Latest bar mill technology

Two Chinese bar mills recently commissioned and a further one under construction represent the latest equipment designs and process technologies for the rolling of steel bars. Designed to meet the rapid expansion in automotive and construction sectors the mills combine high productivity with superior product mechanical properties and dimensional control.

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In the late 1990s VAI Pomini supplied two high-productivity bar mills to Shijiazhuang Iron & Steel Co and Maanshan Iron & Steel Co, China. In 2003 these mills produced 890 and 1,000kt, respectively, considerably more than the original design output of 600kt/yr, and are considered leading producers in their fields of bar for automotive industry applications and high strength steel rebar for construction applications, respectively. Such high productivity has been particularly welcome, given China's continuing demand for steel, currently 307Mt and growing in excess of 10% per year. The automotive and construction sectors are growing particularly strongly, requiring higher quality steel grades, tighter rolling tolerances, increased surface finish and better metallurgical and mechanical features.

To supply these markets two latest-generation bar mills from VAI Pomini have been successfully commissioned for Xuanhua Iron & Steel Group Co (XIS) and Tianjin Tiantie Zhaer Steel Production Co (TTZ), China, and a third for Hangzhou Zijin Industry Co (HZI) is under construction. The HZI mill is specifically tailored to the increasing quality demands of the automotive industry and represents the latest evolution of VAI Pomini equipment and process technology.

Starting billet size, mm-kg	150 x 150 x 12,000 – 2,000
Steel grades	Carbon structural, low alloy, spring, alloy structural and cold heading steels
Furnace capacity, t/ h	150
Production, kt/ yr	750 XIS, 700 TTZ
Finished products, mm	Rebars Ø 10–50
	Rounds Ø 14–50
	Squares 16–45
	FUTURE
	Angles 25 x 3–90 x 8
	Unequal angles 32 x 20–70 x 45mm (XIS only)
	Flats 45 x 5–120 x 15
	Channels 50 x 37–126 x 53
	I-Beams 80 x 42–100 x 50
Finishing speed, m/ s	18

Table1 **Design data of XIS and TTZ bar mills**

XIS AND TTZ BAR MILLS

Main features The design basis of the bar mills is shown in *Table 1*.

The general layout of the mills are shown in *Figures 1 & 2* and each comprise 18 Red Ring-HS fifth-generation stands in horizontal (H) and vertical (V) configuration, including three convertible (H/V) stands in the finishing train. All stands are equipped with VAI Pomini Ashlow rolling guides. Flying shears for end cropping and emergency scrapping are installed along the mill, one downstream of the roughing train and one downstream of the intermediate train. An in-line PQS (Pomini Quenching System) located after the last finishing stand of the mill train provides a specific thermal treatment to the rebar products in order to obtain high strength without extra alloying. A hot dividing shear with dedicated optimisation system, a high delivery speed, a 120m long cooling bed, fast cold cut-to-length line with a 450t flying shear, and a bundling area equipped with high-precision automatic bar-counter and tying machines complete the bar production plant. An example of the roll pass design for rebars at XIS is given in *Figure 3*.

The bar mills feature the most reliable automation equipment and rolling technologies, such as automatic cascade, cobble detection, and rolling mill monitoring to ensure a high degree of efficiency and reduce the risks of human error.

Red-Ring HS rolling stands More than 2,400 Red Ring stands have been supplied world wide (see *Figure 4*). Some of the benefits are:

- Short stress path and low mill spring to provide close tolerances on finished products
- Floating chocks to compensate for roll bending, thus avoiding edge loading on roll neck bearings
- Chock support housing is extremely compact thus assuring good stand traversing
- Screw-down screws are very short with a large diameter giving high strength and rigidity
- Stands are equipped with four row cylindrical roller

bearings; the load supported by bearings is higher than that supported by roll necks
- Thrust bearings to withstand axial loads (20% of radial load)
- Hydraulic balancing of chocks assuring close tolerance finished products from head to tail
- H-V stands are of same design and completely interchangeable
- Symmetrical movement of rolls when adjusting roll gap. Screw-down device placed on the top of the stand thus avoiding scale and water infiltration
- Vertical stands driven from the top to avoid damage caused by presence of water or scale on couplings, spindles, reducer and pinion stand
- Rapid pass and stand changing, and minimum roll change time when roll change robot is used in workshop
- Couplings fitting on spindles by an automatic self-centring device
- Installation of devices for reducing replacement times such as:
  - Rapid connection of piping (water, grease, oil, etc), locking and unlocking automatically when changing the stands

