

# **IDC** Interstand Dimension Control

## implementing U-gauge technology in *rod and bar mills*

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In the past, rolling methods used in rod and bar mills **1** have relied on traditional minimum tension and loop control with adjustment of the roll gaps and mill stand speeds to provide the required product quality. Minimum tension control, which

Industrial users of steel rod and bar are demanding more from these products at a time when competition between producers is growing stronger and the world is faced with a surplus of low and normal steel grades. Mill owners are therefore looking for new ways to achieve higher quality products more economically. Interstand Dimension Control (IDC) was developed to address this issue. By providing accurate, rapid feedback of dimensional data, IDC enables the roll gap and interstand speed to be controlled automatically, significantly reducing mill scrap and making rolling without loops a genuine option for most products.

depends on torque measurements, bases the stand speed relationship on the front-end demands of the billet. This assumes that the billet

dimensions and material temperature profile remain constant along the bar. In reality, however, they are variables, and loop control is

### **1** Hot rolling of long products, such as rods and bars



**2** U-gauge for measuring the dimensions of hot rolled billets and bars. Data from the gauge are used to automatically adjust the mill stand set-up and interstand speed.

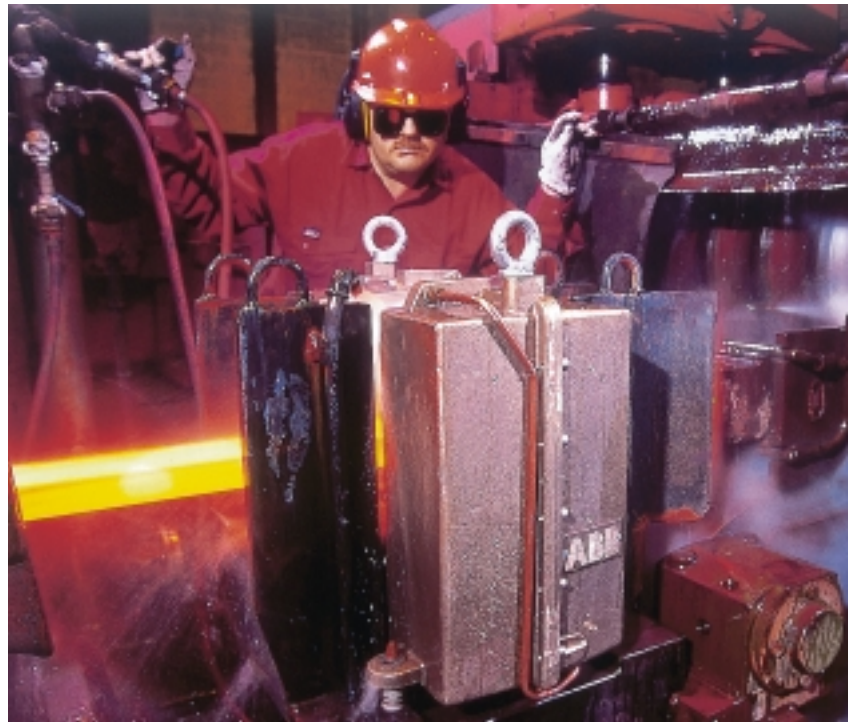
## The case for IDC

Steel producers who want to upgrade their steel mills have several options, ranging from major mechanical revamps to control system upgrades. ABB developed the Interstand Dimension Control (IDC) system to help mill owners to increase material yield, raise plant availability and improve the final dimensional tolerances. By ensuring dimensional consistency, IDC reduces the need for loop control and makes rolling without loops a real option. 'Loop-less' rolling has the added advantage that space becomes available for cooling zones, which in turn improves the material properties.

The IDC system employs U-gauge technology for reliable on-line measurement. As no optical systems, moving parts or sensitive electronics are involved, the U-gauge is well suited to the harsh conditions in a rolling mill. Measurement accuracy is not affected by either steam, scale or vibration.

The U-gauge fits easily between the mill stands and does not need any on-site calibration. Only conventional lifting equipment and tools are required for the installation.

IDC has been installed at the SKF Ovako steel mill in Sweden, where it is demonstrating that it can meet the tough demands made on narrow dimensional tolerances in conventionally controlled mill sections.



