NEW ACHIEVEMENTS IN EWR ENDLESS ROLLING PROCESS, THANKS TO BILLET K-WELDING TECHNOLOGY

BY

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SYNOPSIS:

Since more than two decades Danieli is front running the development of EWR (Endless Welding Rolling) Technology, which consists in continuous welding of billets between the re-heating furnace and the rolling mill in order to establish a continuous rolling process. This technology brings a wide array of benefits, especially in due course of modernization of the rebar industry. The elimination of the inter-billet gap allows to eliminate head and tail cropping and provide much higher stability in the rolling in both slit and single strand modes. Furthermore, in case of production of rebar on cooling bed, the EWR eliminates the short bars and, in case of shifting the production from bar to coil, the K-Welding technology is the key to feed and allow hot rolled coil spooler to produce tailor made weight compact coils up to 8 Ton. Depending of the mill configuration and its initial capacity, the implementation of an EWR process can drive to increase of production from 8% to 12% and yield improvement up to 1,5%. Study and development on this Technological Package can allow nowadays to operate in EWR mode also for output requirements far over 200 Ton/h covering a wide array of steel grades and production segments. The areas of last development are including and not limited to Automation and process control, spark/spatter containment thanks to new “spark killer” solution, amongst the others, and brought substantial improvement in a technology that – even well known since many years – has now reached a proven level of consistency in productivity and operational reliability. Worldwide markets, and particularly Far East markets, are moving to a challenging phase of process modernization which ultimately target to quality improvement, expanding in new products while reducing operational and production costs in effective manner.

Keywords: EWR Endless Welding Rolling, billet welding, rebar coil, spooler.

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1. INTRODUCTION

A number of technological developments have been implemented by Danieli in the last years in order to improve the process and dynamically control it in full integration with the upstream and downstream equipment. On the other hand great efforts have been made to make the billet welder highly performing, even easier to operate and to maintain with less demand in time, thus increasing the rate of utilization.

Main fields of design improvements embraced amongst the various:
- Containment of spark and spatter material diffusion during the butt-welding process.
- Automation platform and dynamic control of the welding process.
- Integration of Induction Re-heating system for the optimization of use of gas fueled re-heating furnaces and consequent reduction of the scale generation.
- Development of a new generation of spooler lines for production of “tailor made” weight hot rolled coils up to 8 Ton, featuring homogeneity of mechanical properties and dimensional tolerances with “twist free” characteristics.

Also Far East is moving in the most recent year toward the same approach started in Europe at end of 90’s and extensively implemented this last decade and half of the new century: the cut&bend industry downstream prefers to process small and medium rebar sizes in coil, thanks to the possibility to virtually minimize to zero the scrap and meanwhile produce on highly automated equipment allowing higher pro-capita productivity rates.

The hot rolled compact coil material has various substantial advantages in respect of wire rod and re-coiled/stretched coils. First of all, the consistency and stability of the mechanical and geometrical characteristics throughout the whole un-coiling, which means easier set-up of the process equipment, no need for repeated adjustment due to sudden change of required straightening parameters and, non the less, the possibility to straight the material applying relatively low pressure on the rollers, which benefit the condition and the height of surface ribs.

The compact coil is substantially deprived of “twisting” stress memory and the material is practically no twisting at all during downstream processing.

The modern cut and bend industry is already able to offer equipment for cut&bend processing of hot rolled coil up to 28mm and 5 Ton in weight; it is reasonably expected to see within the next few years a step forward up to 32mm and 8 Ton weight.

This paper presents primarily the advantages offered by the billet welding and the endless rolling process in terms of improvement in productivity, yield and overall stability in the rolling practice. Furthermore, it offers an overview of hot rolled coil spooling competitive advantages.

As mentioned above, depending on the mill configuration and its initial capacity, the implementation of EWR process can lead to a direct increase of production from 8% to 12%, in case both the RHF and the Rolling Mill have a residual un-exploited capacity.

In any case, under the circumstances that neither the RHF, nor the RM output can be enlarged, the EWR allows the reduction of the rolling speed guaranteeing at the same
time that the full productivity is achieved while the engaged rolling power and the utility consumptions are decreased, electricity above all else. Nowadays, modern EWR systems are designed and installed for output overtaking 220 TPH; also in relatively small lay-out – with available space between the furnace and the roughing mill even below 25m – is possible to install a K-Welding unit.

