Strip Shape Measurement and Control on Wedge Strip in a 20-High Mill

<u>Conversion of a 20-High Mill at MK Metallfolien to a partitioning system</u>

The mill was originally built by I²S (today Tenova) and was commissioned in Germany in the year 2000 at MK Metallfolien.

Following numerous modernization measures, the mill is today state-of-the-art. Today we want to present the latest modernization to you: installation of shapemeter rolls and a fully automatic shape control system on the mill. Special measures were required as this is a wedge strip application.

Preparations have also been made for possible later retrofitting of a strip centering control system.

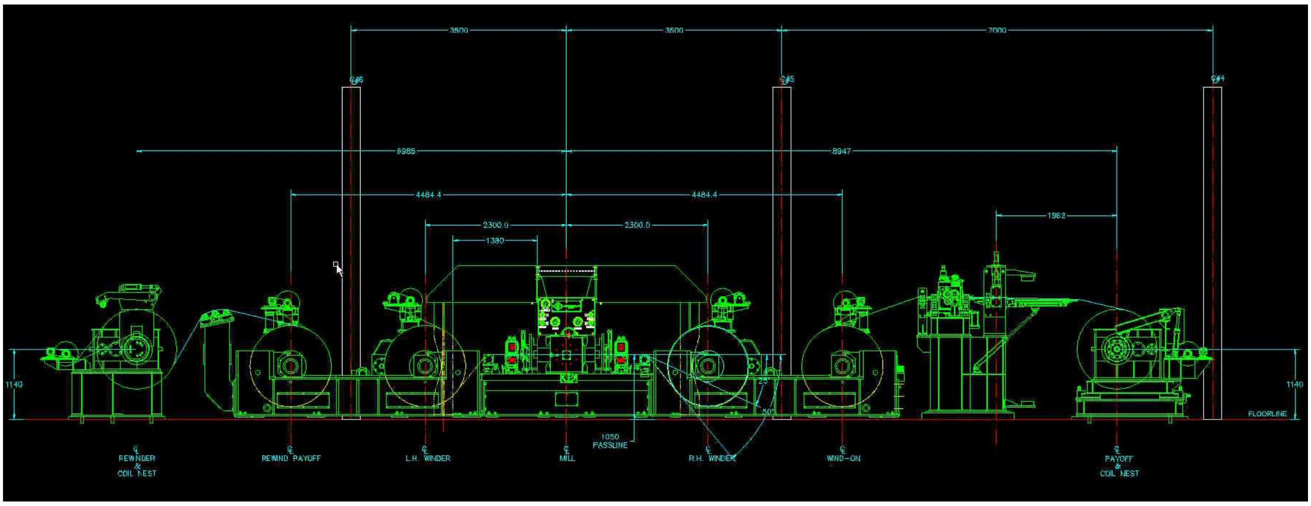


Figure 1: 2D drawing of mill before modification

MK Metallfolien that also has a branch in Duncan, South Carolina (USA) specializes in the production of foils of steel, stainless steel, nickel, titanium and other materials
in the thickness range 1.0 to 0.02 mm
with tensile strengths of 300 – 2200 N/mm².
Metal foils are also produced for high-temperature applications up to 1,200°C.
The precision demands on the strips are very high, and the demands on the measuring and control technology in the mill are correspondingly high.

The 20-roll mill we are talking about today has the following strip data:

Strip thickness	1.5 – 0.025 mm
Strip width	175 – 380 mm
Vmax	300 m/min

In the past, radiometric measuring devices were used for gauge measurement, but these were replaced by VTLG laser strip thickness gauges several years ago.

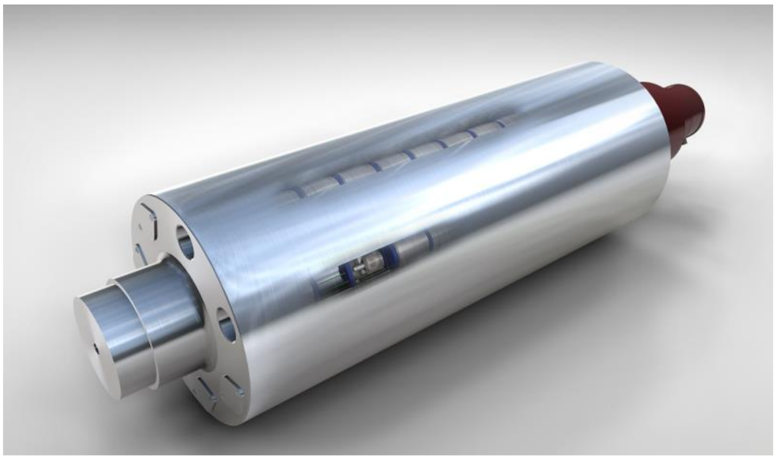
Shape measurement has not been carried out on the mill to date. There were good reasons for this: as in so many medium-wide strip mills, wedge strip is also often rolled here.