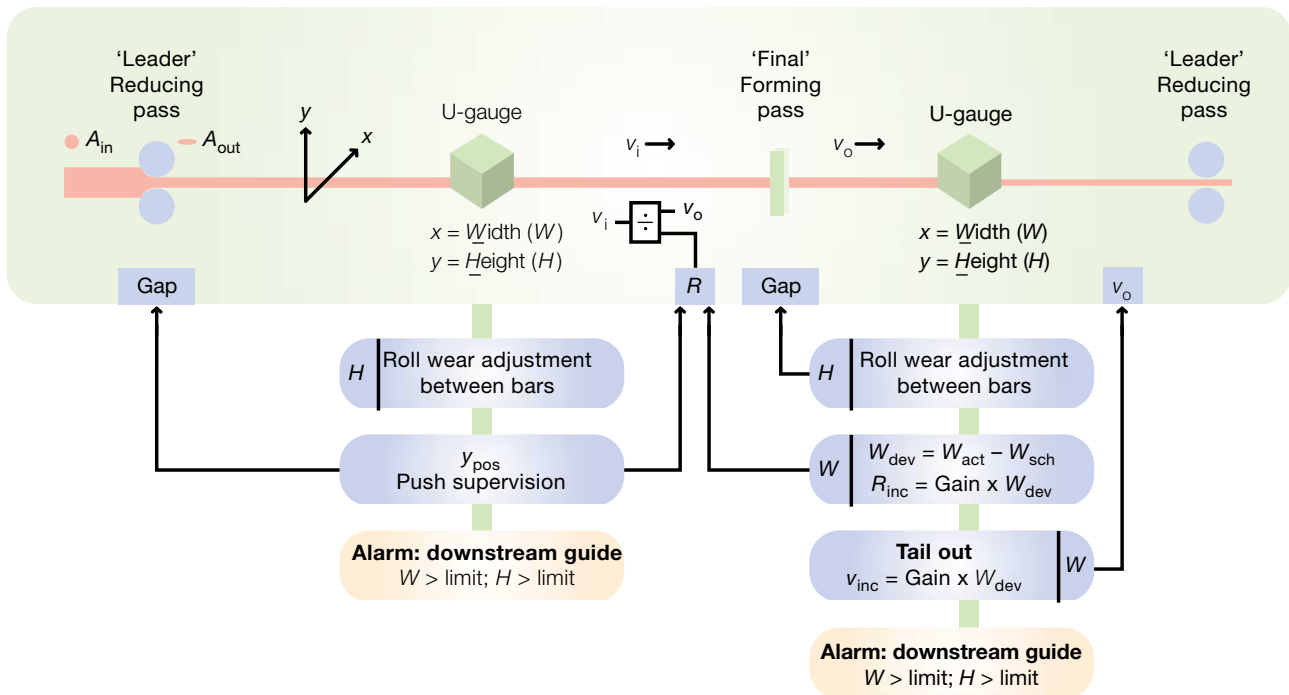
required to adjust the rolling speed and compensate for mass flow variations along the bar. Unfortunately, though, loop control cannot correct the dimensional variations, and these subsequently affect the final tolerances.

A trend in the industry today is towards endless rolling, in which billets are welded together to form a continuous billet, which is then cut to customer-specified lengths on the cooling bed or at the coil forming station. An inherent problem of endless rolling is that the temperature as well as the dimensions can differ from billet to billet. Traditional control systems compensate for these differences through minimum tension front-end adaptation each time a new billet enters the mill, but endless rolling clearly does not allow front-end adaptation. Interstand Dimension Control is the answer to this problem.

## Interstand Dimension Control

Interstand Dimension Control (IDC) is an in-line gauge technology for profile rolling with closer tolerances, simplified and safer operation, and greater dimensional consistency. U-gauge sensors **2** measure the steel's dimensions by creating a magnetic field which is distorted as the steel passes between the gauge arms. The data sent by the gauges to the IDC system are used to automatically adjust the mechanical set-up of the mill. Dimensional variations are automatically corrected by the IDC system, which continuously monitors the exit bar dimensions at each mill stand and controls the stand speeds accordingly.

