A Multiplier of Opportunities for Added-Value Plate Production

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ABSTRACT

The Danieli Multiplate: a single facility that can produce wide-heavy plates, light discrete or coiled plate with yield strengths up to 1,800 MPa.

A layout that can process both ingots and slabs, can make straight or cross-rolling, can roll in flat as well as Steckel mode.

The plant configuration includes Danieli equipment for in-line quenching and a multipurpose leveler to cover the widest product portfolio to serve construction, energy, oil & gas, mining, earth moving and defense industry.

The latest installation at Nucor Steel Brandenburg (KY) establishes a new benchmark in plate production worldwide for many years to come.

Keywords: Plate, Startup, Wind Towers, Elcyon, Nucor, Green Steel, Automation

INTRODUCTION

The long-standing partnership and collaboration between Nucor and Danieli has created many successes over the years. Today, both teams are proud to declare another accomplishment, with the successful startup of the 1.2 Mt/yr plate mill complex in Kentucky.

Nucor Corporation, the largest steel producer in North America¹, is now operating the largest plate mill complex of its kind in America, and the widest plate/steckel mill in the world.

DISCUSSION

1. Project Figures

The numbers give an indication of the magnitude of this project: over 450 acres of land transformed from greenfield into steel complex; over 1,500,000 million square feet under roof; more than 30,000 tons of equipment supplied by Danieli; and 260,000 cubic yards of concrete and civil work underline the exceptional scope of the investment, along with the effort devoted to the installation.
The project was well into the manufacturing phase when the world was paralyzed by the Covid pandemic—an unprecedented situation that impacted everything, from how people worked to the ability to move shipments, to entire supply chains.

Danieli Group’s extended manufacturing capabilities were pivotal in overcoming these novel complications: by splitting the supply between Danieli factories in different strategic locations (USA, Italy, Thailand, India), the resilience of the global Danieli team once again delivered when it mattered most.
Danieli ingenuity also contributed to the progress with technological innovation: part of the inspection was, in fact, smoothly carried out through virtual participation between Nucor and Danieli’s teammates, relying on interactive collaboration tools.
2. **Product mix from the new Mill**

At the time of project award, the $1.7B investment for the Brandenburg mill was the biggest in Nucor history. Nucor entered into such endeavor with the goal of positioning itself as the market leader in plate products. In fact, the new mill capabilities cover 97% of the plate market breadth, with almost 500 different plate recipes.

Shortly after the startup of the Brandenburg mill, Nucor announced the production of Elcyon™, the company’s new, sustainable, heavy-gauge steel plate product specifically designed to meet the growing demands of America’s offshore wind energy producers, to build a green economy and its necessary infrastructure.

The market for wind power is expected to grow substantially in the next years, as illustrated here below:

![Figure 7 - Projected new wind capacity from 2023-2030](image)

Rolled via thermo-mechanical controlled processing (TMCP) starting from 12" thick slabs or even thicker ingots at the new mill, Elcyon is the only steel of its kind in the United States.

Along with exceeding Euronorm specs, Elcyon is characterized by larger plate dimensions, improved weldability, and excellent fracture toughness, compared to competing products.

3. **Danieli MultiPlate - Concept and equipment characteristics**

The modern plate mill must demonstrate the utmost flexibility to cope with an ever-demanding market that ranges from construction to shipbuilding and offshore industries, from wind tower manufacturing to agricultural equipment, and many more applications.

Nucor Brandenburg is the latest manifestation of the Danieli MultiPlate concept, a single layout able to produce the widest mix of final products, from ultra-heavy to light plates, from discrete plates to coiled plates.

The configuration is completely customizable according to the specific needs of the project. A description of the main features and tools available in the Danieli portfolio is included in the following section.
— Process flexibility

Ultimate flexibility calls for multiple process routes efficiently combined in a layout able to produce virtually any plate the market demands.

Input material can be either ingots or slabs, with output plates in the form of discrete light, discrete heavy and coiled plate.