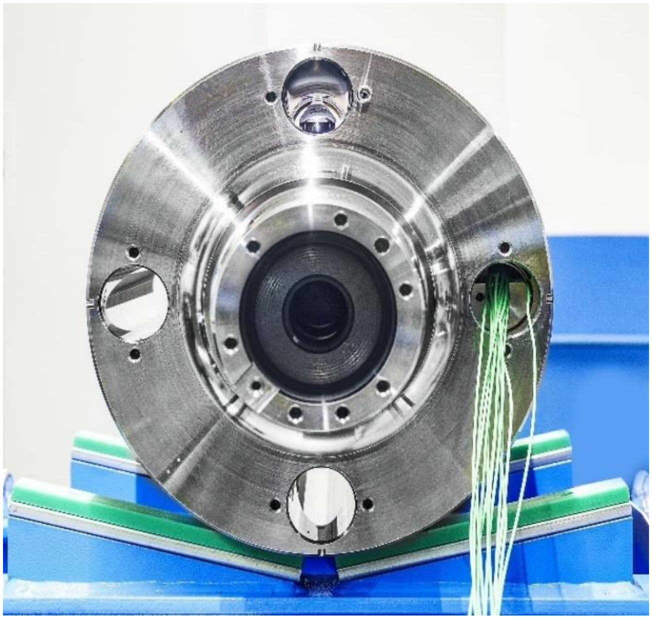
BFI Shapemeter Rolls

Rolls that work using the principle developed and licensed by the German Institute for Applied Research, generally known as the BFI Institute, are used to measure the shape of the strip. That is why these rolls are also known as BFI rolls for short.

These are solid steel rolls in which slotted holes are made from the front. These are fitted with piezo-electric pressure sensors that measure the strip shape under the surface extremely sensitively and precisely. The benefit for the user: The roll can be operated and handled just like a normal deflector roll. No maintenance is necessary, apart from lubrication of the bearings, but the best measurement results are achieved.

Figure 2: BFI roll with a view below the surface of the roll





Figures 3 and 4: BFI roll manufacturing, details out of Vollmer workshop

The strip flatness defines how evenly the strip tension is distributed across the strip width. For example, a long and a short edge is a typical strip unflatness.

Long edges and a short strip middle (easily recognisable from wavy edges) is also a typical strip unflatness. The BFI shapemeter rolls measure this under strip tension via the large number of pressure sensors in the roll body. The unit for strip flatness is the I-Unit. 1 I-Unit corresponds to a fibre elongation of 10 µm per meter of strip length.

Figure 4: BFI roll with measuring zones under the surface

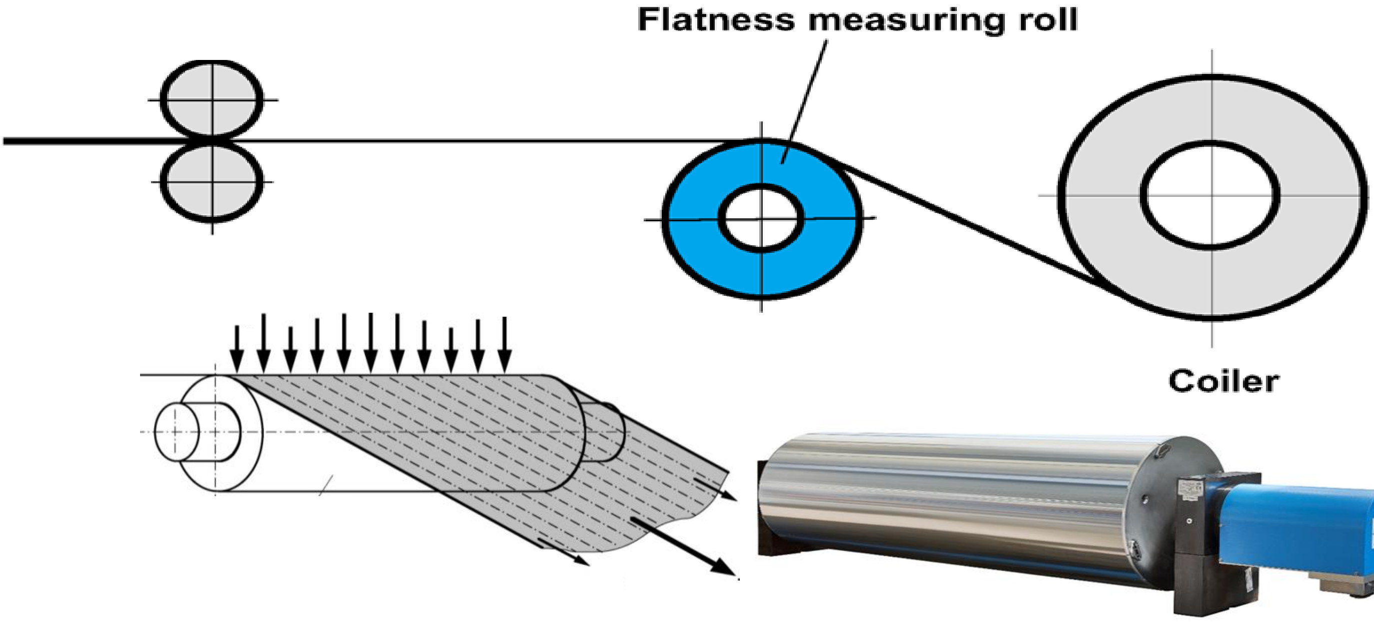


Figure 5: Strip above BFI roll

These are standard applications in hundreds of rolling mills around the world.