Profile mills, new as well as old, feature different levels of automation, eg roll-gap adjustment during rolling, roll alignment, etc. IDC is built up from modules to allow a flexible solution for each rolling mill. However, since most mill stands are



**3 IDC control principle. Continuous supervision and control eliminates the risk of underfill and overfill rolling.**

$A_{in}$	Area in	$R$	Reduction factor	$W_{act}$	Actual width
$A_{out}$	Area out	$R_{inc}$	Reduction factor increment	$W_{sch}$	Scheduled width
$v_i$	Inlet speed	$v_{inc}$	Speed increment	$y_{pos}$	$y$ -position (height)
$v_o$	Outlet speed	$W_{dev}$	Width deviation		

individually driven, the basic IDC is based on control of the interstand speed **3**.

IDC works on two stand groups: first the reducing or leading stand, then the forming or final stand. The first pair of stands uses relative control to register temperature and dimensional variations along the billet and inform the system about its status as it enters the mill. IDC utilizes conventional minimum tension control to trigger the width measurement of the bar, which then serves as a reference. By changing the interstand speed relationships, IDC keeps the width constant along the bar. If the U-gauge notices any slack in the material, it corrects it by changing the interstand speed **4**.

The height is monitored and used as feedback to correct the

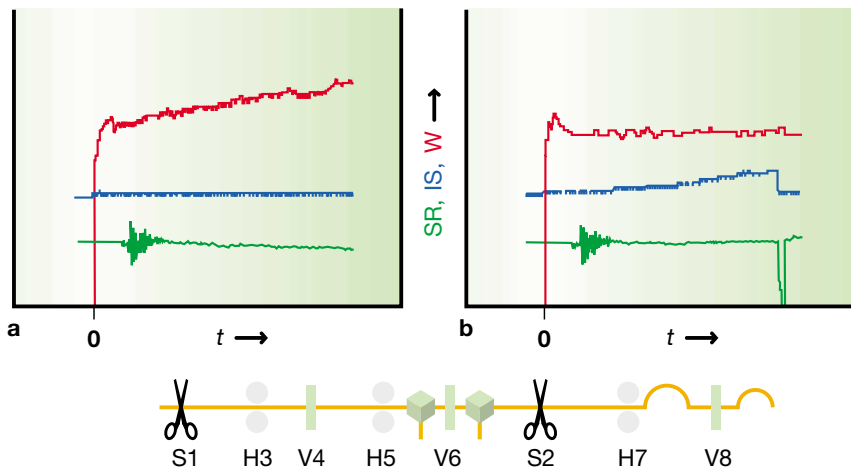
roll gap, thereby compensating for roll wear. The constant mass flow achieved by keeping the width and height of the bar constant along its full length reduces the need for loop control, making

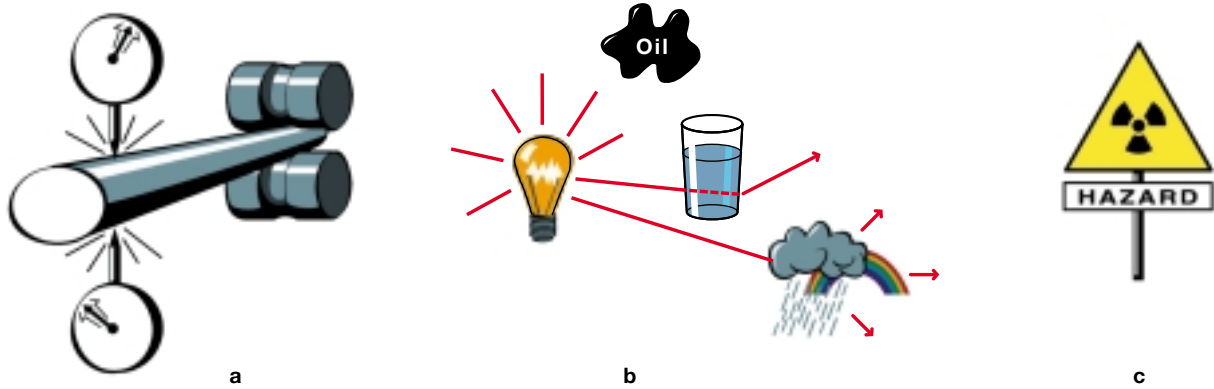
rolling without loops a genuine option for most products.