![Figure 1: K-Welding Plant in operation at Ferriere Nord (Pittini Group), Italy](image)

2. THE K-WELDING/EWR SYSTEM

The EWR process eliminates the inter-billet gap time, the bar head & tail cropping during rolling (as well as the short bars in cooling bed for bar mills and coil trimming in wire rod production). Furthermore, the risk of cobbles occurrence can be significantly reduced; therefore, the EWR process can rationalizes the maintenance, the spare parts & consumables demand, thus resulting in average 4 to 5 USD/ton savings in production cost.
Main advantages of the endless rolling are the followings:

<table>
<thead>
<tr>
<th>Features</th>
<th>Benefit</th>
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<tbody>
<tr>
<td>Elimination of inter-billet gap time</td>
<td>An increase in production capacity that can range from 8% up to 12% in case an unexploited capacity is available in the RHF, since RM operative condition don’t need to change. In case of no-increase of the nominal output, it is possible to achieve same output at lower rolling speed with consequent saving in power consumption and tear of consumables and operational parts.</td>
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<tr>
<td>No head and tail cutting</td>
<td>Increase on yield ranging from 0.7% to 0.9% depending on the specific roll pass design and crop shears lay-out</td>
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<td>Higher operational stability in the Rolling Mill</td>
<td>Consistency of set-up due to the rolling of “one single” endless billet</td>
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<td>Minimize cobbles</td>
<td>Reduction of cobble occurrence risk of approx. 70%</td>
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<tr>
<td>Elimination of short bars from the cooling bed</td>
<td>Increase on yield typically higher than 1%, depending on the specific roll pass design, the product size and level of rolling mill automation</td>
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<td>Longer life of rolling equipment</td>
<td>Drastic reduction of number of head biting in the rolling stands and guides, with consequent dramatic decrease of mechanical hits and improved temperature stability during rolling</td>
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Various Plants have been designed and installed during the last twenty years and significant experience has been matured on the field in order to improve the reliability of the whole process as well as of the individual functions (mechanical, electrical & automation, hydraulic and pneumatic)

### 3. SPARKS AND SPATTER MATERIAL CONTAINMENT, THE SPARK KILLER

The welding is obtained by establishing a controlled electrical arc between the two billet ends with purpose to melt steel material on both sides in enough volume to be subsequently “squeezed” and bond together by means of a hydraulic upsetting device. Part of that steel material is actually “spread” out of the two billet ends. The total amount of this “removed” material should be accounted as loss in plant yield (ranging from 0,2 to 0,3% in weight of a 12m billet) and it directly depends of the billet size.

Since earliest experiences in establishing the EWR process one of the main challenges resulted in an effective containment of the sparks and spatter material (even in relatively big chocks) generated during the joint welding. This material, whenever uncontrolledly spread around the welding area, sticks above the welding unit components and the disappearing roller system including sensors and encoders in a potentially detrimental manner. A “clean” welding plant is easier to inspect and obviously offer a longer durability of mechanical and electrical components.

New innovative spark killer systems are designed to be displaced around the billets joining area before the start of pre-heating and subsequent flashing phase. A large amount of sparks and spatter material, primarily the one that shoots over the top and on both sides of the joint is literally “trapped” inside a “box” and discharged down under upon completion of the welding.

Such “self-cleaning” feature allows to collect and to contain over 60% of spatter material. The remaining material, generated from the lower side of the welded area, goes directly to the collecting devices, such as chutes and boxes or dedicated conveyor.

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<tr>
<th>Mechanical Characteristics</th>
<th>Limited alteration – within acceptable ranges – of yield and tensile stress values; very limited decarburization and modification of grain size in the welded area</th>
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The figure below offers a clear image about the efficiency of this new system, comparing the capability to collect and re-use spark/spatter material with or without a spark killer device.

Thanks to the experience accumulated in real and actual operational conditions, it can be affirmed that the new spark killer design substantially helps in reduction of inspective and maintenance routines. In good practice, the spark killer will merely require a “rotation” on periodical basis (typically each seven up to ten days of continuous production), as the removed one undergoes to an easy routine of inspection and cleaning. Obviously, other on-field components will also substantially benefit from the “spark protection”.

4. DYNAMIC CONTROL OF THE WELDING PROCESS

A modern and effective automation system is the key element in controlling the welding process and assures the achievement of the required level of quality and process stability. A successful and well-executed welded joint shows the following primary characteristics:

- Robustness and mechanical stability of the joint during the rolling process and no surface defects on finished product.
- Acceptable values of decarburization (in the welded area) which are nowadays consistently observed within a variation range of 4% to 8% maximum for all low and medium carbon grades, that is grades up to 0.4% of carbon content.
- Absolute deviation in Yield and Tensile strength values typically not exceeding +/- 8% of the natural one.

Poor homogeneity in the melting material, the presence of cavities and gas bubbles inside the welded area might compromise the achievement of the above parameters. The main reasons behind these defects are commonly identified either in the instability of the electric arc or in an unsatisfactory execution of the upsetting phase, more specifically in terms of applied pressure and achievement of the needed geometrical “squeezing” between the two billets ends.

