Start-up Experiences at Nucor’s CASTRIP® Thin Strip Casting Facility

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Start-up Experiences at Nucor’s CASTRIP® Thin Strip Casting Facility

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ABSTRACT

On May 3, 2002, the first heat was delivered to Nucor’s CASTRIP® facility at Crawfordsville, Indiana. This heat marked the start of the hot commissioning phase of the project following 12.5 months of construction and 2 months of cold commissioning. The Nucor plant is the first, fully commercial strip casting facility, capable of casting both plain-carbon and stainless steel grades. At an annual capacity of 500,000 tons, the CASTRIP plant is expected to produce steel sheet between 0.7 and 2 mm, when fully operational. Ramp-up of production at the plant is now taking place and the following paper provides details on the construction and operation of the plant as well as some background information on the CASTRIP process.

KEYWORDS - strip casting, twin-roll casting, CASTRIP® technology, hot rolled coil, thin gauge hot rolled

INTRODUCTION

Near-net-shape casting of metal products has long been of interest to metallurgists and the metals industry. Obvious savings in equipment plus efficiencies related to hot and cold working as well as reheating have been the main driving force. For more than a decade, BHP Steel and IHI (Ishikawajima-Harima Heavy Industries) collaborated on twin-roll casting design at development facilities in Wollongong, Australia. The codename for this venture was Project ‘M’ and the project covered laboratory, pilot plant and full-scale development facilities. In 2000, Nucor Corporation joined forces with the team, forming Castrip LLC, a joint venture company aimed at commercializing the new technology. Construction is now complete at Crawfordsville, Indiana, also home to the world’s first thin slab caster. Hot commissioning and casting trials began in early May and the Nucor plant is expected to ramp up commercial production over the next 6 to 12 months.

For the past decade or so, strip casting of steels has been an interesting technical curiosity for the steelmaking community. Many projects and collaborative efforts have been initiated, practically worldwide; however none has been run at a full commercial level for extended periods. With the construction of the Nucor CASTRIP® facility at Crawfordsville, the direct casting of sheet products will become a commercial reality. The following paper describes some of the key process fundamentals of CASTRIP technology and provides details on the first installation at Crawfordsville. Physical properties for typical CASTRIP products are also included.
PROCESS OVERVIEW

The CASTRIP process is based upon the same concepts that Henry Bessemer patented in the mid-19th century. Figure 1 shows a simple schematic of the basics of the process – two counter-rotating rolls that provide a surface or mold against which molten steel solidifies. As the figure indicates, the steel begins to solidify against the rolls just below the meniscus and shell growth continues as it moves downwards through the melt pool. At the roll nip or pinch-point, the two shells are brought together forming a continuous strip, which then exits the caster in a downward direction.

![Counter-rotating Rolls](image)

Fig. 1 – Simple schematic of twin-roll strip casting process.

Although the concept is extremely simple, its application at a commercially viable production level has proven to be extremely difficult. Several technical advancements have occurred in recent years that have made twin roll casting possible at a commercial level. These include:

- High speed computing and process control
- Advanced ceramics and materials (including copper alloys)
- Sensing technology
- Mathematical modeling of physical phenomena

A profile schematic of the Castrip facility is shown in Figure 2, indicating the main features of the process. The ladle and tundish are based on standard steel industry designs, as is the ladle turret (not shown). The tundish feeds a transition piece, which is situated just above the delivery (core) nozzle. The caster does not use a dummy bar for start-up. Upon exit from the casting rolls, the solidified strip is directed to a pinch roll and then through a hot rolling stand. In this transition, the atmosphere is controlled to limit oxide formation on the strip. Equipment from the hot rolling mill through the coilers is of standard steel industry design.

Additional detail on the development of the CASTRIP process, key process metallurgy breakthroughs, and product performance and applications are provided in previously published papers. [1-4]
NUCOR’S CASTRIP PLANT

Construction of the Crawfordsville CASTRIP facility began in February 2001. Fed from the existing EAF shop located less than 0.5 miles away, the CASTRIP caster building includes a ladle metallurgy furnace (LMF) to make the necessary temperature and chemistry adjustments prior to casting. Figure 3 shows a sketch of the general building layout indicating dimensions of approximately 135 meters in width and 155 meters in length. The total length of the casting operation, from ladle turret to coilers is only 60 meters. This is in contrast to a slab caster with reheat furnace and hot strip mill that typically requires 500 to 800 meters of length to make the same hot rolled products.

