SIROLL MSM – microstructure monitor for hot rolling mills

Keeps product quality on target
Control your steel quality continuously

The challenge:
Steel is used in numerous applications, thanks to the exceptionally wide range of properties it offers. The requirements to the final product are demanding. In order to reliably produce the desired properties many steel concepts have been developed, all based on the combination of different hardening mechanisms and well defined microstructures. In spite of the complexity of these concepts, constant material quality is required for each product. To document this quality, the rolling mill operator is forced to take samples from ongoing production and to test them extensively.

In addition to being expensive, these tests show the quality of the product only in retrospect. No countermeasures can be taken to react on variations in production. These variations possibly lead to downgrading of the product. In order to reduce sampling efforts, only intermittent controls are performed.

Our solution:
SIROLL MSM monitors the development of the steel microstructure from furnace to cooling and derives typical mechanical properties which are necessary for certificates, such as tensile strength, yield strength, etc. On-line availability of the system allows for continuous quality assurance of the product with respect to mechanical properties.
Advantages of SIROLL MSM:

- **Cost savings** – fewer samplings and faster release of the product help to improve productivity and reduce costs.

- **Improved material quality** – more accurate quality parameters lead to higher material quality, i.e. less scattering of material parameters within one grade.

- **Continuous quality control** – SIROLL MSM lets you continuously control the entire production without an increase of costs.

- **Diagnosis of irregularities** – regular deviations between forecast and sampled strength indicate irregularities in the mill. SIROLL MSM reports these irregularities and helps you correct them.
Figure 1: Measured and calculated tensile strength. Grey crosses show online data from hot strip mills, black diamonds test data from various other hot strip mills and colored circles show results from three plate mills. The deviations for the various mills correspond to the measuring accuracy.

Figure 2: The microstructure monitor is provided with chemical composition as well as with process parameters in order to compute the microstructure and eventually the mechanical properties of the product. It is available for hot strip mills (top) as well as for plate mills and Steckel mills (bottom).
A hybrid model for determining the properties of flat-rolled steel combines the technological capability of a physical-metallurgical process model with the learning ability and accuracy of an artificial neural network.

**Data supply**

Input parameters comprise everything that influences microstructure development, i.e. chemical composition, strains and strain rates in the respective passes, and of course temperature. The principle data flow both for hot strip mills and plate mills is depicted in Figure 2. The implemented models are the same for hot strip mills and for plate mills as the underlying physics is identical. However, the making use of rolling in different temperature regimes opens much more possibilities for product design in plate mills, which still leaves great optimization potential for the future.

**Semi-empirical model calculates microstructure**

Supported by process parameters, including temperature, thickness reduction, strip velocity, process time, and chemical composition, a semi-empirical model determines the microstructure of the steel. The algorithms take into account strain hardening, static and dynamic recrystallization, and grain size, as well as \( \gamma \rightarrow \alpha \) transformation. The results are characteristic parameters describing the microstructure of the material, such as the ferrite grain size and the fractions of ferrite, pearlite and bainite. This kind of calculation allows for analysis of unexpected or unwanted results and as consequence also for definition of robust production windows for process parameters.

**High precision for mechanical properties**

Eventually, not only the microstructure but the mechanical properties are the most important quality measures. For the link between process parameters and mechanical properties, experience shows that employment of neural networks gives best results in terms of agreement between calculated and measured values of mechanical properties. The neural networks implemented in SIROLL MSM are realized via a mixture of experts, i.e. actually different types of neural networks. This turns out to be the best way to achieve both robustness and precision of the results.

The results for tensile strength are shown in figure 1. Deviations between the computed and measured values are close to the precision of measurement.
Controlling the microstructure for improved quality – features of SIROLL MSM

Features of SIROLL MSM for improved quality

Embedded solution
SIROLL MSM is completely embedded in the SIROLL automation solution of Siemens. A precise temperature model including a sophisticated model for phase transformation is combined with the microstructure monitor models. These joint models can be utilized within the realtime control (<200 ms) of pass schedule calculation and/or microstructure target cooling. In this case SIROLL MSM is an integral component of the SIROLL automation.