Challenge: Shape measurement at wedge strip

With wedge strip, however, there is something different.

Wedge strips are strips with an asymmetrical cross-profile, i.e. with a thicker side and a thinner side.

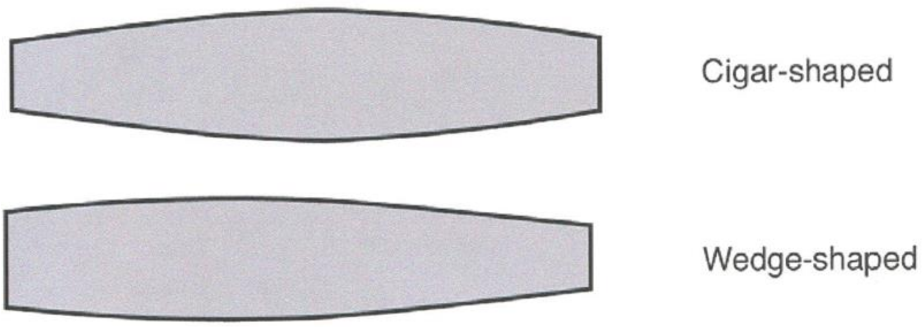


Figure 6: 3D diagram of symmetrical and wedge strip cross-profile

The special thing about wedge strip applications is that even if the strip were perfectly flat, higher tension would build up on one side at each loop during coiling due to the thicker strip edge. This simulates a short strip edge for the shape measuring system.

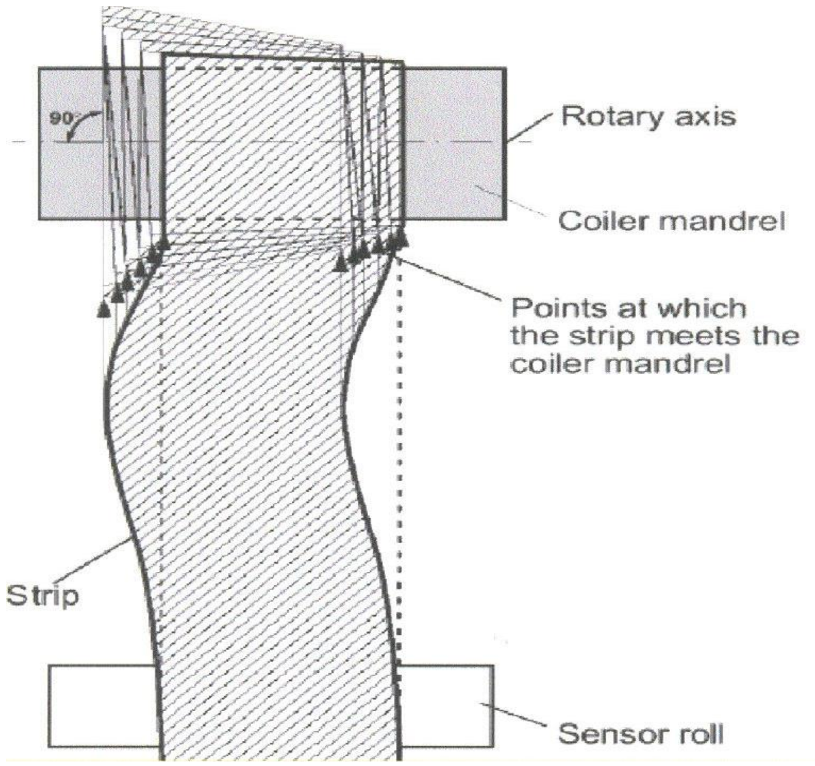


Figure 7: Change in strip tension due to wedge strip

The theoreticians among us could assume that this effect could be compensated by calculation. The problem is, the process is not sufficiently uniform. The strip jumps between loops as it gives way to the increasing tension on one side. This results in additional and constantly changing transverse forces that prevent software compensation, as the influence of the wedge on the coiling pattern is undefined and varies continuously.

Partition System

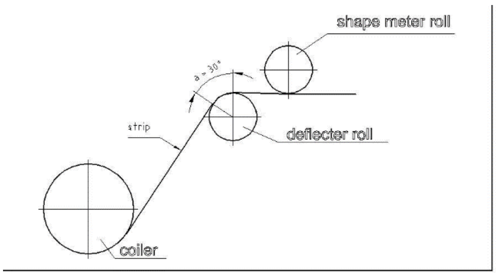
In most cases, shapemeter rolls are used instead of deflector rolls. A different solution has to be found for wedge strip applications due to the effect of the additional forces just described. In these applications, the deflector roll has to be retained and the shapemeter roll is installed parallel to the deflector roll.