After the first few stands, when the material is uniform, the IDC system can use height and width reference values from the pass

**4 Width (W, red curve) of rolled material (V6), interstand speed relationship (IS, blue curve) and speed reference (SR, green curve) versus time, with (a) and without (b) IDC**

H Horizontal stand      S Shear      V Vertical stand





**5 Conventional measuring technologies**

- a** Mechanical technology
- b** Optical technology
- c** Radioactive technology

schedule. Knowledge of the actual material dimensions after each stand enables the operator to optimize the guide and roll settings, and so avoid material twist and asymmetry. A constant width also makes it possible to increase the groove fill without risk of overfills, thereby getting more tonnage out of each groove.

**U-gauges are the key**

The conditions in hot rolling mills are hardly conducive to accurate measurement, with heat, steam and particles combining to hinder sensors from gauging the dimensions and properties of materials. Added to these difficulties are heavy mechanical loads, strong vibration and the rapid movements of the rolled material.

In spite of such conditions, the sensors are expected to perform flawlessly. Reliability must be high and maintenance has to be kept to a minimum. What ever happens, the measurement accuracy must not be compromised.

It is easy to see that a measurement technology requiring physical contact with the material – eg with wheels or points **5a** used to measure the dimensions – is not a

viable option for rolling mills. The kind of sensors that are needed are too fragile to withstand the mechanically demanding conditions in the long run. Also, their measurement accuracy diminishes at high speeds and when material surfaces are less than perfectly smooth and clean.

The problem with optical technologies **5b** is that their use is more or less restricted to comparatively clean and mechanically undemanding environments. Obviously, rolling mills do not comply with this requirement. Also, light does not easily penetrate airborne dirt and steam, and is diffracted in water. Another factor are the actual optical components, such as lenses and lamps, which are mechanically sensitive and require regular cleaning.

Even systems employing radioactive and X-ray radiation **5c** – another commonly used measurement technology – are sensitive to environmental conditions, although not as much as optical systems. Besides being reduced when water, particles and steam have to be penetrated, radiation is also negatively affected by dirty

material surfaces. The hazardous nature of radioactive radiation is another aspect that makes this technology particularly difficult to envision as a general measurement solution in the long term.

One way to avoid interference due to dust, smoke and dirt in the measurement environment is to use a low-frequency electromagnetic field **6**. Such a field not only penetrates everything but metal; it also induces electrical currents in the metal, which in turn produce changes in the electromagnetic field. These changes can be measured via the voltage they induce in a coil.

This technology is referred to as *eddy current measurement*, a term suggestive of the induced currents whirling around in the material. The technology has been the subject of ongoing development for 50 years and exhibits exceptional environmental tolerance.

Until recently, however, attempts to use this technology to measure dimensions and other physical properties of the materials with sufficient accuracy have not proved successful. ABB has now developed a completely new method of measurement utilizing

eddy current technology – a method that makes real-time, in-line measurement of dimensions and other attributes possible with exceptional accuracy.

### Eddy current principle as platform for new measurement technology

In simplified terms, earlier versions of eddy current technology were based on a conventional alternating current (AC) operating principle **7**. According to this principle, the material being measured influences two parameters: the *amplitude* and the *phase change* of the electromagnetic field. However, in order to measure dimensions, eg the thickness of a plate, three parameters must be taken into account:

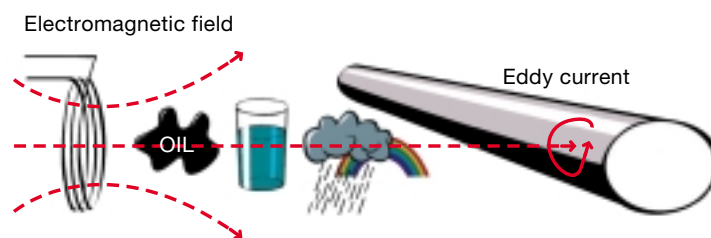
- The *distance* between the coil and the material
- The *electrical resistance*
- The *thickness* of the plate

To make eddy current technology suitable for this type of measurement, attempts were made to keep one of the parameters constant. One such attempt was a design that maintains the distance between the coil and material. In practice, however, these efforts were not successful, especially when harsh environments are involved and the material is moving.

