolling cylinder diameter due to redressing. On the exit side a twisting RTC-RS guide typically is used to twist the ovals, considering a horizontal-horizontal configuration for the last stands (for two strand slitting it is eventually possible to use an horizontal-vertical configuration for pre-finishing and finishing passes). The guide base will foresee one RTC guide for each strand; the configuration will allow reliable operating conditions due to the guide's long-life components and easy set-up (the rolls can be symmetrically adjusted maintaining the centerline, by acting on a single screw).
- The finishing stand foresees the installation of a roll guide on the entry side, while on the exit side static guides with replaceable pipes are used. Typically, the roll guide is a two-roll 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 reduce operating costs, thus granting the necessary precision.

Figure 5: Exit twisting guide RTC and entry guide SR type.

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It is very important to have the above guides properly maintained and prepared before any utilization. That's the reason that special tools have been specifically developed for guide set-up and alignment. Different type of devices can be provided, according to requested precision and customer experience.
When the target is to grant the best precision, the Hiline is the proper tool to be used. This computerized device is able to help the guide engineers to obtain repetitive setting independently from human eyes, with tolerances that are impossible to reach with the standard tools.
Another option is to use optical devices: 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.
Good results also can be obtained with mechanical devices. Templates are used to check the shape of the guide rolls and the adjustment of the guides. Once guides have been properly prepared on the workshop they are aligned with the cylinder grooves utilizing dedicated setting gauges.

4 REST BARS

Rest bars make it possible to keep roll guides in the proper position during the complete rolling campaign. On all stands, but in particular on the former and slitter passes, the 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 during the complete rest bar life and therefore the rest bars should be easy to maintain and design tolerances should be recovered after usage.
Danieli recommends using square rest bars at least for the critical passes. Danieli's new bars are equipped with replaceable sliding pads and utilize a specially designed screw thread to simplify guide alignment, while the "scraper" shaped nut keeps it clean.

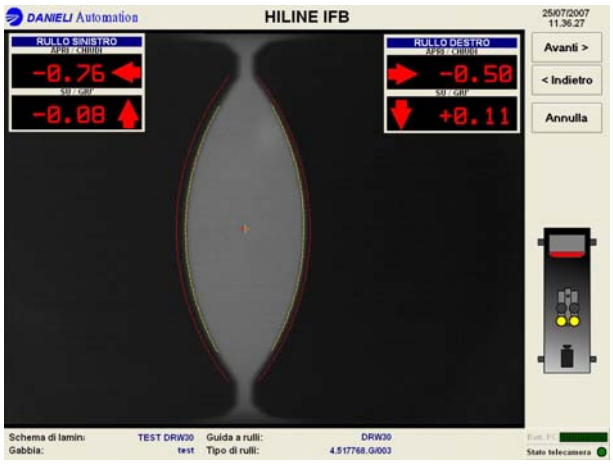

Figure 6: Hiline screen-capture indicating necessary adjustment on guide set up.

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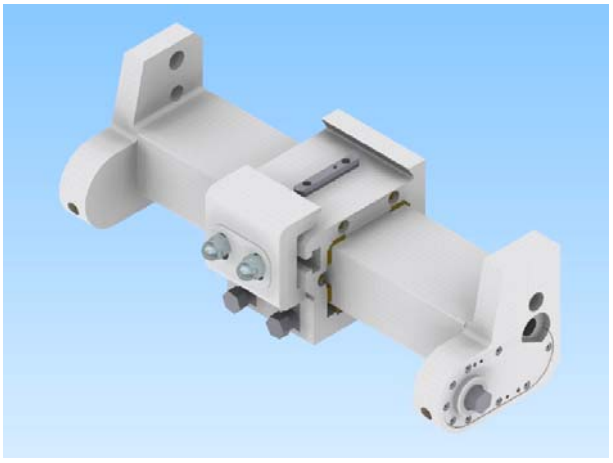

Figure 7: Danieli new square rest bars.

5 CONVEYORS, LOOPERS AND OTHER EQUIPMENT

Attention to details both in engineering, manufacturing and installation on conveyors and vertical loopers will ensure that different strands are conveyed smoothly through the different equipment without risk of obstacles. Above all, during rolling of multi-strand slitting particular attention has to be paid to all contact points between conveyors and bars, to avoid chips or splinters that will accumulate and cause cobbles.

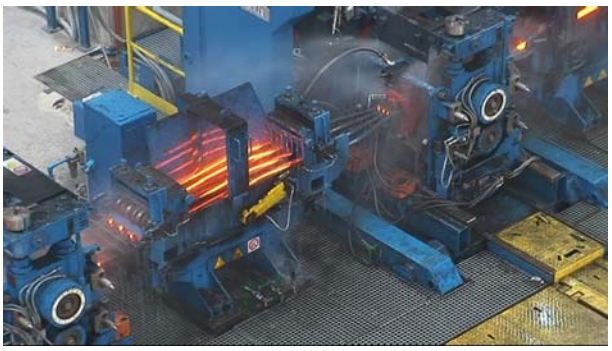

Figure 8: Vertical looper and conveyors.