The BFI Institute has coined the term "partitioning system". It describes the boundary conditions that must be observed in order to eliminate the force effect of the wedge strip on the shape measurement, i.e. to partition the shape measurement from the effect of the wedge strip.

This involves installing the shapemeter roll parallel to the deflector roll and observing minimum wrap angles:

With sufficient wrap around the deflector roll (min. 30°) and enough grip on the deflector roll, this arrangement eliminates the influence of the wedge strip.

The shapemeter roll needs a wrap of at least 9°.



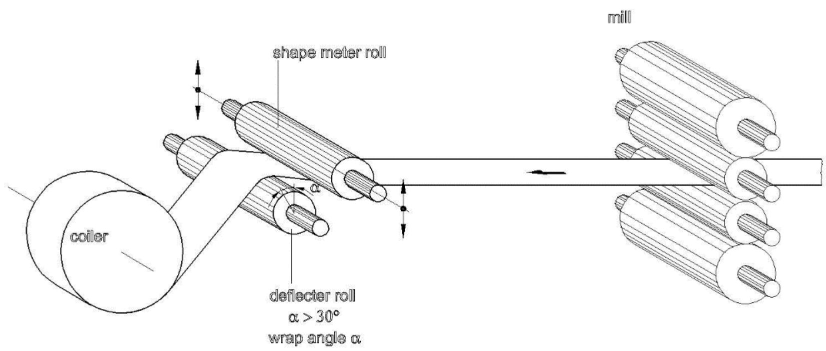


Figure 8: Partitioning system

That is no problem with new mills. The shapemeter roll can run under the strip next to the deflector roll, often with a wonderfully small diameter, so that not much additional space is taken up despite the double roll arrangement.

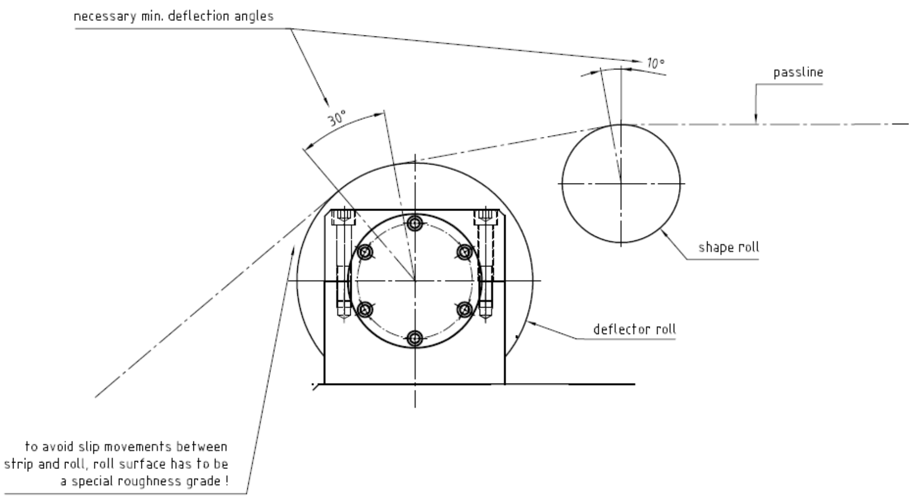


Figure 9: Double-roll system, BFI under the strip

Realization of Partition System in 20-High Mill of MK Metallfolien

In existing mills that are to be retrofitted with shapemeter rolls, space is often at a premium and although we only need 180 mm diameter for the smallest shapemeter roll, that space is not always available. This is also the case with the mill that we are talking about today.