The new ABB technology is based on measurement of the voltage pulse induced in the coil when the current is suddenly interrupted. After abrupt interruption of the constant excitation current fed to the coil, the magnetic field produced by the eddy current in the plate is measured as a factor of the voltage it induces in the coil **8**.

At the time of interruption, the

eddy current exists only on the surface of the material and has not yet penetrated deeper into the substrate. By tracing the entire penetration sequence via the voltage induced across the coil, it is possible to derive three unique signal values at three different times. This is how the new measurement technology – known as Pulsed Eddy Current Technology – overcomes the limitations of the earlier design: all three dimen-



### **6** Low-frequency electromagnetic field

sional parameters can now be measured.

Another fundamental difference between the two technologies is that in the new design the current supply is completely interrupted when each of the measured values is generated. As a result, only the magnetic field actually induced by the eddy currents in the material is measured, resulting in exceptionally high measurement accuracy.

Other distinguishing features of the new Pulsed Eddy Current Technology include:

- The technology is contactless.
- Fluids, steam, particles and general disturbances do not affect the results.
- Only an electrical conductor – the metal product being measured – can influence the sig-

nal, which is derived from a current induced in the material.

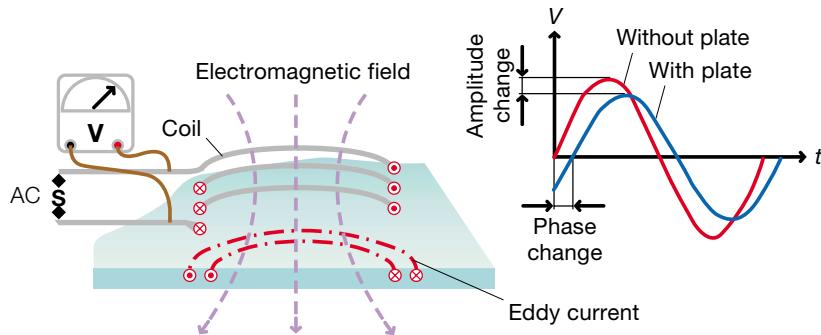
- Only a single coil is needed to create and sense the electromagnetic fields. Sensors can therefore be made simple and exceptionally robust, ie highly tolerant of vibration and other mechanical influences in the production environment.
- The weak, low-frequency electromagnetic fields are not haz-

ardous to people and have no adverse effect on surrounding electrical equipment or the material itself.

With these functional attributes and performance qualities, the new Pulsed Eddy Current Technology ensures reliable measurements in even the most difficult conditions found in the metals industries.

The U-gauge sensor ensures that measurements are performed with exceptionally high accuracy, even under very difficult environmental conditions. When long products are rolled (bars, rods, wire and others), the width and height of the material can now be measured in real time after each roll stand.

The consistency in width and height defines the quality of the rolled material. Being able to mea-



**7** Earlier eddy current technology, based on AC operating principles. The measured parameters are the amplitude and phase change of the electromagnetic field.

sure these parameters in real time provides new opportunities for controlling the dimensions and improving the tolerances of the finished bar, rod and wire products. Measurement of this kind has been considered too difficult with other technologies.

The width, height and position of red-hot material at 1000 °C should ideally be measured to an accuracy of about one tenth of a millimeter. Water is sprayed continually all around the material to protect its surroundings from overheating, producing steam and reducing visibility. An oxide scale forms continuously on the surface, and this should not be included in the measurement. Inevitable mechanical challenges include heavy impact forces and wear.

Even in such an extremely demanding situation, ABB's sensors measure product dimensions accurately and reliably without interfering with the process.

**What varies in a mill?**

**Billets**

The dimensional tolerances of billets normally lie in the range of ±2 %, but the section may be rectangular or rhomboid instead of an ideal square. Another factor

can be the temperature drop between the furnace and the first mill stand, resulting in a colder tail end, or temperature variations caused by skid marks. As cold material tends to spread more, the width is increased. Measurements show that the increase is in the order of 1 % or more, representing an area increase of 2 to 3 %. To avoid overflow, account needs to be taken of this when calculating the utilization of the first grooves.

**Mill stands**

The roll alignment is usually set in the roll shop, but during rolling axial forces will tend to cause misalignment of the grooves due to play in the bearings. This is especially true when a rhomboid bar is entering a groove. If the

axial bearings cannot absorb the thrust or if the inlet guides cannot keep the bar straight, it will twist. The material tries continuously to adjust its position to where the deformation force is at its minimum.

