PROFILE SIZING PROCESS (PSP) FOR HIGH-QUALITY MEDIUM/HEAVY SECTIONS AND RAILS [1]

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Abstract
High quality products at ever-lower production costs are the main objectives of producers of hot-rolled sections. Today various rolling mill concepts are available for the production of sections and they are all aimed at the production of superior products with closer tolerances and lower conversion costs. The PSP-Profile Sizing Process is the latest Danieli cost-breaking innovation for the production of superior quality medium and heavy sections and rails. The PSP is the optimal combination of two rolling technologies merged in an innovative process, featuring highly productive reversing rolling in a 3-stand intermediate/pre-finishing mill, plus a single continuous "Sizing" pass at a separate independent finishing stand. Installed after a reversing Break Down mill, the PSP rolling line includes a 3-stand UFR ultra-flexible reversing mill and an independent continuous finishing "Sizing" stand, followed by a HiPROFILE® laser gauge for constant contactless rolled stock measurement and automatic control/self-adjustment of mill rolling parameters through the SCS-Section Control System. This article describes in detail the PSP technology and its application for the competitive production of superior quality beams, sections, special profiles and rails.
Key words: Profile; Section; Rolling-mill.

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INTRODUCTION

High quality products at ever-lower production costs are the main objectives of producers of hot-rolled sections. Today various rolling mill concepts are available for the production of sections, and they are all aimed at the production of superior products with closer tolerances and lower conversion costs. In terms of product mix, preferred solutions for beam and section mills are either a Continuous Rolling Process (CRP) or a Profile Sizing Process (PSP). The latter applies the reversing rolling mode in an UFR intermediate/pre-finishing mill with a continuous finishing "sizing" stand. The various processes and associated product mixes are shown in Table 1.
This article describes the latest Danieli Morgårdshammar PSP technology for the competitive production of superior quality beams, sections, special profiles and rails.

Table 1. Different Rolling Mill Concepts and associated product range

Light Section Mills (CRP process	Medium and Heavy Section Mills (PSP process**)**
Beams up to 300 mm Channels, angles etc.. (flange height up to 200mm)	Beams up to 1,100 mm Channels, angles, sheet-piles, special sections, rails, etc.. (flange height up to 400mm)

THE PSP - PROFILE SIZING PROCESS

The PSP-Profile Sizing Process is a cost-breaking innovation in the production of superior quality medium/heavy sections and rails. It is the optimal combination of two rolling technologies merged in an innovative process, featuring highly productive reversing rolling in a 3-stand UFR intermediate/pre-finishing mill, plus a single continuous "sizing"pass at a separate independent finishing stand. The process finds its ideal application in medium and heavy section mills for the production of H beams up to 1,100 mm (flange height of up to 400 mm) equal/unequal profiles, special sections and rails. Installed after a reversing breakdown mill, the PSP rolling line includes a 3-stand reversing mill and an independent continuous finishing "sizing" stand, followed by a HiPROFILE® laser gauge for constant, contactless rolled stock measurement, and automatic control/self-adjustment of mill rolling parameters through the SCS-Section Control System. The PSP process provides the following main benefits:

- Superior products with closest possible tolerances.
- Very economical production with low conversion costs.
- High material yield.
- High mill utilization factor thanks to quick changing systems.
- Most flexible roll pass design possible, also in view of a future extension of the product range.
- Extremely productive equipment ensuring high hourly production.
- Less spare parts demand thanks to standardized equipment.

The independent finishing "sizing" stand concept is one of the highlights of the PSP process, substantially contributing to the achievement of the above mentioned benefits thanks to its unique features, i.e.:

- The "sizing" stand is in operation only for the finishing pass, providing the best possible tolerances due to small reductions and longer life of rolls and guides.

- Best surface quality of the finished product due to reduced contact between the stock and the finishing stand rolls and high rolling temperatures.
- Lifetime of tandem group rolls not determined by finishing stand, thus resulting in longer roll lifetime.
- Maximum roll pass design flexibility for future extension of the product range.
- Installation of the Danieli Automation HiPROFILE® laser gauge close to the finishing stand, thus enabling direct feedback on the same bar.
- Up to 40 % higher production for rolling of channels.
- Multi-groove finishing rolls (for two-high rolling), thus providing limited idle time.

All of this means higher plant productivity, better efficiency, superior product quality and reduced transformation costs.