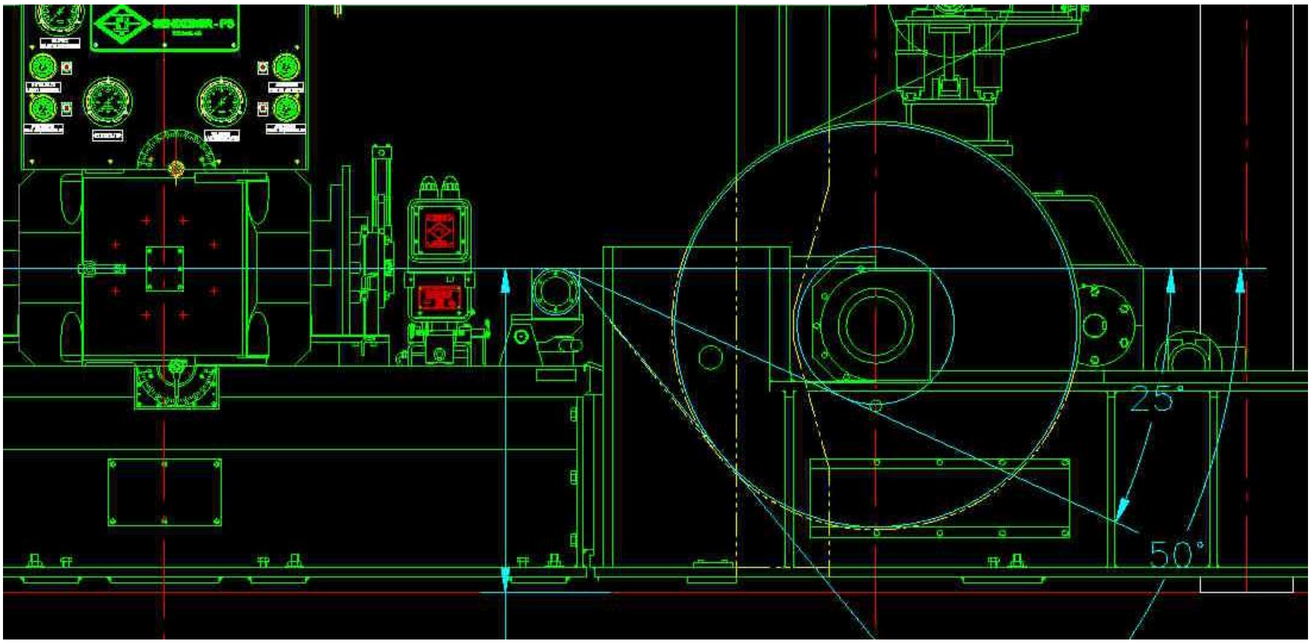


Figure 10: Repetition of Figure 1 but enlarged detail of right-hand side of mill

A 9° wrap around the shapemeter roll and 30° wrap around the deflector roll could only be achieved with a redesign of the complete entry and exit sides

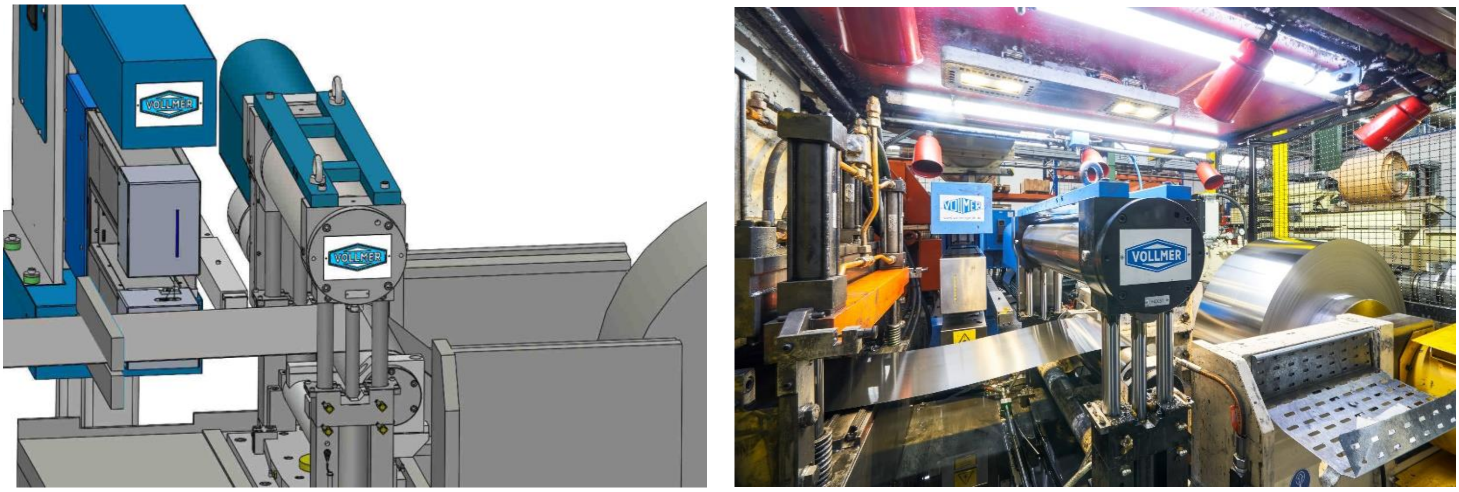


Figure 11: 3D view of the right-hand side with roll at the top

We had to move the deflector roll slightly towards the coiler and slightly downwards and have the shapemeter roll contact the strip from above in order to achieve the necessary wrapping.

This makes it possible to partition the wedge strip influence in a minimum of space.

The BFI roll is raised while the strip is being threaded in.

And after the strip is under tension, the BFI roll is immersed in the strip from above.

Figure 12: Same view as in Figure 9 with roll at the bottom

The wrap of at least 30° on the deflector roll (with sufficient grip ensured by at least 1.0 Ra) ensures reliable strip shape measurement even when producing wedge strip.

That is the basis for the fully automatic strip shape control system that has also now gone into operation.