Fig. 2 – CASTRIP process schematic.
General specifications for the Crawfordsville CASTRIP facility are shown in Table I. Of particular note is the diameter of the casting rolls – 500 mm. This diameter is significantly smaller than other twin-roll casting projects and one of the main advantages of the CASTRIP process. Smaller rolls are less expensive to build, have a lower operating cost and are capable of producing thin, high quality cast products. The CASTRIP process has the capability of casting steel strip at 1.0 to 2.0 mm in thickness, plus a single hot rolling stand to reduce the material another 30%. At casting speeds of ~80 m/min and strip widths of 1345 mm and greater, the output of the plant is expected to be ~500,000 tonnes per year.

Table I – Crawfordsville CASTRIP Plant Specifications

<table>
<thead>
<tr>
<th>Unit</th>
<th>Specification (in metric units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building Dimensions</td>
<td>155 m x 135 m</td>
</tr>
<tr>
<td>Heat/Ladle Size</td>
<td>110 tonnes</td>
</tr>
<tr>
<td>Caster Type</td>
<td>500-mm Diameter Twin Roll</td>
</tr>
<tr>
<td>Casting speed</td>
<td>80 m/min (typical)</td>
</tr>
<tr>
<td></td>
<td>150 m/min (maximum)</td>
</tr>
<tr>
<td>Product Thickness</td>
<td>0.7 to 2.0 mm</td>
</tr>
<tr>
<td>Product Width</td>
<td>2000 mm maximum</td>
</tr>
<tr>
<td>Coil Size</td>
<td>25 tonnes</td>
</tr>
<tr>
<td>In-Line Mill</td>
<td>Single stand – 4 High with Hydraulic AGC</td>
</tr>
<tr>
<td>Unit</td>
<td>Specification (in metric units)</td>
</tr>
<tr>
<td>--------------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>Work Roll Dimensions</td>
<td>475 x 2050 mm</td>
</tr>
<tr>
<td>Back-up Roll Dimensions</td>
<td>1550 x 2050 mm</td>
</tr>
<tr>
<td>Rolling Force</td>
<td>30 MN maximum</td>
</tr>
<tr>
<td>Main Drive</td>
<td>3500 kW</td>
</tr>
<tr>
<td>Cooling Table</td>
<td>10 top and bottom headers</td>
</tr>
<tr>
<td>Coiler Size</td>
<td>2 x 40 tonne coilers</td>
</tr>
<tr>
<td>Coiler Mandrel</td>
<td>760 mm diameter</td>
</tr>
<tr>
<td>Annual Capacity</td>
<td>~500,000 tonnes/year</td>
</tr>
</tbody>
</table>

**COMMISSIONING AND OPERATIONS**

The first heat was delivered to the CASTRIP plant early on the morning of May 3, 2002. Just over a week later on May 11, the line produced its first coil. Over the following months the plant increased its success rate on casts and began to produce full-size, 20-ton coils and empty ladles on a regular basis. In July, the first commercial material was shipped from the plant, to be used by Nucor’s Vulcraft division for structural decking. This material had been side trimmed, pickled, cold rolled and galvanized at the Crawfordsville plant. Typically, two to three 110-ton heats were delivered to the caster each day during the early phases of commissioning. Figure 4 indicates the number of ladles sent to the caster between late May and early August. As of the end of mid-August, 5000 tons of material has been coiled.

![Fig. 4 – Ladles delivered to the CASTRIP plant since late May.](image)

During start-up, manning of the plant has been limited to two crews. In addition, BHP Steel, IHI and Siemens Energy and Automation have had employees on site supporting the Nucor crews. Each crew of 11 has responsibility from the LMF through coil handling of the finished product.
Heats arriving from the melt shop are treated by the LMF prior to casting. Initially, commissioning was carried out 5 days per week, two 8-hour shifts each day. More recently, the crews have been running the plant on a 24-hour basis for 4 days per week to allow better pacing with the Crawfordsville melt shop. The 24-hour schedule is expected to enable 4 ladles per day from the melt shop to the caster. Over the next month or so, two additional crews will be added and the plant will step up to a round-the-clock operating schedule, seven days per week.