PSP PLANT STARTING SECTIONS AND PRODUCT MIX

The optimal size, length and/or weight of the starting section is chosen case by case depending on the actual product mix.
Today there is a tendency to use, a section which is already close to the end product dimensions. In this connection a typical beam blank web thickness is between 80 and 100 mm, whilst flange thickness is chosen accordingly.
The advantage of using a Breakdown (BD) roughing stand is that the beam blank section can be determined either by edging or stretching it according to the leader section size. Thus a wider range of products can be rolled out of the same beam blank.
Depending on the availability of starting sections (as the purchasing market for beam blanks is relatively small) blooms can also be used, particularly in the medium section mill range, by using a BD stand as roughing mill.

THE PSP PLANT LAYOUT

Figure 1 shows a typical PSP layout applied for a medium section mill. The product mix is in the range of IPE beams (100 to 600 mm), HE beams (100 to 300 mm), channels (100 to 400 mm), angles (100 to 250 mm and corresponding sections in ASTM, BS or JIS standards)

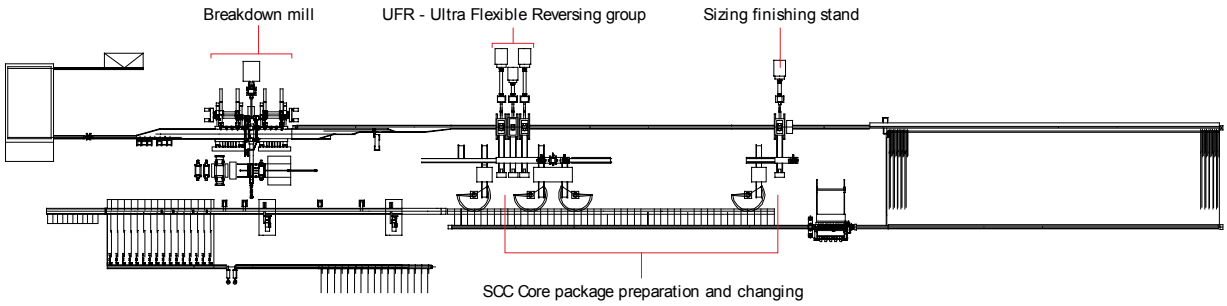

Figure 1. Typical PSP layout applied to a Medium Section Mill

Reheating Furnace Area

Hot charging is a key factor in reducing production costs.
The direct feeding of the starting material at 500 to 800 °C from the continuous casting facilities to the reheating furnace leads to substantial savings in energy consumption. This operating concept, known as the Danieli Direct Casting Rolling process (the so-called Black Box minimill) has been operating very successfully at various plants all over the world since the late '80s. To ensure a high rate of hot charging and maximum operational flexibility, the walking beam furnace is provided with a buffer section on the entry side. With this the mill changes from one section to the next (out of the same starting size) are performed without interrupting the casting process thanks to the fast changing procedures of the rolling mill stands and straightening machines.

The Breakdown Mill

Beam blanks coming from the furnace are fed to the BD mill through a high-pressure descaler to obtain a finished product with perfect surface conditions. The BD stand, fitted with side-guard manipulators and shifting devices, prepares the leader section for the UFR group in 5 to 7 roughing passes. After the roughing stand a metallic disc saw produces a clean head to make sure that it enters the UFR group properly.

THE UFR-ULTRA-FLEXIBLE REVERSING MILL AREA

The UFR group consists of three identical SCC mill stands, operating in U-universal or in H two-high mode, depending on roll pass design requirements. A stand of the same type and size, acting as a "sizing" mill, is also used in the finishing mill. The so-called SCC (Stand Core Concept) super heavy-duty stands, designed according to the latest section rolling technology, feature:

Figure 2. SCC stand in operation.

- Highest possible mill stand stiffness due to short force pass flow, resulting in small deflections under load and better product tolerances.
- Fully hydraulic adjustment system featuring under load adjustment.
- Automatic Gauge Control system in combination with the Danieli Automation HiPROFILE® Laser Gauge and SCS Section Control System.
- U-universal or H two-high mode possible for all stands.
- Fully automatic guide and roll set changing procedure (plant production stoppages for size changing in only 20 min).
- Zeroing and mill modulus determination after each changing procedure.
- Different H-chock centerline for U and H modes resulting in lower stand deflection.