In order to save on investment and product changing Danieli has developed a looper that can be used with all different slitting processes (from two up to four strands). In order not to reduce water-cooling on the roll grooves, it is recommended to take water for guides and conveyors directly from the looper feeding. This water is used to clean the parts, thus maintaining the lubrication effect. Groove cooling has to be maintained in full efficiency: this will reduce groove wear and therefore rolled stock dimensions are stable during rolling (extra cooling capability has to be foreseen if carbide cylinders are used).
Also, inside the thermal treatment box the design and disposal of the internal elements is studied to grant smooth and good guiding of the bars through this equipment. Design of the different parts has to enable simple alignment of all the different elements. Moreover, in particular for small products, we have to prevent bar head cobbles due to the water inside the cooling elements. Danieli, in these cases, foresees the treatment on the first part of the box, while toward the exit by pass

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channels are installed; these channel also start to guide the different bars toward the following pinch roll and shear. In this equipment the different strands have to get closer to each other; in this way the different strands drag each other and tail extraction is simplified.
Another important issue to take into consideration along the mill is the position of the photocells and sensors: these have to be protected from light, water and steam. It is suggested to foresee a dedicated cleaning air flow to keep them clean, in particular from steam. In case of light it is important to consider all the different directions during the day.
All the equipment here described is designed with the possibility to let eventual possible cobble free to take out. This will simplify cleaning and reduce start-up time (for example, the slitting guide is not fixed but in case of cobbles is expelled from its base). Dedicated protections are foreseen to the different equipment and systems to reduce the eventual damages caused by cobbles.

Figure 9: Cooling bed.

6 COOLING BED AND COLD SHEAR

The cooling bed run-in table is another critical area of the whole process. If this equipment is not aligned to prevent high steps between the rolls and tables, the bar can accelerate and the whole process will no longer be under control. This area (in particular the diameter of the different rolls), in case of multi-slitting application, is therefore closely analyzed and optimized.
Furthermore, to simplify the bar delivery to the cooling bed it is important to have the length of the different strands as much as possible equal. 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 and optimization.

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Figure 10: Danieli specialists with customer.

7 TECHNICAL ASSISTANCE AND START-UP

On a new plant the equipment is manufactured and installed with the supplier supervision. In this case the equipment is dedicated to multi-slitting and therefore the start-up team will be focused mainly on establishing the correct process (working on automation, sequences, …) and to ensure proper customer training and learning curve.
On an existing mill more attention has to be paid to the refurbishment (or eventually replacement) of the existing equipment to grant reliability during rolling. Furthermore, even if people have enough experience with rolling, it is important to ensure that attention is given to details and preparation of equipment, considering that this type of process is much more critical than in single-strand rolling.
A typical Danieli start-up team is composed of four specialists:
-Rolling specialist: He takes care of the rolling and the performance of the slitting process, in particular for the rolling mill area. The rolling specialist will be the team leader and will coordinate the other specialists to ensure equipment is properly installed; he will have the responsibility for rolling, in order to optimize the process both from the mechanical and automation point of view.
-Mechanical specialist: The task of the mechanical specialist is very critical on an existing mill where all the main equipment needs refurbishment to grant the necessary precision and stability required of a multi-strand slitting process. During the rolling process he will assist the rolling specialist mainly for the finishing area equipment, where it is necessary to have direct supervision of operative conditions.
-Guide specialist: The preparation, set up and installation of guide system is a key point to getting a positive result from the slitting process, where the requested

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precision is completely different from the standard rolling. That's the reason that a guide specialist is necessary in the start-up team. He will prepare all the guide systems and ensure that all guides are ready to be installed. It is important that during his activities the customer personnel will work in close cooperation with him: in this way he can also give dedicated training to these people. Also, he can help the rolling specialists during groove changing to speed up the activities and reduce mill stoppage.

-Drive and automation specialist: During the four-strand slitting start-up it will be necessary to keep under control the motor utilization and the sequences of the different machines (motor cycles, shear cycles, …); the rolling specialist will require the presence of such a figure in order to optimize rolling conditions, getting the maximum results from the mill.

According to the customer experiences and capabilities these specialists can be integrated with other technicians. In any case, Danieli believes that this team represents the optimal solution in terms of competence to start-up this process.

One common problem faced during the start-up in various mills is that the different shifts have a different level of knowledge and know how. It is therefore important, during the mill preparation to have the presence of all the shift leaders who then can share their know-how with their colleagues. Furthermore, it is important to rotate the different shifts during the presence of the Danieli team. In this way all the personnel will be present during the equipment preparation and rolling. As already stated, it is really important to involve the people in this change who will implement a process that can lead to productivity improvements. Therefore, all the people need dedicated training and involvement; otherwise the results will not be constant during the complete rolling campaigns.

In order to speed up the learning curve and maintain a continuous focus on the necessary steps to produce with multi-strand slitting process, it is recommended to assist the customer with the start-up team on different rolling campaigns during the first year (Danieli suggests three or four assistance periods). This win-win approach will maximize the learning curve for all the personnel, since leaning can be better distributed during the rolling campaigns and the periodical calls can fix the learned lessons.