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**Figure 8 - Reference technological layout of a MultiPlate mill**

**Figure 9 - Production routes available at the MultiPlate®**

<table>
<thead>
<tr>
<th>Input Material Specification</th>
<th>Final Product Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Slab</strong></td>
<td><strong>Discrete plate</strong></td>
</tr>
<tr>
<td>Thickness</td>
<td>Thickness</td>
</tr>
<tr>
<td>5 ÷ 12 in</td>
<td>(\frac{3}{16} \div 14) in</td>
</tr>
<tr>
<td>Width</td>
<td>Width</td>
</tr>
<tr>
<td>60 ÷ 124 in</td>
<td>60 ÷ 168 in</td>
</tr>
<tr>
<td>Length</td>
<td>Length (max)</td>
</tr>
<tr>
<td>126 ÷ 600 in</td>
<td>120 ÷ 1,500 in</td>
</tr>
<tr>
<td>Weight (max)</td>
<td>Weight (max)</td>
</tr>
<tr>
<td>80 ston</td>
<td>60 ston</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Ingot</strong></th>
<th><strong>Coiled plate</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness</td>
<td>Thickness</td>
</tr>
<tr>
<td>17 ÷ 36 in</td>
<td>(\frac{3}{16} \div 1.25) in</td>
</tr>
<tr>
<td>Width</td>
<td>Width</td>
</tr>
<tr>
<td>43 ÷ 76 in</td>
<td>60 ÷ 125 in</td>
</tr>
<tr>
<td>Height (max)</td>
<td>PIW (max)</td>
</tr>
<tr>
<td>132 ft</td>
<td>1,300 Lb/in</td>
</tr>
<tr>
<td>Weight (max)</td>
<td>Weight (max)</td>
</tr>
<tr>
<td>50 ston</td>
<td>60 ston</td>
</tr>
<tr>
<td></td>
<td>Productivity</td>
</tr>
<tr>
<td></td>
<td>1,200,000 stpy</td>
</tr>
</tbody>
</table>

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— Fine microstructure

A true thermo-mechanical control process (TMCP) is enabled by the tailored technical solutions developed by our designers to produce advanced steel grades such as API X100.

The rolling area consists of a primary descaler equipped with horizontal and vertical headers to process both slabs and ingots.

The reversible Roughing Mill is designed with 80MN of separating force, with the proper opening for ingots rolling and a 44" WR diameter suited for the big drafts which are required during the first rolling stage. On the entry side a powerful vertical edger with 7MN of separating force is used for rolling the edges and for the width control, which is especially critical when the mill is fed with stock of this thickness.

Downstream the RM, the Finishing Mill is equipped with Steckel furnaces. The FM is designed with 80MN of separating force. The 38.6" WRs are provided with Danieli’s OSR technology: the special profiles combined with the shifting and bending grant the maximum profile control in the production of thinner gauges.

The very long master plates produced with the steckel process are instrumental in increasing the overall material yield. The division in mother plates 3,000" long is accomplished by the drum shear, designed with a huge 22MN cutting force: it is capable of separating 2" x 168" plates.

The offshore wind energy sector is one of many steel consumers with an ever-increasing demand for tall and heavy steel structures which require thick plates with a challenging combination of properties: medium/high strength structural with high toughness and weldability.
The solution comes with thermo-mechanical rolling and cooling processes tailored on thick slabs and ingots rolling, aiming for a fine acicular ferrite homogenous microstructure. Numerous process variables effect the acicular ferrite formation process: the chemical composition, austenitic grain size after first rolling stage, the holding gauge promoting sufficient pancaking, the final grain size after rolling and the cooling rate. All of them are controlled carefully in the MultiPlate, as per the sketch below indicating the different phases of the process.

--- Advanced mechanical properties

The Danieli proprietary Exstream II Cooling system reduces the alloying elements required, as well as water and energy consumption, ensuring the prime properties for the steel grades of tomorrow. Due to the very fast response time and global efficiency of the system, a water flow saving of 25% can be obtained when compared with traditional technologies. The cooling patterns obtainable by the system enable production of steel grades using less microalloys. This results in an advantage both in terms of cost, but also in a better weldability of the steel.

Figure 14 - Reference ExStreamII Cooling System
The Exstream II cooling system features an innovative proprietary design of the header, with a very fast response time: less than 1.1 seconds from the valve activation, the water reaches the material surface.

This ultra-fine tuning of the header enables the homogeneous, controlled cooling along the material width & length.

The different products of the portfolio are analyzed through the models developed in-house by Danieli. The rolling and cooling models which define the production pattern and strategy are then validated by the microstructure analysis model, which confirms that the required microstructure of the specific steel grade is obtained.

The following example shows the analysis for a structural A572 Gr50 grade with a thickness of 4".

The Q-MPE is the tool used for the prediction of product quality, in terms of mechanical properties, yield strength (YS) and tensile strength (TS), using process variables recorded from all production chain.
It’s used to maximize the share of prime quality products, to optimize process variables in order to guarantee properties stability and to minimize the amount of Lab Tests to be performed.

The possibility to build tailor made models based on the specific plant data helps achieve outstanding performances in the prediction of mechanical properties: being a self-learning algorithm, as more results become available, the Q-MPE increases its accuracy.