- Adjustable guiding system for automatic, simultaneous movements resulting in close guiding of the stock during the reversing passes.
- Standardization of components on the 3 tandem stands and finishing stand, resulting in capital investment savings for spare parts.
- All stands are shiftable, thus the rolled stock always remains on the roller table centerline (fixed pass-line concept).

The SCC is the latest generation “housingless” stand, the well known concept originally developed, patented and introduced into the market by Danieli Morgårdshammar back in 1948. Since then more than 5,700 “housingless” stands have been supplied worldwide in all different kind of applications.

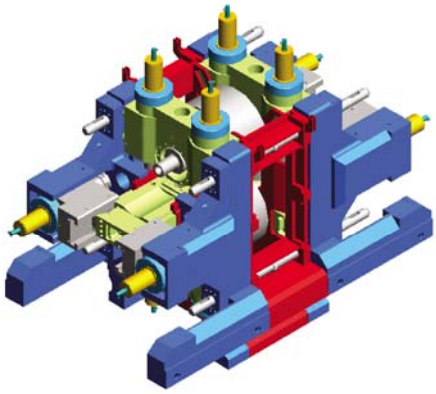

Figure 3. 3-D view of the SCC roll unit

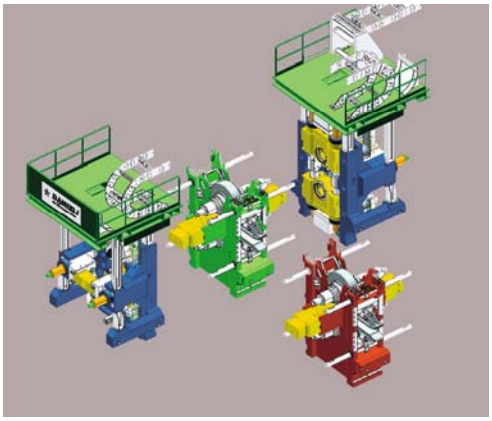

Figure 4. 3-D view of SCC stand automatic changing concept

The sizing finishing stand area

The continuous finishing SCC stand is the same type and size as the UFR group stands. The separate finishing “sizing” stand concept greatly contributes to the PSP advantages described in the previously paragraph. Just like the others, the finishing stand is also equipped with a parallel liftable roller table section in front and behind as well as a centering device.

A Danieli Automation HiPROFILE® Laser Gauge is arranged after the stand for constant contactless measurement of the final dimensions and, if necessary, for feedback control to the finishing stand or to the tandem group automatic gauge control system for adjustment within the same bar or from bar to bar.

Figure 5. HiPROFILE® laser gauge system

Double-support straightener under final assembly,

Stacking unit at Nucor Berkeley - USA

Cooling bed and finishing services

Depending on product mix either a walking beam or chain-type cooling bed (with or without water cooling system) can be provided. In the PSP plant, the cooling bed is designed for full-lenght as-rolled products, increasing material yield.

In order to avoid rest-ends, the automatic gauge control system operates in connection with the mill stands to adjust the as-rolled length by setting product tolerances within the respective standard. Thus the as-rolled length between different beam blanks can be equalized and large differences from one bar to the next are avoided.

Furthermore, this can be used to adjust the length to fit the required as-rolled length for the multiple finished length. Sampling and tail-end cropping are performed by pendulum saw at cooling bed entry for safe feeding to the straightener and elimination of non-transferable rest ends.

At the cooling bed delivery side, depending on product mix, a cantilever or double-support type / fixed or variable pitch straightener with 9 or 11 straightening rollers is installed. The latest-generation double-support straighteners provide high dimensional product quality and efficiency (automatic robotized roll replacement in 20-minutes, in line with rolling mill program changing procedures).

After straightening, full-length bar layers are transferred to the cut-to-length area, which is fitted with two cold saws and associated overhead beam-type gauge. These units, as well as the one on duty at cooling bed entry, are equipped with special mandrels for quick changing of cutting-disk. All saws can be installed in a noise-proof cabin to provide noise protection for the operating personnel.

After cutting, products are delivered to the stacking station for the formation of regular nested or un-nested stacks, depending on product shape. Typical stack weight ranges from 1 to 6 ton or up to 10 tons in the case of heavy sections.

Stacks are then transferred through a strapping line and finally loaded onto the shipping bed.

Figure 6. SCC stand in operation at VAS

The Roll Preparation Area

To increase flexibility in the rolling schedule the SCC stand has been designed in such away that only rolls, guides and V-chocks (the stand “Core” package) are changed and automatically replaced with a new previously prepared package before the changing operation starts. Special attention has been paid to the automated, simultaneous roll and guide changing procedure in order to ensure the minimum lot size possible and the highest mill availability (only 20 minutes of plant production stoppage for size changing).