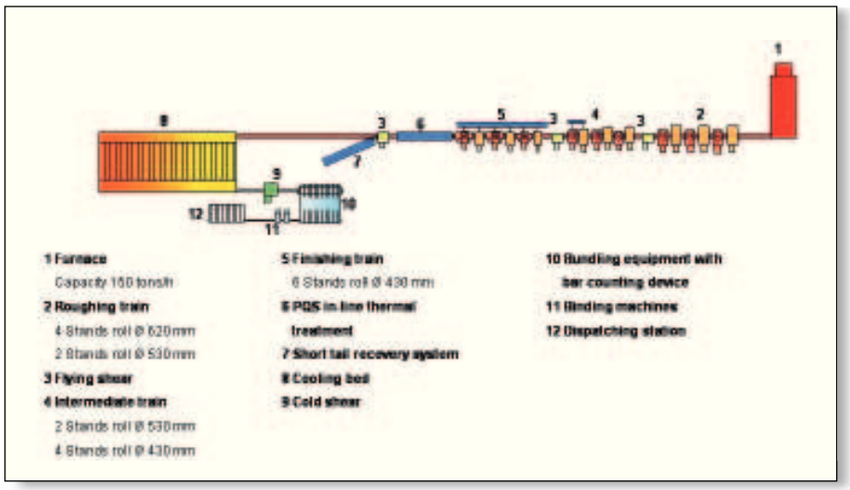

Fig.1 **Mill layout XIS bar mill**

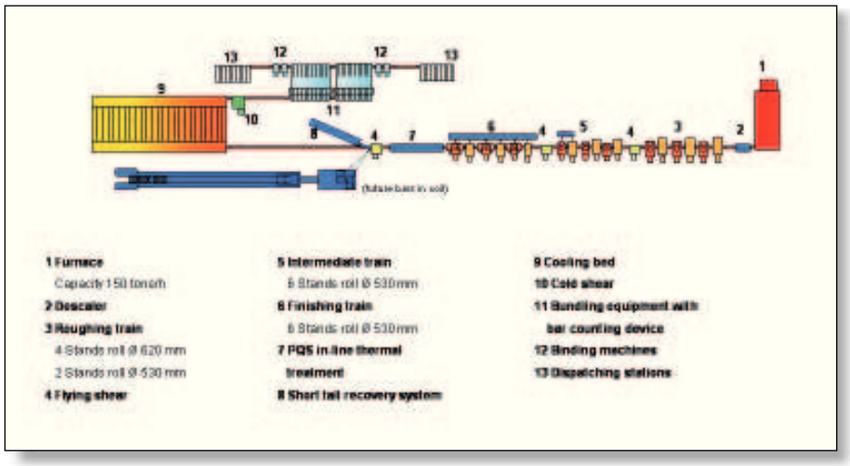

Fig.2 **Mill layout TTZ bar mill**

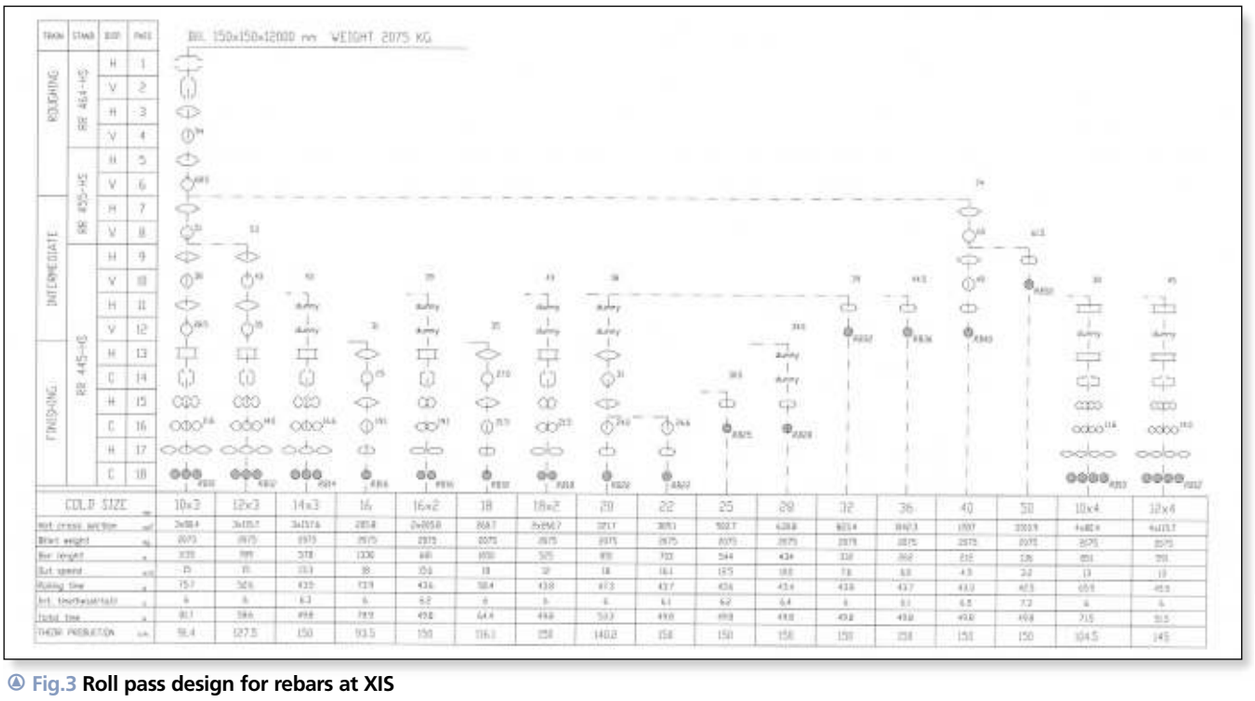

Fig.3 **Roll pass design for rebars at XIS**

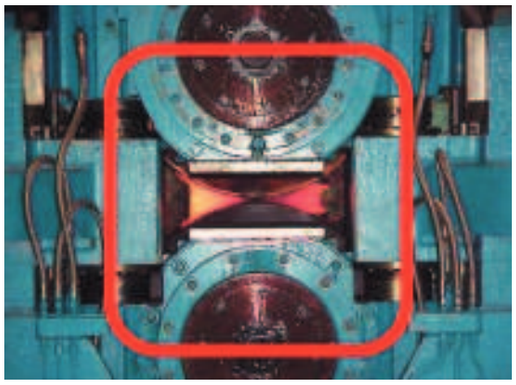

Fig.4 **Red-Ring HS rolling stands**

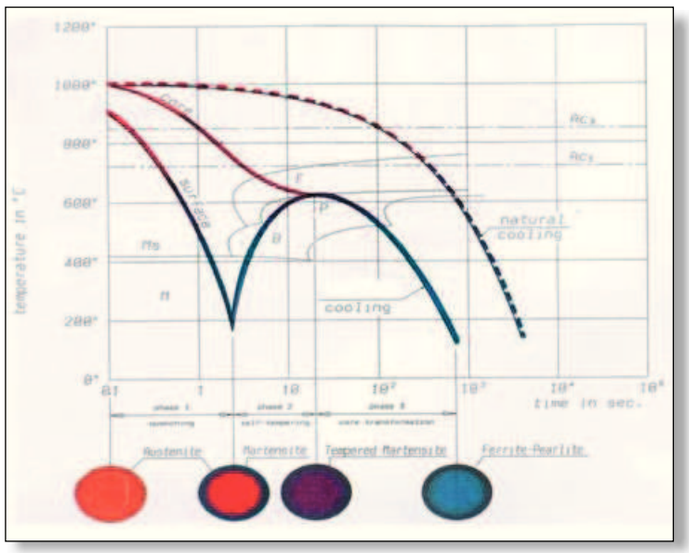

Fig.5 **PQS bar quenching processs**

– Quick change stand device for simultaneous changing of all the finishing stands
- Self-aligning spindle supporting device for automatic meshing of couplings on the roll necks
- Device for fixed stop position of the couplings with an accuracy of +/- 2°

Stand changing on the mill is by crane on stands 1–12 and by a rapid simultaneous changing device on stands 13–18. All operations are controlled by one operator from the local control pulpit. Roll changing in the roll shop will be via robot. The design of the stand and use of the robot reduce dramatically the roll changing time compared to traditional stands. A tilting cradle is also foreseen to rotate the vertical stand into horizontal for easier changing.