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**Flatness**

Our leveling technology has reached its sixth installment, a testament to the Danieli InnovAction mindset.

The leveler double cassette system proprietary design enables a huge capability extension compared to single cassette.

The important range on the thinner gauges is maximized, without having to trade off the capability on the thicker gauges.

The following diagram of the Brandenburg Hot Plate Leveler with an API X80 product clearly shows the advantage of this design: a 55% increase in range.

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Figure 21 - Reference performance of a Danieli EVO6 Leveler

The control model of the leveler offers a significant increase in plate quality thanks to **process optimization**. Using the flatness gauge close loop, the process control system ensures the perfect quality of the plates in terms of flatness, the overall process optimization thanks to plate inline diagnostic and an increase in quality yield.

Figure 22 - EVO 6 Hot Leveler (Nucor Brandenburg)

— **Shearing**

The electrical rocking type shear of Brandenburg is capable of cutting plates with thicknesses up to 2.36" (60 mm) and with tensile strengths up to 175 ksi (1,200 MPA). Thanks to a recent evolution of the rugged and reliable design of the shears (both the dividing and the side trimmer type), now the MultiPlate finishing lines for light gauges can accept an unprecedented 2.75" (70 mm) maximum thickness.

Figure 23 - View of the dividing shear from the control pulpit
The MultiPlate concept can be enhanced by a range of tools that are ready to be implemented to aid operator activities.

For example, one such tool is the **Q-VPM – Visual Production Management** drawing from the Danieli’s extensive experience in vision systems development.

Recent progress on the machine vision and AI algorithms extended the range of information that can be extracted from video camera images in an industrial environment.

Typical Q-VPM applications range from piece identification and tracking along the line, piece dimensions evaluation, process conditions and status, events detection, anomaly detection and others.

The main target is to support operators in the production monitoring, with useful and reliable information.

In the plate finishing line, a set of cameras capture the images of the incoming plate; the images are processed by an advanced AI powered system which detects the true shape and the position of the product.

![Figure 24 – Typical View of Reference Trimming Line Pulpit](image)

The true shape is utilized by the cut-plan optimization model to create a strategy for both the product movements in the shearing line, as well as the determination of cutting sequences.

![Figure 25 – Plate Geometry Detection](image)  
![Figure 26 – Cut Plan Optimization Model Principle](image)

Having detected shape, position and cutting sequence, the following controls are automated by the system:

- Movement of the positioning devices before the trimming shear, obtaining the best solution both in terms of trimming operation and maximizing yield
- Movement of the positioning devices before the dividing shear and handling of the plate forward movements, obtaining the best fitting of the cutting to length operation at the dividing shear.

4. **Environmental Friendliness**

In terms of sustainability, the Danieli MultiPlate represents a truly green solution, slashing energy consumption by 10% and water consumption by 5% when compared to a traditional plate mill.
Technologies that bring an operation’s carbon footprint to zero by replacing all fossil fuels are furthermore already available in the Danieli portfolio: for example, we manufacture (completely in-house) induction heating systems as well as electric furnaces. Combustion technology also feature burners working with alternative fuels (e.g. H2, oxyfuel).

Notably, Nucor Steel Brandenburg is the first steel mill in the world to achieve the LEED v4 certification (Leadership in Energy and Environmental Design), a more stringent iteration of previous LEED rating systems, which provides a globally recognized framework for sustainability achievement.

The Q3-Premium Quality Execution system, embedding powerful AI, tracks production quality in real time, identifying non-conformities and providing tools to optimize process setup and prevent issues. One important module is the **Q3-DEMS**: the Danieli Energy Management System.

The complete and detailed energy consumption recording, for all energy vectors of the plant, is the base for the supervision of the energy utilization. Advanced analytic tools establish reference best practices and allow gaining a full “energetical awareness” and reduce consumption accordingly.

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**CONCLUSIONS**

The total annual value addition of Danieli MultiPlate technology is substantial when compared to a traditional plate mill, thanks to the energy savings, higher yield and the extremely diversified mix.

Nucor and Danieli spared no effort to ensure the project would be completed smoothly and ahead of a schedule despite the impact of the pandemic. The high level of equipment preassembly, combined with the shipment of the fewest possible number of subunits, contributed to quick erection of the machines, with little to no reassembly required on site.

Nucor’s mission is to supply not only the highest quality steel but also the most sustainable plate products in the world for the nation’s military, infrastructure, heavy equipment, offshore wind, and other markets. Operating the most advanced plate mill in the world, Nucor is all set to establish itself as the benchmark in the plate market.

**REFERENCES**

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