The Roll Pass Design

The separate continuous finishing “sizing” stand is the optimal solution for the production of superior products with higher production (even for smaller product sizes), best product tolerances and surface quality in modern section mills, enabling easy roll pass design expansion for possible future additional
products as well. Low conversion costs and maximum plant flexibility are achieved. In addition to the above, the PSP roll pass design gives specific advantages if compared to other systems:
- Less roll wear at high temperatures during the rolling process and only one run per bar for the finishing stand.
- Maximum roll pass design flexibility for future products.
- Equalized reductions between U1 and U2, meaning that standardized equipment (even main drives) can be used.
- Multiple finishing grooves possible with two-high rolling, resulting in higher mill utilization factor.
- Up to 40% higher production for rolling of channels compared to a rolling concept without a separate finishing stand.

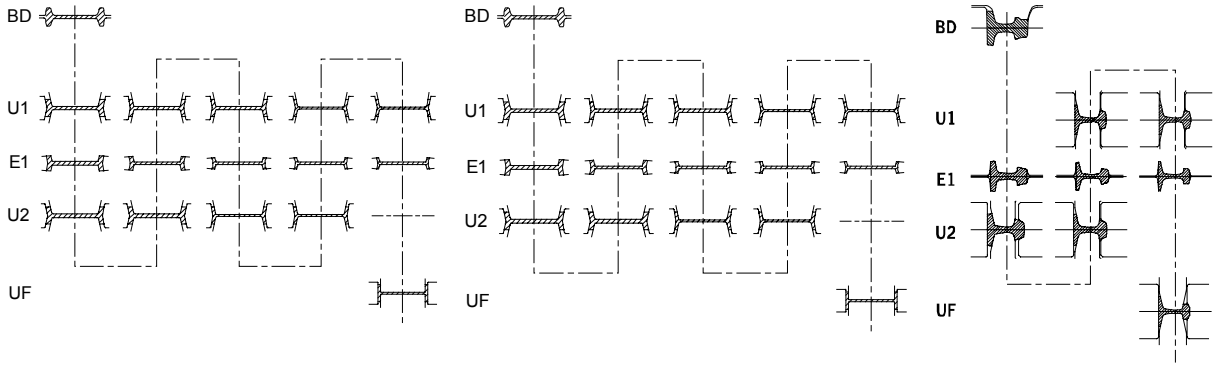

Figure 7. PSP Typical pass design for beams, channels and rails

Rolling of Beams

The leader section coming from the roughing mill is processed in 3 to 5 passes in the UFR group. In all these, except for the last one, both universal stands (U1/U2) are simultaneously in operation. In the last pass only U1 is in operation and the final “sizing” reduction is performed in the separate universal finishing stand. The edging stand performs the necessary flange edging to ensure the final flange width.

Rolling of Channels

In the production of channels both tandem group universal stands are always simultaneously in operation, resulting in a production increase of up to 40% if compared to other mill concepts without a separate finishing stand. The edging stand is multi-grooved for the different edging passes, whereby the respective groove is shifted in line according to the pass schedule. In the last run through the UFR group, just like for
the rolling of beams, stand U2 is open and the final section is “sized” in the separate finishing stand.

Rolling of rails

The PSP plant applies the universal rolling method for rails, which, compared to other processes, has the following advantages:

- Superior product tolerances.
- Less friction between roll & rail resulting in a better surface of finished rails and a higher lifetime of the rolls.
- Symmetrical shaping of the rails.
- No opening / closing of finishing stand rolls, thus more reliable rolling conditions and no intermediate contact between finishing rolls and guides during prior contacts.
- Reduced internal stresses.
- Furthermore it results in various advantages for the production of the rails due to the fact that 3 different shaped universal stands are used.

Rolling of other sections

Other sections such as angles, sheet piles or special profiles can be rolled in U-universal or traditional H-two-high modes. All different pass design schemes share the advantage that the operation of the separate finishing stand is independent from the tandem mill.

THE AUTOMATION PROCESS

An advanced automation system controls equipment and process on-line functions. The main functions are: sequential control of the movements of the mechanical equipment, closed-Loop Control functions, set-up calculation function and logging of the process parameters.