PQS bar quenching process Standard bar rolling mills are usually designed for the production of bars to be used in the as-rolled condition after cooling in air. For such material the yield strength can be increased by:

- Increasing carbon and manganese contents
- Adding small quantities of dispersoid forming elements such as vanadium and niobium
- Cold deformation after hot rolling

While use of carbon is relatively inexpensive, it results in a significant decrease in weldability. The second option increases the yield strength without decreasing the weldability but the additions are costly. The third option is very expensive in terms of equipment, labour and instrumentation and also reduces ductility and weldability.

To avoid these drawbacks, VAI Pomini employs the PQS which makes it possible to economically produce high yield strength concrete-reinforcing bars, without the need for expensive additives or further working processes.

This in-line water cooling system has been extensively employed since 1972 and has proven itself to be most efficient and reliable. The process essentially consists of heat treatment of the bar being rolled utilising its rolling heat (see *Figure 5*). The bar leaving the last finishing stand immediately passes through special water cooling pipes – the cooling efficiency of these pipes is such that the surface layer is quenched to martensite, while the core remains austenitic. As the bar leaves the quenching pipes, the temperature gradient causes heat to flow from the centre to the surface of the bar causing a self-tempering of the martensite, while the core is still austenitic. Finally the austenitic core transforms to ferrite and pearlite during the slow cooling of the bar on the cooling bed. By modifying the water flow/pressure or the quenching line length (by removing cooling elements from the rolling line), the cooling rate can be controlled in accordance with steel grade requirements.

Highlights at XIS The final acceptance certificate was signed on 24 November 2003, two months after the start of hot plant commissioning, and only 14 months from the award of the contract, thus fixing a new benchmark for this kind of project. During the test period, the mill reached all the guaranteed performances in terms of speed (>18m/s), productivity (>150tph, >3,000tpd) and rolled products (from Ø 14mm tri-slitting to Ø 50mm).

The combination of modern equipment with the skills and the high motivation of the Xuanhua production personnel enabled very rapid achievement of high production levels. Output rose rapidly after commissioning, from 28kt in month one to 55kt in month two and in excess of the target capacity of 60kt in month three.

HANGZHOU ZIJIN INDUSTRY CO BAR MILL

Overview This new rolling mill will employ the latest rolling mill technology including automatic control of rolling; and use of sizing technology, low temperature rolling and finishing. The trend in the steel industry is to obtain the required product quality in terms of mechanical properties and dimensions as much as possible with in-line treatment, so avoiding off-line (and expensive) treatment.

The general layout of the mill is shown in *Figure 6*. It comprises 16 Red Ring-HS fifth-generation stands with horizontal and vertical configuration and is equipped with VAI Pomini Ashlow rolling guides. Fully automated water cooling sections provide controlled temperature rolling, and the combined use of tension and tension-free rolling, ABB U-gauges, in-line size gauge and defect detector, anti-scratch design cooling bed for high quality steel and the Long-Life Disk abrasive saw with robotic disk change, will all help to produce the highest quality bar products. The roll pass design for rounds is shown in *Figure 7*.

Flying shears for end cropping and emergency scrapping are installed along the mill, one downstream of the roughing train and one downstream of the intermediate train. Two cooling sections are placed downstream of the intermediate train to control finishing rolling temperature. Additionally three PSG stands of the CGA 180/100 type, representing the last generation of reducing and sizing stand, are installed to achieve the highest bar finishing quality. An additional four-roll ultra precise sizing unit can also be installed to achieve even tighter tolerances.

