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ADVANCED COOLING SYSTEMS – LATEST DEVELOPMENTS[1]

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Abstract

On September 12th, 2010 Siemens VAI signed an order to install an intensive cooling unit at the 2,250 mm hot strip mill of ThyssenKrupp Steel in Beeckerwerth, Germany. The upgrade included the installation of high-capacity interstand cooling headers behind finishing stands to further enhance the mill capabilities especially for pipe-grade steel. As part of the contract, the cooling section automation system was extended to include the new actuators in the existing Microstructure Target Cooling model. In further steps, the model will be upgraded to provide a comprehensive temperature model for finishing mill and cooling section. Carried out as a fast-track project, the new equipment was put into operation as contracted on December 22nd, 2010 and has been in permanent operation since then.

Key words: Cooling system; Finishing mill.

SISTEMAS DE RESFRIAMENTO AVANÇADO – ÚLTIMOS AVANÇOS

Resumo

Em 12 de Setembro de 2010 a Siemens VAI assinou um contrato para instalar um sistema de resfriamento acelerado no laminador de tiras a quente de 2,250 mm para ThyssenKrupp Steel em Beeckerwerth, Alemanha. A modernização inclui a instalação de rampas de resfriamento de alta capacidade após a cadeira acabadora F7 para aumentar a desempenho do laminador, especificamente na produção de aço para tubos. Também parte do contrato, a automação da seção de resfriamento foi incluída para usar os novos atuadores e sistemas no modelo de resfriamento. Numa outra fase, o modelo será atualizado para permitir uma previsão completa das temperaturas na zona do laminador acabador e zona de resfriamento. Organizado como um projeto *fast-track*, o equipamento novo foi colocado em operação de acordo com as condições previstas no contrato original em 22 de dezembro de 2010 e esta em operação desde esta data.

Palavras-chave: Sistema de resfriamento; Laminador de acabamento.

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1 INTRODUCTION

ThyssenKrupp Steel is one of the leading suppliers of high-quality steel in the world. The multinational group of ThyssenKrupp operates hot strip mills in Europe and the United States of America.
In order to improve the metallurgical properties of the strips, especially for API pipe grade material, which shall be produced up to a maximum thickness of 25.4 mm, an upgrade of the cooling line was proposed to extend the cooling capabilities of the mill. The major targets and boundary conditions were the following:

- increase of maximum cooling rate for high-strength material;
- adjustment of flow rate depending on steel grade and strip gauge;
- ensuring uniform cooling conditions from top an bottom side;
- adjustment of top header position.

2 MILL LAYOUT

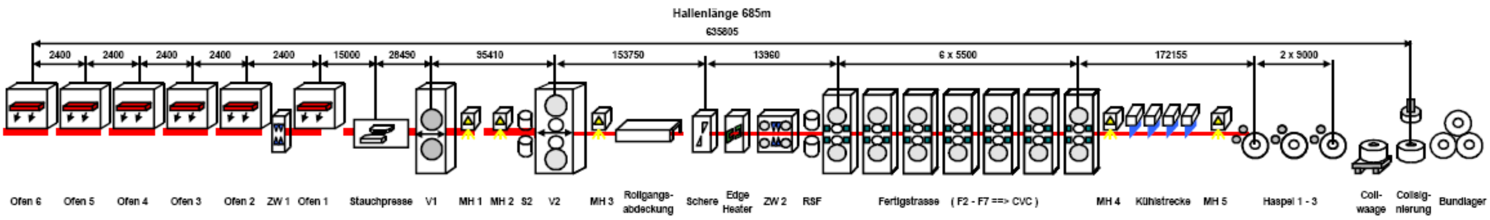

Figure 1. Layout of Hot Strip Mill No. 2 in Beeckerwerth, Germany.

The Hot Strip Mill No. 2 of ThyssenKrupp Steel in Beeckerwerth is one of the most powerful hot strip mills in the world capable of an annual production of up to six million tonnes of steel. It consists of the following major components:

- six reheating furnaces;
- slab sizing press;
- two-high roughing mill;
- four-high roughing mill with attached edger;
- heat conservation panels;
- seven-stand finishing mill;
- laminar cooling line;
- three down coilers.