A PLC and microprocessor-based system automatically controls the equipment in the reversible stand area by means of level 1 and level 2 systems. Level 1 is in charge of the actuating systems ensuring their fastest dynamic performance. Actuator set-up is either by look-up tables (operator adjustable) or by level 2. Level 2 calculates the mill pass schedule by means of a model and provides it to the mill set up to level 1. The model is adapted using field measurements both in a “pass-to-pass” and “piece-to-piece” mode, and can be executed in “off line” mode in order to show its results.

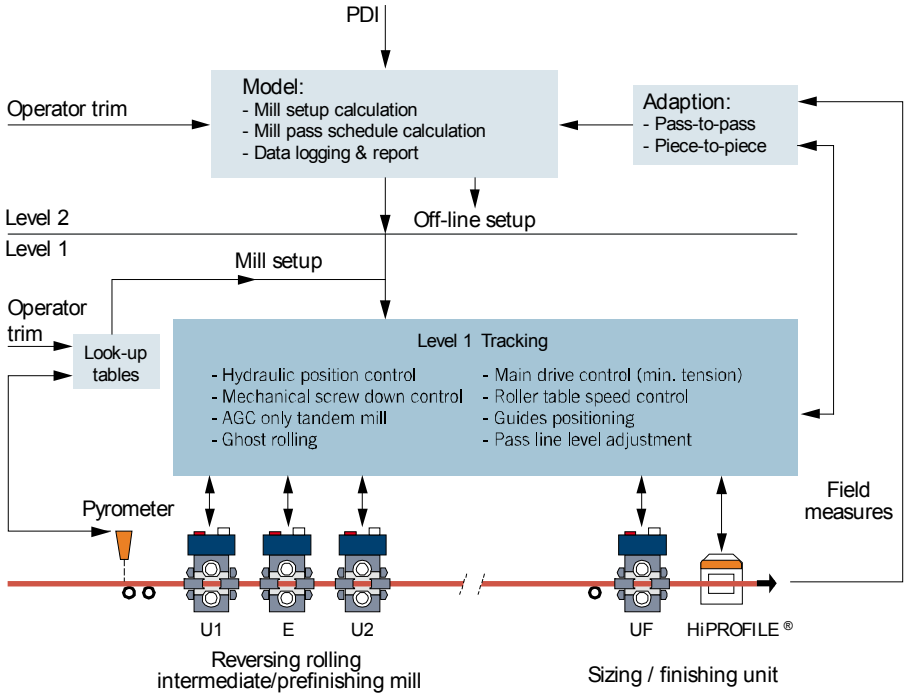

Figure 8. Automation structure of the PSP Profile Sizing Process

The Level 1 control system performs several different functions such as: material tracking, centering guide positioning, roller table speed control, look-up tables for the pass schedules, main drive speed control, hydraulic gap control, automatic gauge control.Level 2 control system is in charge of:

- Pass schedule actualization system for calculating mill setup before entering the tandem group, actualizing the roll gap adjustment according to measured values. The calculation is based on rolling force/rolling torque prediction and bar temperature evolution models.
- Pass schedule adaptation based on measures taken in the field through feedback from the HiPROFILE® laser gauge system.
- Off-line pass schedule calculation.

Part of the process control system, the pass schedule calculation program performs the following functions:

- Calculation of main rolling parameters, providing graphic / numerical outputs for a reversing PSP rolling mill for beams.
- Calculation of the temperature development path on the rolled stock along the mill, considering: radiance cooling in the inter-stand areas, roll water-cooling effect, conduction cooling to the work rolls, heating effect due to mechanical deformation.
- Calculation of intermediate dimension values on the different runs once the feeder size and the required final beam dimensions have been set in accordance with the number of passes.
- Verification of driving motor utilization values, thus allowing the best choice between two possible reduction ratios for each reducer.

- Monitoring of loads acting on the rolls so that they are always lower than the maximum admissible loads.

All calculations are carried out separately for billet head, tail and intermediate section.

PSP economical advantages

The PSP provides considerable benefits in annual costs compared to conventional rolling mills, and even to other rolling concepts without a separate finishing "sizing" stand. Further savings are achievable if the PSP plant operates in combination with hot charging of continuously-cast beam-blanks.

Influence of rolling roll cost

When comparing a PSP-plant with a solution without a separate finishing stand, the initial investment for one roll set and guides is higher for the PSP process. Nevertheless, since in the PSP process the lifetime of tandem and finishing stand rolls is considerably higher than in other solutions, and product output capacity is substantially increased, the initial investment is definitely compensated by the reduced conversion cost.