In addition to the low-carbon grade that has been the main focus for Nucor’s construction markets, the Castrip plant has cast 409 stainless grades and very low-carbon grades for motor lamination applications. Initial trials with both grades were successful and subsequent heats have been cast. In particular, 409 stainless has shown excellent castability with minimal change in practice, representing a potentially significant cost savings for the production of sheet 409 products.

At the time of writing of the paper, Nucor has limited shipment of the product to internal divisions. This is to provide close monitoring of the UCS (Ultra-thin Cast Strip) product and the applications where it is utilized during early commissioning. More recently, orders have been placed from outside customers and these will be filled over the coming weeks and months.

Photos taken during plant commissioning are shown in Figures 5 through 7. Figure 5 shows a view of the caster deck with the ladle rotated into casting position on the turret. The tundish and transition piece are directly below the ladle but obscured in this view by the upper level of the caster deck. The casting rolls are set in the lower level of the casting deck and material flow of the solidified strip is from left to right. Figure 6 shows solidified strip emerging from the hot mill stand and on its way along the run out table to the cooling section of the line. Figure 7 shows a close-up of the sidewall of a typical UCS coil. Typically there will be a small amount of the edge trimmed from the coil.
Fig. 5 – Ladle on the turret, rotated into casting position at Nucor’s CASTRIP facility.

Fig. 6 – Strip exiting the hot rolling stand during CASTRIP plant commissioning.

Fig. 7 – Typical untrimmed UCS coil edge from the CASTRIP facility commissioning.
CHALLENGES AND NEXT STEPS

As the plant moves from early stages of commissioning to more routine casting operations, a number of key areas will attract focus. Whereas early commissioning was focused more on the operation of the process and full testing of mechanical, electrical, sensing and computer systems, in addition to training of operators, the next phase will concentrate on product quality, yield, throughput from the operations and the cost of production.

The product quality focus will be on maximizing the prime material produced from the line. As was discovered during the development phase of the technology, a host of surface and internal defects can be created during strip casting. The methods for avoiding and eliminating these defects were also developed during the Project M work. Examples of finished coils produced during commissioning are shown in Figures 8 and 9.

Operationally, the challenges will be to work on establishing significant periods of plant operation to determine the financial performance of the technology. Of key interest will be the metal-in-mold time achievable from the process, liquid metal to coiled product yield and overall operating cost figures per ton. Discussions pertaining to expectations and the required levels for commercial success were discussed previously by Herbertson [5] and Wechsler et al [6]. In terms of the casting process and metal-in-mold time, the critical factors are the sequence length, the machine turnaround time and the reliability of the start-of-casting event. Performance during commissioning at Crawfordsville has indicated that the Crawfordsville plant should attain the minimum commercial hurdle rates for each of these parameters. A two-ladle sequence has been performed already and the commercial minimum is projected to be three ladles. The machine turnaround time is dependent on the time required to change several of the main consumables in the casting process – namely the tundish, transition piece, side dams, core nozzle and casting rolls. The current machine design has a target time for a complete change of these components in less than 20 minutes. Recent experience has indicated that this target is achievable. Finally, the start of casting procedure must become reliable, repeatable and routine. This will be a focus area in the coming months.
Fig. 8 – CASTRIP UCS coil banded and prepared for transit to finishing operations.
CONCLUSIONS

The commercial-scale production of steel sheet products via the twin-roll casting process has begun with the start-up of Nucor’s Crawfordsville CASTRIP facility. The production of flat rolled products utilizing the CASTRIP process has many advantages over conventional casting and rolling technology, including lower capital and operating costs, reduced energy usage and emissions, thinner higher value products and a smaller, more flexible operating regime. Further, due to its lighter gauges (< 1.5 mm) and excellent surface quality, CASTRIP products can be substituted for cold rolled sheet in many applications and will likely create a new product category for flat rolled sheet products known as UCS.

REFERENCES

5. J. Herbertson, Dr. Manfred Wolf Symposium, Zurich, 2002, 60.
6. R. Wechsler and P. Campbell, Dr. Manfred Wolf Symposium, Zurich, 2002, 70.