8 RESULTS

The above approach, with particular attention to all the details of the different equipment and with high consideration to the personnel, has radically improved the results during multi strand slitting operations. Different experiences show that with this method results come earlier and are maintained when the Danieli team is no longer at the customer's site.

For example in BSRM (Bangladesh), in November 2009, Danieli started the production of rebar 4X8 and after the third day the productivity of the mill was stable above 1,150 tonnes/day. Similarly for the 4X10 slitting, started on February 2010, when on the first day the customer was able to produce 800 tons of good quality product.

Another example is Kroman Çelik in Turkey, where slitting 4X10 and 4X8 were added to slitting 3X12 on May 2009. The results of the start-up of the new products are given in the diagram below.

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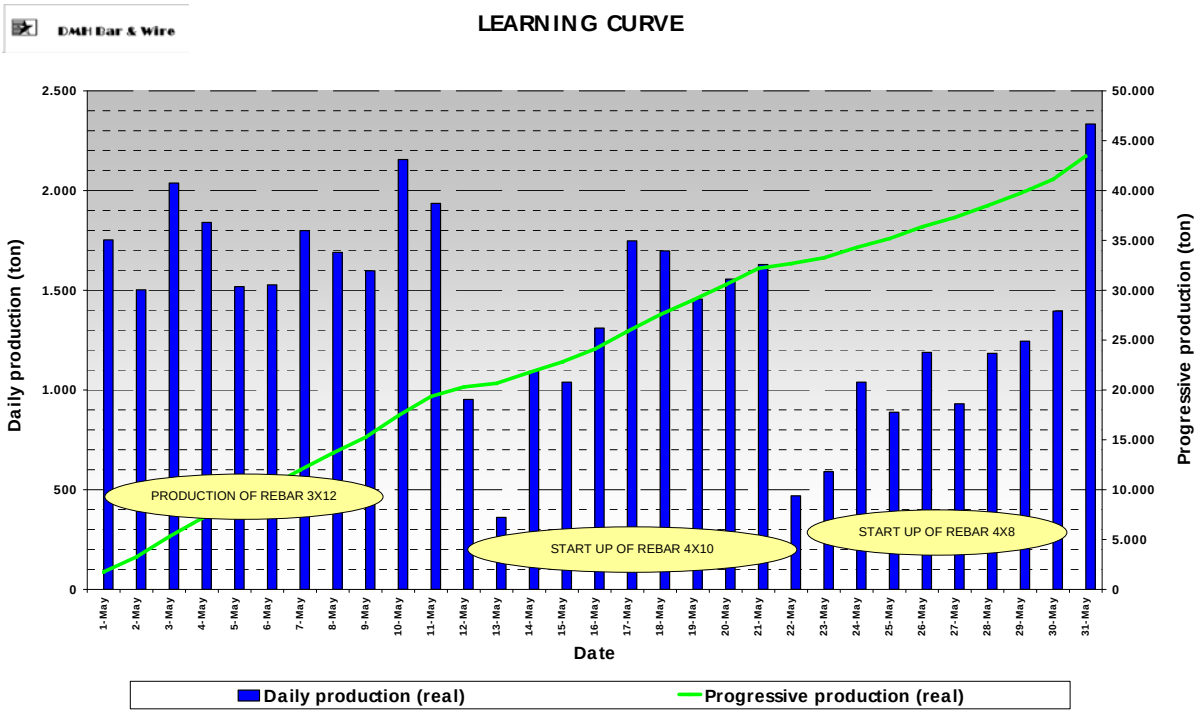

Figure 11: productivity data during the multi slitting start-up in Turkey.

The above experiences have been done on new rolling mills with new equipment, but similar results have been obtained also when multi-strand slitting technology has been applied on existing mills. For example, in Arequipa (Perù) the production of 3/8" rebar exceeded 1,200 tons starting from the fifth day after the start-up. In this rolling mill the customer requested very close tolerances on weight between the different strands (the difference on linear weight between the four bars is requested to be within 3 grams); in this case it is therefore extremely important to have all the customer personnel well trained on maintenance and operating procedures. That's the reason that Danieli experts assisted the customer also in further rolling campaigns in order to obtain the required results.

Figure 12: Linear weight of the four strands.

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9 CONCLUSIONS

We have here analyzed the reasons that introducing the multi-strand slitting process can be interesting both on new and existing mill. Together with the dedicated analysis of process and rolling conditions, the main equipment used in multi-slitting technology has been described, with particular attention to the guide systems. To achieve stable and reliable rolling conditions, the equipment needs to be designed, manufactured, maintained and prepared considering that multi-strand slitting processes are more critical if compared to standard single strand rolling. It is therefore important to develop a project for multi-slitting operations with an experienced and reliable supplier, like Danieli. But equipment is not the entire solution: it is highly important to involve all the personnel, giving dedicated training and advice, in particular during the start-up of this process. It is therefore essential to have a supplier with all the know-how and resources to grant the assistance during the rolling campaign. In this way, the learning curve will be much shorter and the production results will remain high during the following campaigns.