Shape Control in the mill of MK Metallfolien

It is a 20-roll mill with the actuators:

Saddle roll adjustment (6 saddle rolls) and lateral roll shifting (i.e. intermediate roll shifting)

Figure 15: Detail with 20 rolls

The possibilities for influencing the strip shape are very good with these actuators. We assume a finished strip flatness in the range of +/- 4 I-Units relative to a specified shape target curve.

The saddle roll adjustment affects tilting and bending just like the actuators normally used in 4-high mills.

Intermediate roll shifting allows the strip edges to be selectively influenced. In order to achieve the full performance of the flatness control, it is also necessary to optimize the roll grinding, i.e. the roll shape of the working and intermediate rolls.

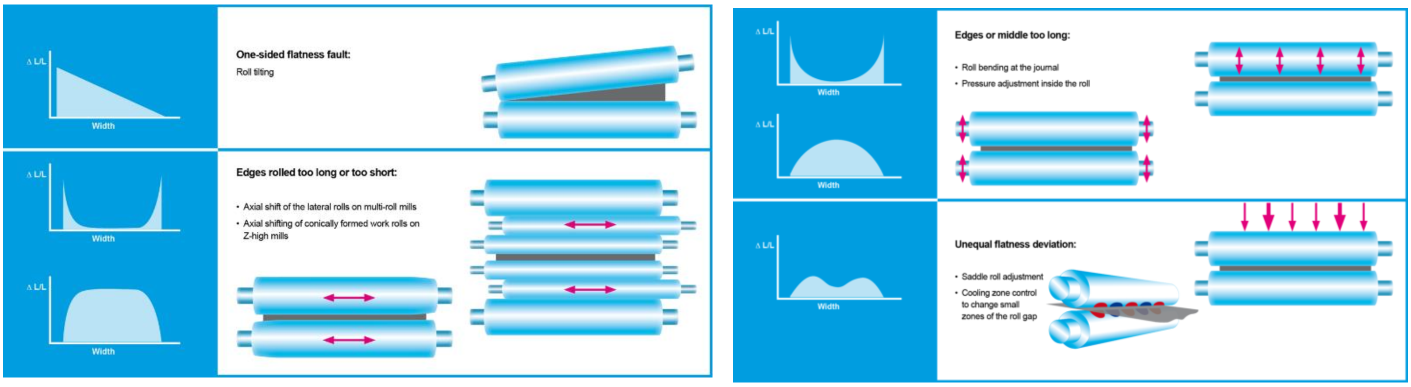


Figure 16: Shape control actuators

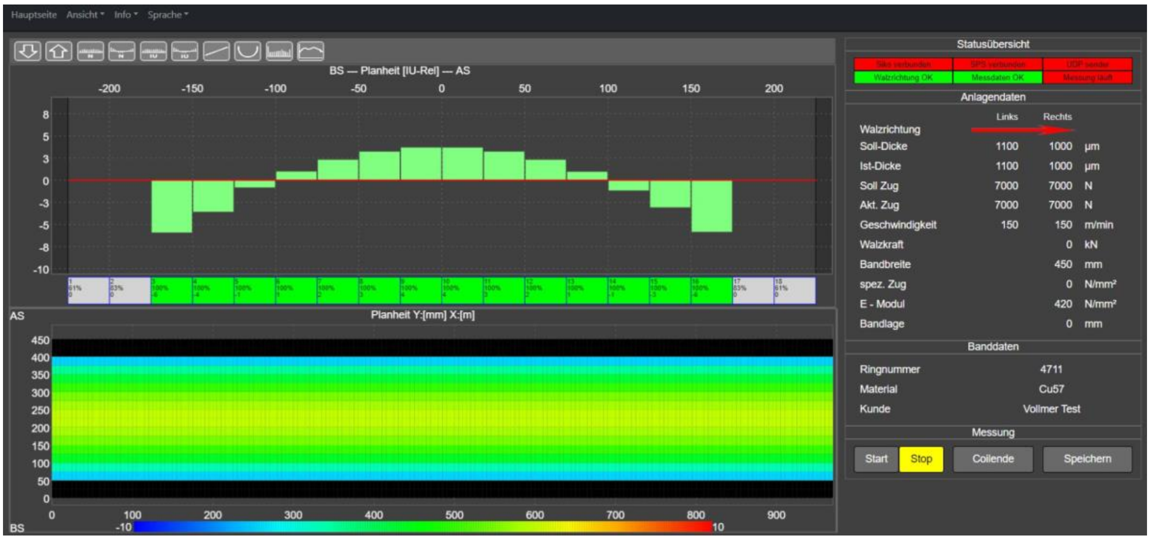


Figure 17: Display of shape on the monitor (only a sample, not from this project!)

<u>Preparation for Strip Centering Control:</u>

During the redesign of the entry and exit sides of the mill, we took the opportunity to make preparations for the installation of an automatic strip centering control system.