The automation and process model of the cooling line had originally been supplied by Siemens VAI in 2007. In that project the new Microstructure Target Cooling model was implemented, improving the quality of the cooling results already significantly. The existing Microstructure Monitor from Siemens VAI was integrated in the cooling model at that time.
As part of the new project, Microstructure Target Cooling and the Microstructure Monitor were upgraded. One part of the upgrade is to accommodate the new features of Power Cooling yielding new capabilities in terms of cooling range and possible cooling rates. On the other hand, the model upgrade includes the implementation of the newest development of a comprehensive temperature model, integrating the model calculation of the finishing temperature and the cooling temperature course. This ensures an optimum result for the whole product in respect of microstructure and mechanical properties. An additional feature provided by this model is the calculation of the temperature profile over the thickness

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observed at the pyrometer location in case that the measurement there should not be usable.

3 PRODUCT PROPERTIES

The main characteristics of the products produced at hot strip mill no. 2 are summarized in the table below. The mill is capable of producing both carbon steel and stainless steel.

Table 1. Product properties

Product Properties	Slab	Strip	Coil Data (max.)	
Thickness	150 - 258 mm	1.5 - 25.4 mm	Weight	36 t
Width	650 - 2090 mm	650 - 2030 mm	Spec. Weight	23 kg/mm
Max. Length / Production	10 m	>6 Mtpy	Outside Ø	2150 mm

4 PROJECT TIME SCHEDULE

The complete project was carried out within less than three months from the date of signing:

- signing of contract: September 30th, 2010;
- start of mill shutdown: December 12th, 2010;
- start of operation: December 22nd, 2010.

There were no additional shutdowns in preparation for the mill upgrade. A photo showing a top-header group being installed can be found in Figure 2.

Figure 2. Top-header group being put in place.

5 SCOPE OF SUPPLY

In order to install the new equipment immediately behind the gauge house behind mill stand F7, some of the existing cooling headers had to be removed. The new

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intensive cooling unit consists of 16 height-adjustable top headers and 16 bottom cooling headers as sown in Figure 3.
Moreover, two top and two bottom interstand cooling headers were installed. The take-over point was defined as the main supply pipe of the cooling line.

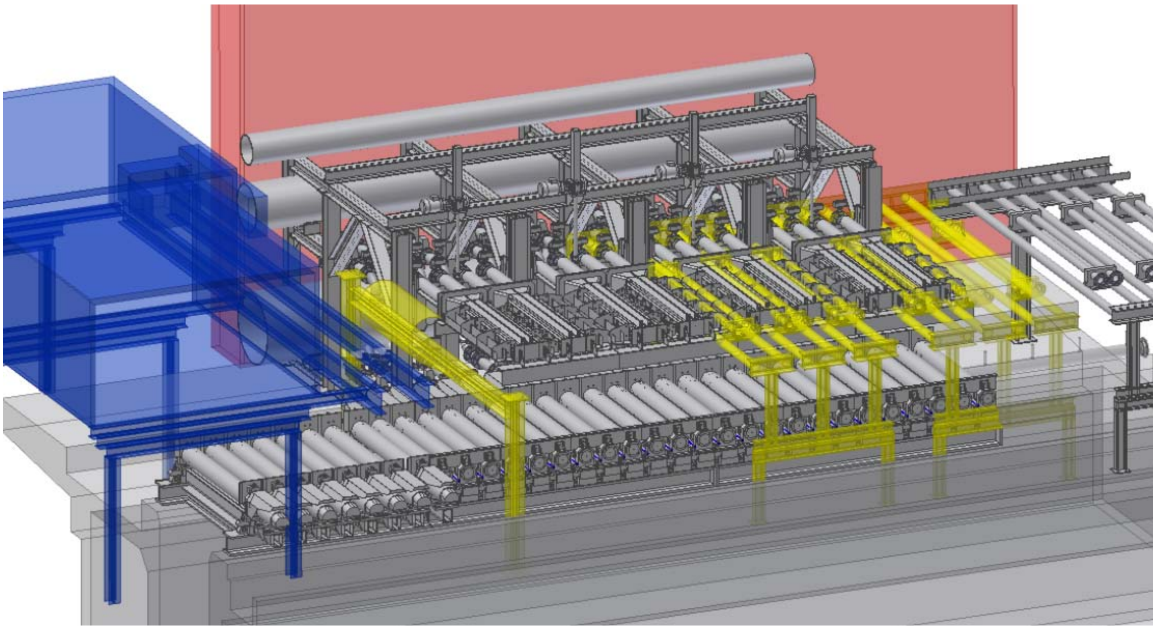

Figure 3. Scheme of intensive cooling unit (equipment to be removed shown in yellow).