**Guides**

With the above area variations it is impossible to set the guides to the desired fit. If they are set too tight, they might reduce the material, with a major risk of wear and breakage. If they are set too loose, the bar is more likely to twist.

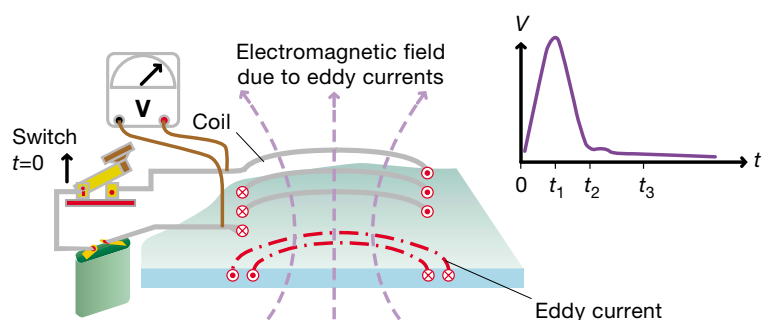
**Steel grades**

It is well known that different steel grades spread differently. Measurements confirm, however, that the different grades (eg, ferritic and austenitic steel) act with approximately the same dynamics but with different amplitudes. With present-day control systems, individual pass schedules are required for each grade and dimension. IDC eliminates the differences in spread, so fewer schedules are needed.

**Implementation in mills**

IDC is based on the use of Advant OCS hardware. In addition to the specific IDC benefits, there are a

**8** Pulsed Eddy Current Technology. The magnetic field produced by the eddy currents is measured as a factor of the voltage they induce (at  $t_1, t_2, t_3$ ) in the coil.



number of other advantages in having a state-of-the-art control system [9]. More information about the upgrading of old mills can be found in [1].

### Mechanics

The U-gauge forms a dedicated unit with a specially designed in/outlet guide. It is placed on a baseplate, which is part of the unit, aligned with the mill's fixed pass line. The U-gauge has to be as close to the delivery side of the mill stand as possible. (An exception is the horizontal–horizontal stand arrangement, in which the oval material is twisted 90 degrees. The U-gauge is then placed in a location where the twist has already finished, ie close to the entry of the following stand.)

The integrated U-gauge with in/outlet guide can easily be lifted from the baseplate in bar mills when heavy products are being rolled and not all the stands are required.

The U-gauge is cooled by water sprays; only normal mill process water is required. A special protected cable provides the electrical connection to the local junction box, which is joined to the Advant Controller by a bus cable.

### Operator interface

The IDC is integrated into the Advant Operator Rolling Mill Control (RMC) station, where the mill set-up and analysis, etc, take place. A graphic panel on the mill floor enables the floor operator to supervise rolling locally via displays that show width and height dimensions as well as 'off-center' information.

For example, roll utilization or groove fill can be checked easily.



9 State-of-the-art process control in a rolling mill

The CAD dimensional drawing of the groove and the calculated reduction, which gives the 'fill', are compared with the actual measured width of the rolled material. Since all the parameters (eg, the height and width during rolling) and the shape of the groove are now known, the pass designer can rely on the feedback being reliable. And since the risk of rolling overflow is eliminated, the groove can be utilized better and a higher tonnage obtained from the roll.

### A boost for mill availability and yield

The ABB IDC system is now in commercial operation and is meeting the high plant availability and yield goals. By ensuring constant dimensions along the bar, starting already in the roughing mill, IDC allows the loopers in the intermediate and finishing mills to be dispensed with.

The influence of dimensional and temperature variations along the billet is eliminated by IDC. This results in closer tolerances for heavy gauges in bar rolling,

'looper-less' rolling for lighter gauges, and constant dimensions for the material fed into the rod blocks. The reduction in cobbles and downgrades improves the yield and shortens start-up times after size changes. The time formerly spent on adjusting the loopers can now be spent on rolling, thus raising plant availability. ■

#### Reference

[1] D.N. Sollander: *Upgrading rod and bar mills with state-of-the-art control technology*. ABB Review 4/99, 27–32.

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