Shape control always runs as feedback control, which is why the shapemeter roll on the entry side acts only as a deflector roll. The deflector roll (or shapemeter roll) on the entry side can be used to center the strip perfectly.

For this reason, the double roll assembly on the entry and exit sides is anchored to a pivoting plate that is connected to the base with a swivel joint.

Threads and countersinks for centering rings have already been provided on the sides and can later accommodate the hydraulic cylinders that rotate the upper plate.

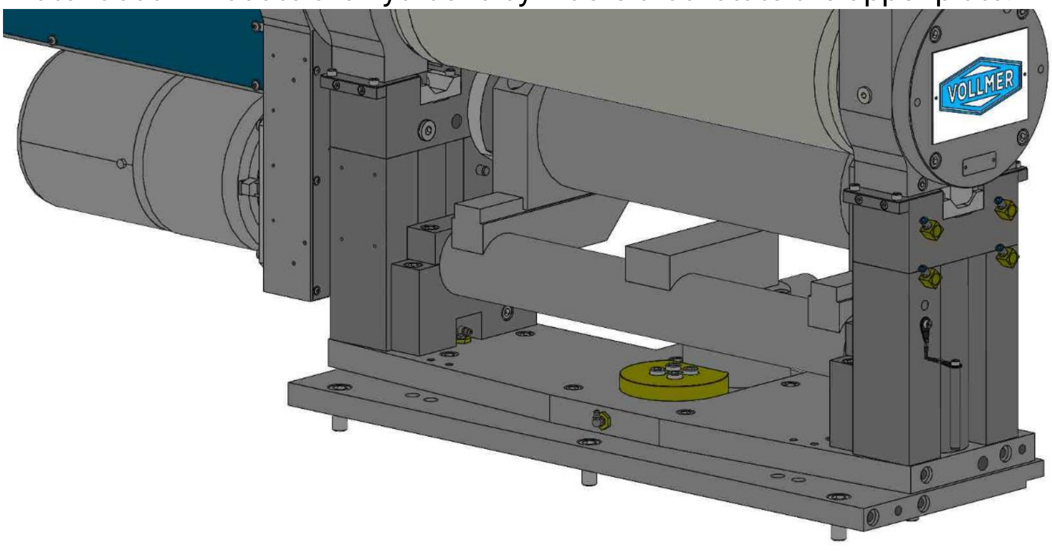


Figure 18: 3D preparation for pivoting plate

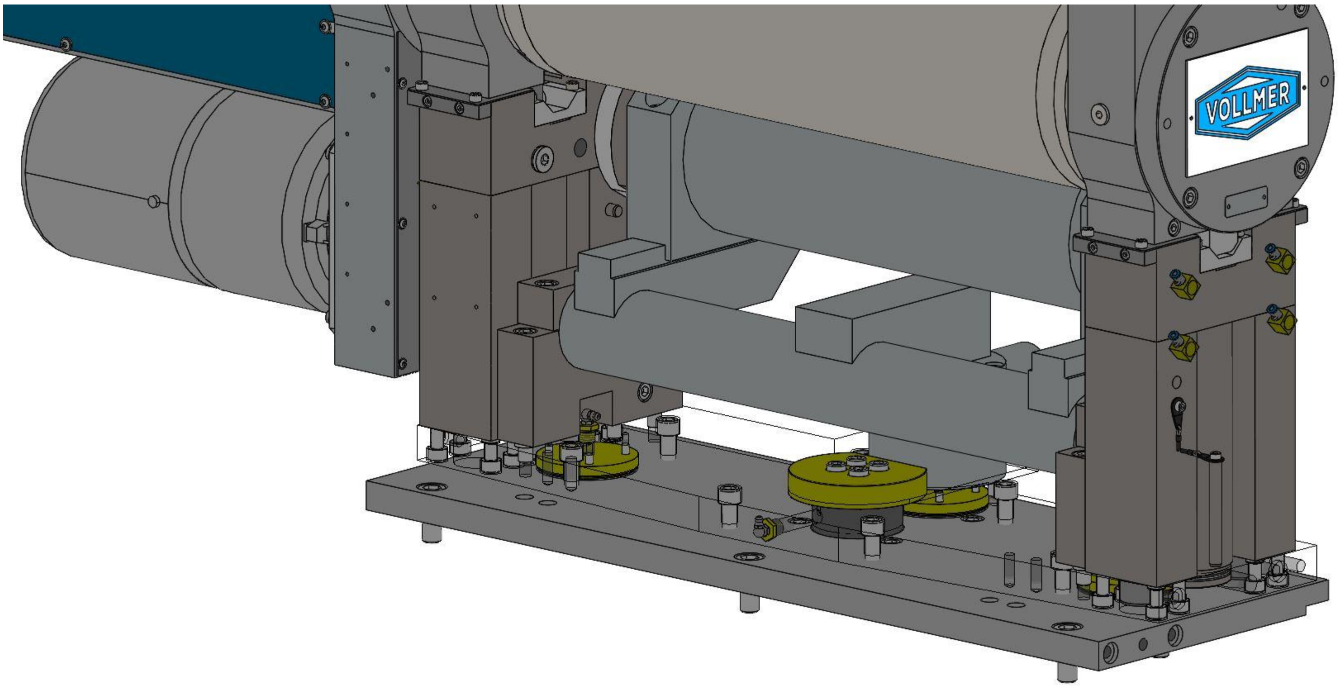


Figure 19: 3D preparation for pivoting plate (shown transparently)

The associated strip centering control system runs on the flatness computer.