Stand-alone solutions for upgrades
In the stand-alone solution, data supply comes from outside, i.e. from the existing level 2 models because a separate and independent modeling of the temperature behavior could lead to inconsistent results. The stand-alone solutions are supplied with data via well-defined interfaces (TCP/IP). Example screens for a microstructure monitor for a plate mill can be found in Figure 3. This solution is of course also available as an option for a SIROLL level 2 automation system. For existing plants – even older ones – this is a great opportunity to become more competitive with relatively low investment.

Off-line Solution
For off-line application, the input data can be entered manually, or a similar product can be selected from the database of the on-line system. The off-line system allows for cost saving computer experiments and supports the investigation of problems like “How much niobium is necessary to achieve a certain tensile strength value”? or “How does the coiling temperature affect the tensile strength for a certain steel”? or in general “What happens if...”

Microstructure optimizer (for HSM)
Based on the microstructure model, even an optimization of process parameters is possible during running production: For example the coiling temperature can be optimized such that the strip meets the target mechanical properties more accurately.

Features of SIROLL MSM

- On-line monitoring of microstructure evolution
- Mechanical properties can be calculated over the entire length of the product
- Definition of production windows. Analysis of the production with respect to microstructure development may improve flexibility of production and avoid critical production paths.
- Reduction of sampling efforts
- Faster release of product
- Optimization of process parameters (like restart temperature, finish rolling temperature, finish cooling temperature)
### Proven and tested by leading steelmakers

<table>
<thead>
<tr>
<th>Customer/Plant</th>
<th>Country</th>
<th>Plant/Project Description</th>
<th>Year of start-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xiangtan</td>
<td>China</td>
<td>New plate mill</td>
<td>2010</td>
</tr>
<tr>
<td>P.T. Krakatau Steel</td>
<td>Indonesia</td>
<td>Hot strip mill modernization</td>
<td>2010</td>
</tr>
<tr>
<td>Bhushan Steel</td>
<td>India</td>
<td>New hot strip mill</td>
<td>2010</td>
</tr>
<tr>
<td>Shougang Iron and Steel</td>
<td>China</td>
<td>New hot strip mill</td>
<td>2007</td>
</tr>
<tr>
<td>Jiangsu Shagang Group</td>
<td>China</td>
<td>Relocated and revamped hot strip mill</td>
<td>2006</td>
</tr>
<tr>
<td>Wuhan Iron and Steel</td>
<td>China</td>
<td>New hot strip mill no.2</td>
<td>2003</td>
</tr>
<tr>
<td>ThyssenKrupp Steel</td>
<td>Germany</td>
<td>Hot strip mill WBW2 (Beeckerwerth)</td>
<td>2001</td>
</tr>
<tr>
<td>voestalpine Stahl</td>
<td>Austria</td>
<td>Hot strip mill</td>
<td>2000</td>
</tr>
<tr>
<td>Hoesch Hohenlimburg</td>
<td>Germany</td>
<td>Hot strip mill for narrow strip (25 – 685 mm)</td>
<td>1998</td>
</tr>
</tbody>
</table>
For further information, please contact:

Siemens AG
Industry Sector
Industry Solutions
Metals Technologies
Schuhstr. 60
91052 Erlangen, Germany
E-mail: hotrollingmill.metals@siemens.com

Headquarters:
Siemens VAI
Metals Technologies GmbH & Co
P.O. Box 4, Turmstr. 44
A 4031 Linz, Austria
E-mail: contact.metals@siemens.com

The information provided in this brochure contains merely general descriptions or characteristics of performance which in actual case of use do not always apply as described or which may change as a result of further development of the products. An obligation to provide the respective characteristics shall only exist if expressly agreed in the terms of contract.