6 DEVELOPMENT OF INTENSIVE COOLING EQUIPMENT AT SIEMENS VAI

Siemens VAI carried out an extensive R&D program in cooperation with the Linz University to develop intensive cooling equipment for hot strip mills. Backed by numerical calculations, cold and hot trials were carried out in the laboratory as well as on the small-scale rolling mill at the Freiberg University in Germany.
The major tasks of these trials were the following:

- selection of optimum nozzle type;
- optimization of header design;
- optimized ventilation of header;
- optimization of nozzle pattern;
- selection of proper valve type.

The photo below was taken during a laboratory trial. A plate equipped with sensors that was oscillated underneath the cooling header could be submerged in the mould of a continuous casting simulator to study the effects of a thick water layer on the strip surface.

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Figure 4. Trial at the continuous casting simulator at vatron, Linz.

The first field test of the newly developed equipment was carried out at the hot strip mill of voestalpine Stahl in Linz. Two pairs of headers were installed between the roughing mill and the finishing mill to study the effects under real operating conditions.

Figure 5. Trial at the voestalpine Stahl hot strip mill in Linz.

7 FUNDAMENTALS ABOUT INTENSIVE COOLING

The main reason for the employment of an intensive cooling unit is the need for highest possible cooling rates. In recent years a clear trend can be observed to develop new steel grades with higher strength.[1] A chart showing steel grades currently employed in the automotive industry is show in Figure 6.

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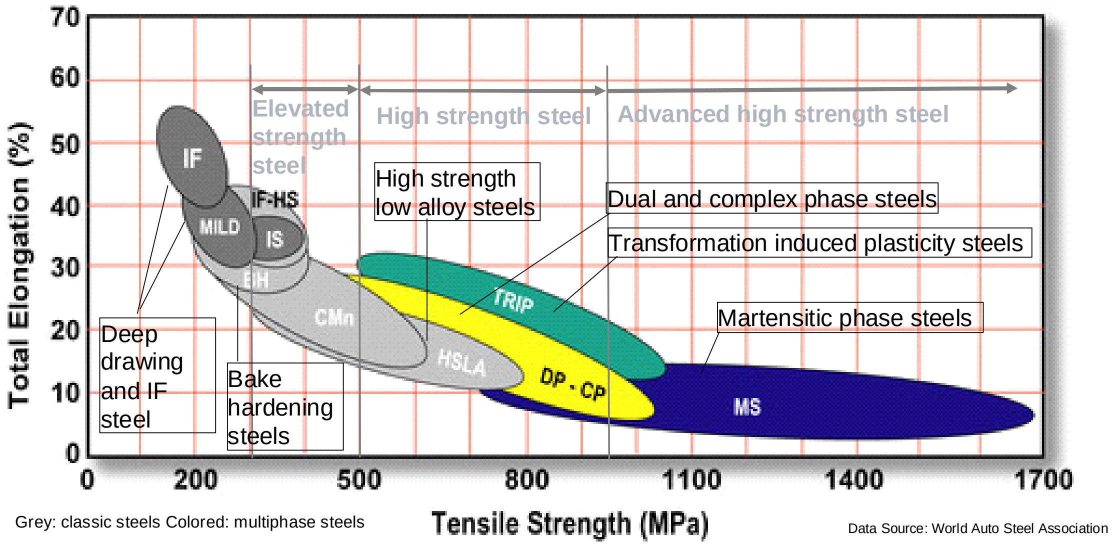

Figure 6. Steel grades currently employed in automotive applications.

All of the high-strength grades shown in the picture above, including multi-phase steel grades, gain their extraordinarily high strength through advanced cooling technique in the cooling section. High cooling rates leading to a fine-grained structure are the key for the production of most of these products. Reducing transformation into ferrite, hence increasing bainite or martensite content in the microstructure is a further mechanism improving strength.
On the other hand, a fine-grained structure helps to improve the toughness of the material, which is a prerequisite when it comes to the production of high-strength API pipe grades. These grades, which, at higher thicknesses, were produced exclusively on plate mills in the past, can now be produced on conventional hot strip mills, too, by employing a practice known as thermo-mechanical rolling.
A picture showing the difference in grain structure of API X70 made either via a production route applying an extremely low finishing temperature of 700°C followed by air cooling or via a significantly higher finishing temperature in conjunction with accelerated cooling down to a temperature of about 600°C can be found below.