Therefore, the automation system is devoted to keeping a strict and punctual real time monitoring of the following main parameters:

- Temperature of the billets exiting the furnace
- Temperature of joining surfaces based of billet fusion model
- Position of the clamps, the tension between the clamps and the current passing through the clamps
- Burning speed of joining surfaces
- Burned length during flashing
- Melting depth and flashing time
- Pressure and «squeezed» depth during the upsetting phase.

The automation system is based on a LQG (Linear Quadratic Gaussian) controller which implements a non-linear Kalman filter due to arc model non-linearity. The automation system uses following model:
- Billet fusion model
- Upsetting hydraulic model
- Welding arc model
- Power supply model

This K-Welding controller gives high levels of performance and robustness even in case of uncertainties/perturbations or change of plant dynamics compared to classical PID controllers.

The LQG controller takes account of the clamps DC voltage Vm, the clamps DC current Im and the position of the clamps (dXm). The weld arc length, dLarc, and the amount of molten material during the process are estimated using a thermal model. The controller generates the references for the upsetting servo valves, which control the distance of the head and the tail to be soldered, adjustments to the length of the arc and generates the reference for the bridges to achieve the required welding power.

Thanks to the implemented robust control, almost all welding cycles are repetitive with respect to flashing time and molten depth. The automation system is able to detect fluctuations and/or deviations of real time monitored parameters from the ideal welding cycle and advise operators whether a specific parameter is moving beyond the preset threshold levels. In common cases, the variation of billets temperature, surface conditions and geometrical tolerances lead to slight variations of welding cycle and therefore, automation system self-adapts the flashing time and the arc power to achieve the right amount/depth of melt material which is, as stated before, one of key parameters for quality joints.

A billet welding plant should always provide an extra available stroke, in addition to the design welding stroke – to accommodate extra welding time in case of altered cycle, for whatever reason.

Beyond that there is the possibility of “critical levels” of deviation. These are those which identify the execution of a weld being carried out with parameters that are potentially affecting the acceptable quality level; these generate an automatic alarm and an abort procedure which helps to avoid a wrongly executed weld being fed into the rolling mill.

5. OPTIMIZATION OF PROCESS TEMPERATURES AND Q-HEAT INDUCTION HEATING INTEGRATION
In principle, the K-welding standard lay-out foresees the installation of a descaling unit. It covers the primary function to descale the head and tail of the billets to be weld to achieve the better electrical current conduction. Nonetheless, in the last few years three main factors contributed in considering this design aspect from different angle:

- Poor efficiency of traditional gas fired Re-Heating Furnaces – generally between 50% to 55% of the total engaged power – and scale generation, which tends to dramatically increase from 0.7% up and over 1% and more when overtaking 900°C level.
- Urgent necessity – also in respect of local legislations – to reduce pollution emissions, CO2 especially and generally to reduce the ecological footprint of the steel production activity.
- To feed the billet welding plant with a “de-scaled” material (scale does not only contribute in the dirtiness of the plant, but also marginally in “disturbing” the signals required by the automation system) and equalize as much as possible head with tail and consequently the overall “endless billet” feeding the rolling mill plant.
- To conceive “flexible” plants able to combine higher utilization rate and variability in recipes management when operating with hot or cold billet charges.
- In various Far East countries it is possible nowadays to access.

A new generation of plants is therefore shifting to the adoption of induction heating just before the RHF exit and the K-Welding plant. Induction heaters are preferably positioned between the welder and RHF only, in order to keep the welder itself as close as possible to the roughing mill. However effective solutions can be also implemented in having additional modules after the welder itself, in order to implement an even more accurate control of the temperatures and material equalization.

For example, by delivering out of the RHF at 950°C (a level whereas the scale generation is still very low, around 0.1 to 0.2% for low carbon grades), throughout a first set of IH modules the welding temperature can be easily set up at a level ranging from 1,000°C to 1,050°C. By that, it will be also possible to better control the head and tail differential in temperature, assuring an optimum welding cycle from a timing and process stability points of view.

Figure 4: 8MW Induction Heating System in operation
A second IH module can help after welding, to stabilize the ideal 1,050°C necessary to initiate the rolling at the first roughing stand. Modules configuration, in number and individual power can be easily tailor made in consideration of material grade and size and obviously the rolling speed.