The system receives the necessary strip position information via strip edge detectors. Optical or inductive systems or radar-based sensors can be used for this purpose.

The additional cost of the mechanical and design work for preparation of the strip centering control system was moderate. The control loop was already available. If the system is installed, only hydraulic cylinders (with position detection) for rotating the plates and sensors for strip edge detection would have to be retrofitted.

The deflector roll and shapemeter roll package on the entry side would then be the control roll. Control rolls stabilize the strip passage and often enable a faster rolling process and higher productivity.

The charming solution in this mill is that the additional cost for the rotation is really very moderate and the control loop for strip centering control runs on the flatness computer without the need for additional intelligence.

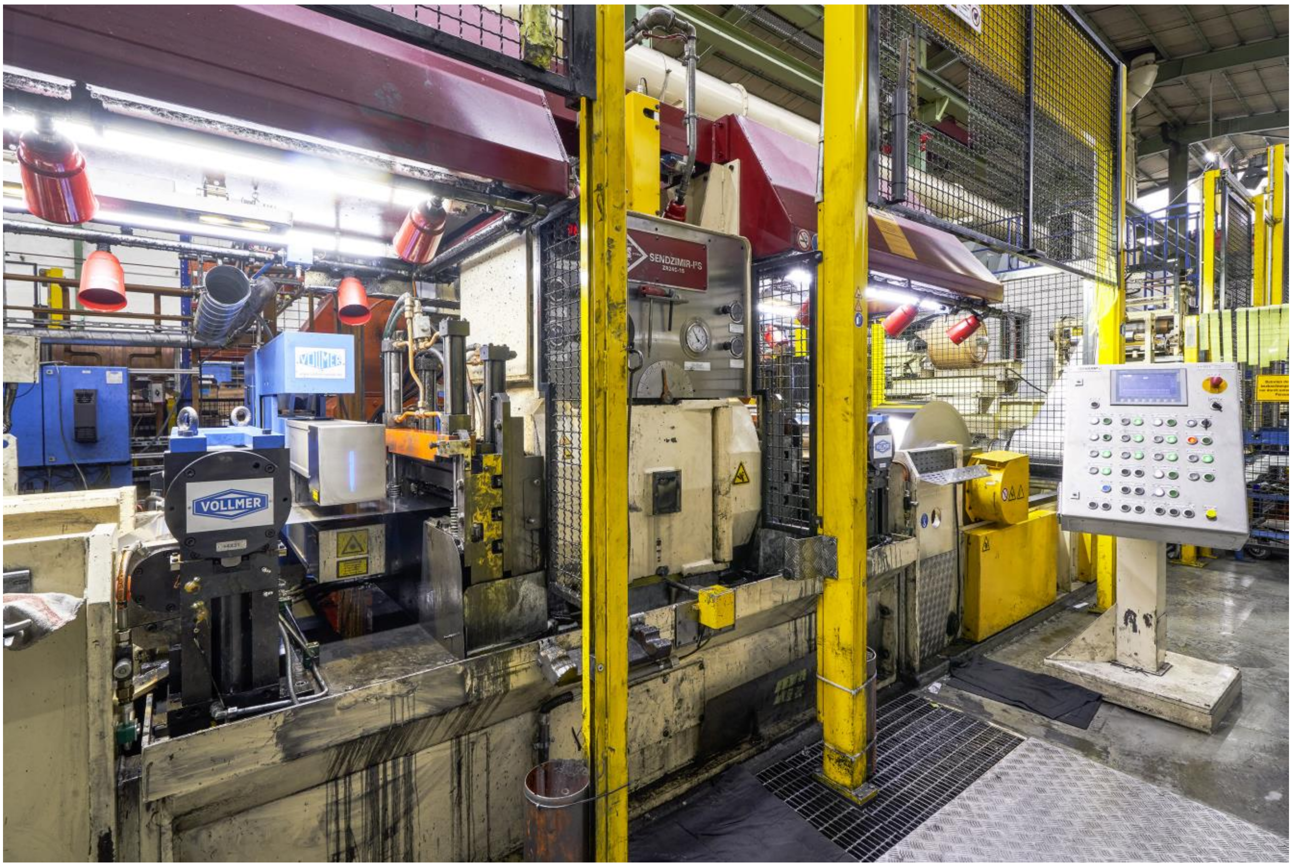


Figure 20: Photo of mill entry and exit sides

Elke Roller, May 10th, 2024