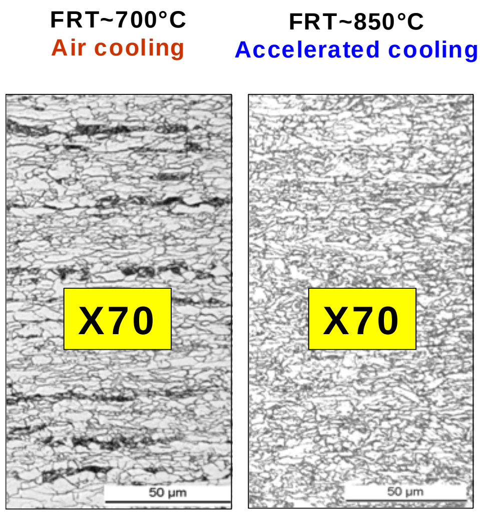

Figure 7. Influence of production process on microstructure for API X 70.

It can be seen that despite the higher finishing temperature in the second case the grain structure is much finer if accelerated cooling is applied (Please note that in terms of production capacity a higher finishing temperature is always favorable.).

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As a rule of thumb it can be said that the higher the cooling rate is, the higher the strength and the toughness of the steel will be. Especially the increase of toughness at low temperatures, as a consequence of the fine grain structure, is a property important for pipe-grade steel.

8 TECHNICAL DESCRIPTION OF INTENSIVE COOLING EQUIPMENT

The new intensive cooling unit at ThyssenKrupp Steel consists of 16 top headers and 16 bottom cooling headers. For each header a separate on/off valve, a flow control valve, a flowmeter and a pressure transducer was installed to allow for maximum operating flexibility. Each header is equipped with numerous solid-jet nozzles. The total flow rate of the 32 headers of the intensive cooling unit is about is about 6,200 m³/h. The overall length of the cooling section is only about 7.5 m. The valve control is implemented in the control process of the process computer working in a 200 ms cycle and giving direct actuator commands via the Simatic S7 basic automation to the valves and the pumps.
In order to take the lower efficiency of the bottom cooling headers into account, the design flow rate on the bottom side was somewhat higher than on the top side.
When producing standard products, the headers are normally operated at a lower flow rate according to the actual cooling rate requirements. Since the new cooling unit replaced the first headers of the existing cooling line, the new headers are used for all strips that require early cooling. In order to avoid the danger of collisions, especially when producing thin strips exiting the finishing mill at high speeds, the top headers are moved to the uppermost position.
The water is supplied from an overhead tank at 25 m height yielding a static pressure of about 2.5 bar. When cooling thicker high-strength strips like e API pipe-grade material, the top headers will be lowered to further increase the cooling capacity.