Latest references in section mills

Danieli most recent references in section and rail production plants include:

Duferdofin Giammoro, Italy: In May 2003, a new SCC universal finishing stand was started up at Duferdofin's heavy structural mill. Installed after existing tandem stands, the unit is the main component of the plant modernization project aimed at increasing product quality, plant efficiency, productivity and material yield. The 125-tph mill produces up to 600-mm parallel-flange beams, up to 200-mm angles and channels.

Panzhihua I&S Co P.R. of China In August 2003 a new "Jumbo"-size combined H/V straightener for high-speed rails started operation at delivery side of the cooling bed for on-line straightening of up to 75 kg/m, 103-m-long quenched rails for high-speed railways, at a rated capacity of over 240 tph.

voestalpine Schienen GmbH, Austria In January 2006 the new rail mill started operation in Leoben/Donawitz. The supply included a new reversing BD mill, plus a 3-stand UFR reversing intermediate/finishing mill made up of SCC stands, suitable for operation in 4-roll universal and 2-roll horizontal arrangement. VAS mill produces all kind of rails such as Vignole rails, grooved rails, crane rails and other special sections for the rail market, rolled in 125-m lengths.

Maanshan I&S Co Ltd (Masteel), P.R. of China A new 500,000-tpy medium section mill for production of up to 400-mm high-quality parallel-flange beams, I-beams and channels started operation at Masteel in March 2005. The plant is made up of 15 SHS housingless stands, 7 of which of Universal type for production of high quality H-Beams. Finishing facilities include cooling bed, in-line straightening, cut-off saws, automatic stacking and strapping services.

Hengshui Jinghua, P.R. of China In February 2004 a new 750,000-tpy super-flexible medium section mill started operation at Hengshui Jinghua Steel Pipe Co Ltd. The product range includes up to 150-mm angles, 300-mm I-beams and channels and up to 350-mm H-beams. A particular feature is the production of special ultra-light H-beams with web thickness of down to 3.2 mm and linear weight of 5.4 kg/m. The 120-tph mill is composed of a reversing BD stand, 10 SHS stands in H, V and Universal arrangement, plus cooling bed, in-line straightening and finishing facilities.

Dongkuk Steel Mill Co Ltd, Korea In June 2005, Dongkuk Steel Mill Co Ltd awarded the order for a new Jumbo-size straightening machine for its Pohang works existing section mill. The new 9-roll double-support straightener will process up to 600x300 or 400x400 H-beams, up to 150-mm angles and 250-mm channels, granting high final product quality with closest size tolerances. Machine startup is scheduled for the 3rdQ 2006.
Siderurgica Balboa (Alfonso Gallardo Industrial Group), Spain In spring 2007, a new 750,000-tpy medium section mill will start operation at Siderurgica Balboa. The PSP-based mill will produce up to 600-mm I-beams, up to 260-mm H-beams, up to 400-mm channels and corresponding flats and angles. The new medium section mill will be part of a new complete 1,2 Mtpy Danieli Minimill which will also include a 1,2 Mtpy steel making and conticasting plant for billets, blooms and beam blanks and a 500,000-tpy multi-line superflexible mill for production of round bars, spooled bar-in-coils, wire rod coils, small and the lower range of medium sections.
Arcelor Differdange, Luxembourg In February 2006 Arcelor, world leader in production of heavy sections, contracted Danieli for the major upgrading of its "GREY-mill" in Differdange, for enhancing efficiency and final product quality. Plant modification foresees the complete re-arrangement of the intermediate/pre-finishing rolling mill area, with installation of a 2-stand universal-reversing Tandem Mill with automatic fast changing system, installed in-line with the present UF finishing stand. The mill's product range includes up to 1,100-mm parallel-flange beams, rolled in up to 120-m-lenghts. Plant startup is scheduled for the 3rdQ 2007.

CONCLUSION

The innovative PSP plant concept results from the synergy of Danieli Morgårdshammar's extensive experience in designing and manufacturing rolling mill plants for long products, backed by the merging of the well-established technologies of Morgårdshammar, Sweden, Wean United, USA, and Danieli, Italy. Today the PSP is the ideal tool for the production of superior quality products with maximum plant flexibility at lower conversion costs and will represent the front-head technology in medium and heavy section mills in the years to come.