6. INTEGRATION WITH K-SPOOL HOT ROLLED COIL SPOOLER LINE

The establishing of the EWR process is the pre-cursor of an approach to production of hot rolled coils of customized weight; already installed plants can produce coil in weight up to 5 Ton, meanwhile design is already available to move further on, up to 8 Ton. The Spooling process consists of twist-free coil formation by regular and “intelligent” distribution – assisted by a sophisticated system combining high-resolution detection camera and laser technologies - of the rolled and on-line control-cooled bar into subsequent homogeneous layers on the Spooler horizontal rotating drum. Bar controlled cooling, before spooling cycle, is another key factor playing an important role in this innovative process. Optimized bar cooling throughout the bar section makes it possible to obtain a homogeneous product, fully complying with ductility requirements. Furthermore, the optimized-cooling capability provides constant quality with extremely small deviations in material characteristics amongst the various heats that form a production lot of the same steel grade.

Figure 5: Horizontal Drum station ready for coiling and 20mm rebar coiling in progress

The typical Spooler plant consists of two coiling lines alternating each other, equipped with a single extraction fork and strapping system. Double spooler lines, therefore having a total of 4 forming reels, can be installed to serve two strand slitting mode rolling. A common benefit of these technologies is represented by the possibility to be applied also to existing Rolling Mill plants, as long as the plant lay-out has the availability of the necessary technological lengths, specifically:
- Length between the RHF exit and Roughing Stand #1 to install the billet welding plant
- Length necessary to operate temperature control, quenching and self-tempering of the material
- Length necessary to brake the bar rod upon completion of the "spooling" taking in account bars size, the finished speed and the inertia of rotating masses.

![Figure 6: Spooler plant](image)

The hot rolled coil, commonly called as “the spool” is taking a major role in the worldwide downstream industry, especially the cut&bend sector serving the construction industry with pre-shaped rebar steel reinforcement. This material in fact actively responds to a number of issues and optimization needs on both productivity and safety sides. Only to mention the most important ones:

- Possibility to transfer production traditionally made out of straight rebar, labor intensive also on semi-automatic equipment and scrap generating (regardless the intensive use of optimization/scheduling software) to “coil” processing adopting automated equipment, less workforce, improving safety while drastically reduced the scrap to a negligible amount.
- To process material with high ductility, consistency of geometrical and mechanical characteristics all along the whole material decoiling and, very importantly, being virtually twist-free, thus absolute minimum “rotation” of material along the longitudinal axis allows the processor to produce shapes (stirrups, link as well as large shapes) precisely within tolerance and in full planarity.

The market drove for production of coils in even larger sizes; as long ago as 2005, the possibility emerged in Europe to work 20mm coil, nowadays technology allows the production of up to 32mm and, in actual fact, 25/26mm is already a reality, upstream and downstream. Various market areas, as in example in North America and South Korea are already consistently moving in an analogue direction as the European cut&bend industry. Notable mention should be made about Australia, one of most technologically developed cut&bend industry Worldwide.

The spooler technology can therefore provide:

- Production of compact coil in hot rolled technology that, alternatively to cold-recoiling (stretching) can exploit a saving ranging from 18 to 20 USD/Ton purely on transformation cost.
- Thanks to EWR upstream, possibility to produce customized weight coils to punctually serve the customer in respect of availability and configuration of their own decoiling equipment (that in example might not be fit for 5 Ton coils or more).
- On-line optimized bar cooling before spooling for consistent product quality, fully complying with tensile and ductility requirements.
- Very high filling factor, from 58% up to 62% for bigger sizes, resulting in minimized storage requirements, handling and transportation costs.

![Figure 7: Finished and strapped compact coil produced in Europe and Far East](image)

Furthermore, in endless rolling it has been introduced the “layer cut function” that allows, synchronizing the dividing shear cut with the distributor, to obtain a last layer always completed resulting in a perfect cylindrical coil shape. The last loops are therefore perfectly tied and they cannot slay down or unwind during subsequent coil handling.

## 7. CONCLUSIONS

EWR/K-Welding and Spooler/K-Spool technologies are the breakthrough technological innovations that drive a phase of evolution and heavy modernization especially in the rebar and the merchant industry.

This process vertically involves upstream steel producers and downstream processors.
As highlighted in this paper, the EWR process constitutes the pre-condition for a highly performing, and fast investment repaying, Spooler line. Nonetheless the application of billet welding technology offers full benefit of cost saving, increase in productivity and yield, also when applied to production of straight products on cooling bed, regardless if rebar, rounds or merchant.

Tailor made arrangements and flexibility to adapt these solutions to the existing plants – together with re-engineering and update to the state-of-the-art modern automation platforms with the most advanced criteria of Industry 4.0 – represents a new exciting stage of industry modernization.

Tight technical collaboration and partnership are obviously on the background of these processes. As long as these packages are conceived for improvement of quality, maximization of productivity and material yield, a multi-discipline approach is required, involving design and manufacturing, commissioning and post-sale ramp-up phases, automation and best practices in training of personnel as well as in predictive maintenance.