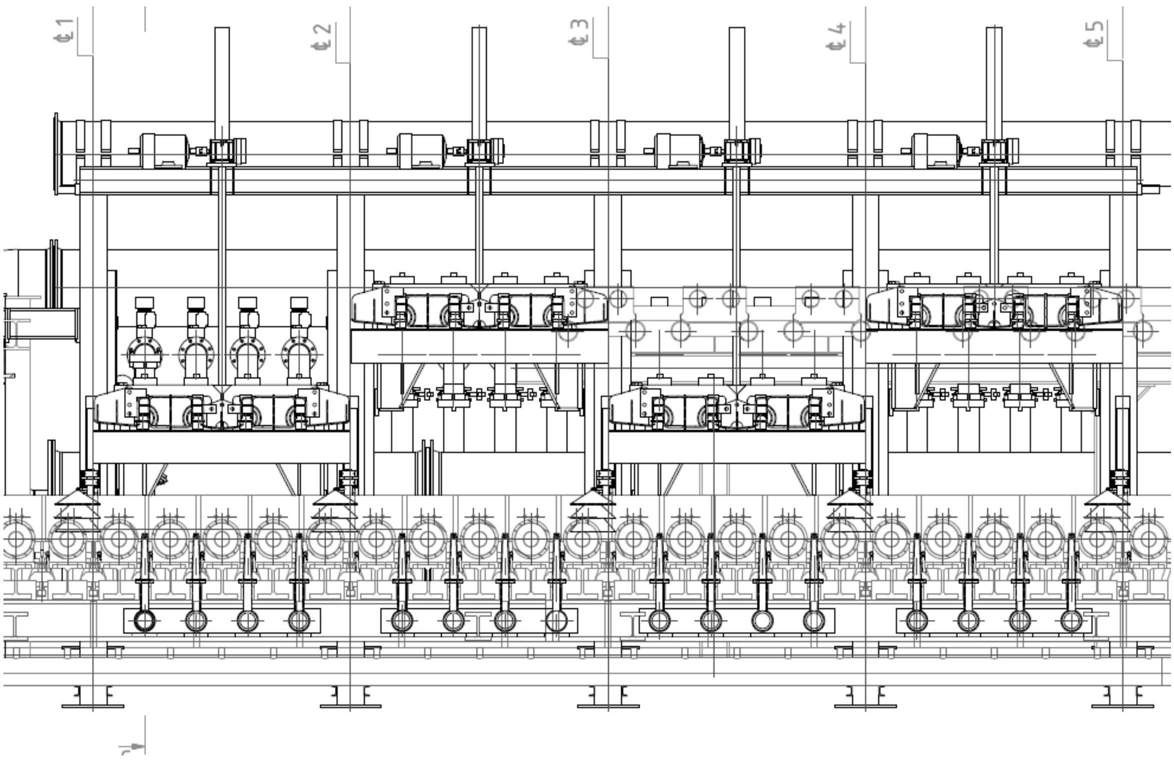

Figure 8. Side-view of the fast cooling unit with height-adjustable top-side headers.

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A photo showing a test of the top headers in is presented in Figure 9.


Figure 9. Test of fast cooling unit during start-up.

When maximum flow rates are required, the water can be pressurized by pumps to a level of about 4 bar. The first thick-gauge strips utilizing the full potential of the new cooling unit were successfully produced in February 2011.
A photo showing the cooling unit in operation can be found in Figure 10.


Figure 10. Fast cooling unit in operation.

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9 UPGRADE OF THE ELECTRIC AND AUTOMATION SYSTEM TO THE NEW COOLING MODEL

To accommodate the modifications in the mechanical design of the cooling section and the finishing mill, the existing Microstructure Target Cooling model and the existing Microstructure Monitor had to be upgraded. With Power Cooling providing a much wider range of coolant flow rate than standard laminar cooling headers, Microstructure Target Cooling has now a much more capable actuator to influence the temporal temperature course of the material, implemented as the first stage of the automation part of this upgrade.(2) To improve the capabilities even further, the newest development, a comprehensive temperature model, will be implemented as the last stage of the upgrade. This model will have a horizon from the entry of the finishing mill down to the coiler and optimize the temperature calculation altogether, not just the finishing mill temperature and the coiling temperature separately. The cooling control is depicted in Figure 12, showing the principle of the new control concept.

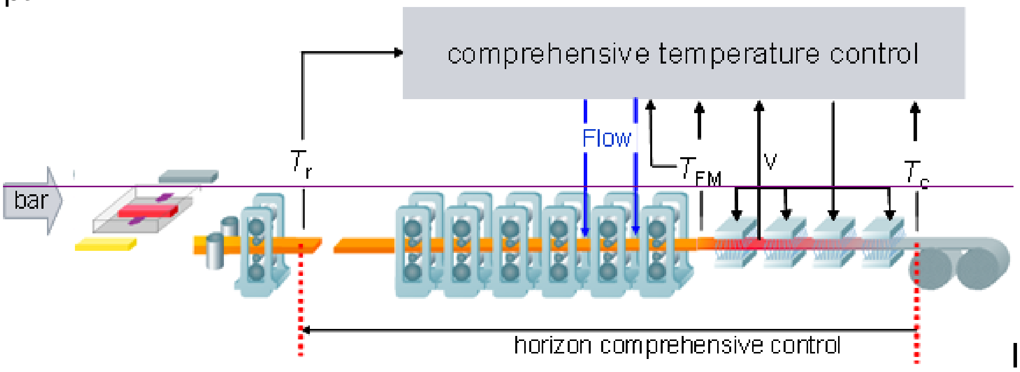

Figure 12. Control area and advantage of the comprehensive temperature control.

10 SUMMARY

With the new cooling solution consisting of a powerful and accurate cooling actuator and the corresponding automation and control system, the capabilities of the Hot Strip Mill No. 2 at ThyssenKrupp Steel got a significant boost in regard to the production of high-strength steel grades ensuring that the plant will maintain its leading position as one of the major hot strip mills in Europe.(3) The short project time and the minimum downtime for the installation during a regular shutdown have also been a highlight in making this project a success.

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