A third cooling section is placed before bar cutting in multiples of commercial lengths to control the rolled product finishing temperature, thus preparing it for subsequent treatments on the cooling bed. A hot dividing shear with a dedicated optimisation system, a high delivery speed, 126m long cooling bed, a quality cold cut-to-length combined line with a 1,200t start-stop static shear and a fixed abrasive cut saw, and a bundling area equipped with a dedicated stacker and ▷

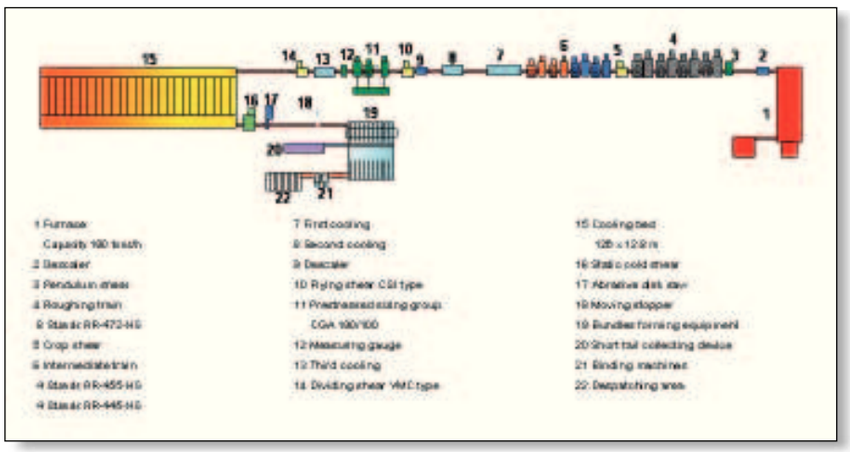

Fig.6 **Mill layout HZI bar mill**

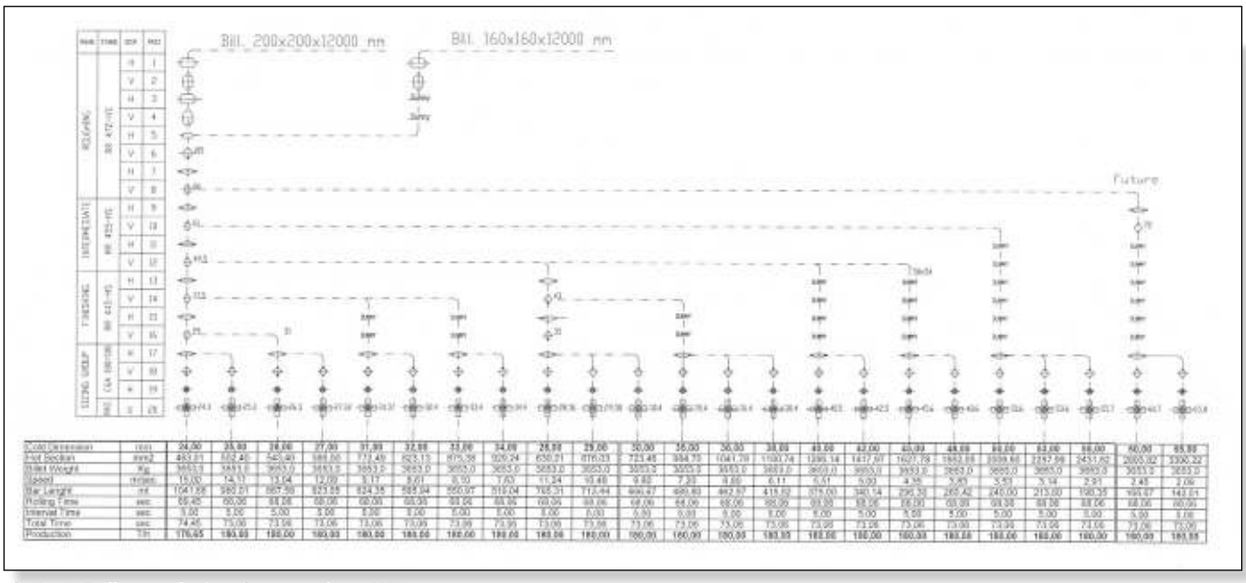

Fig.7 **Roll pass design for rounds at HZI**

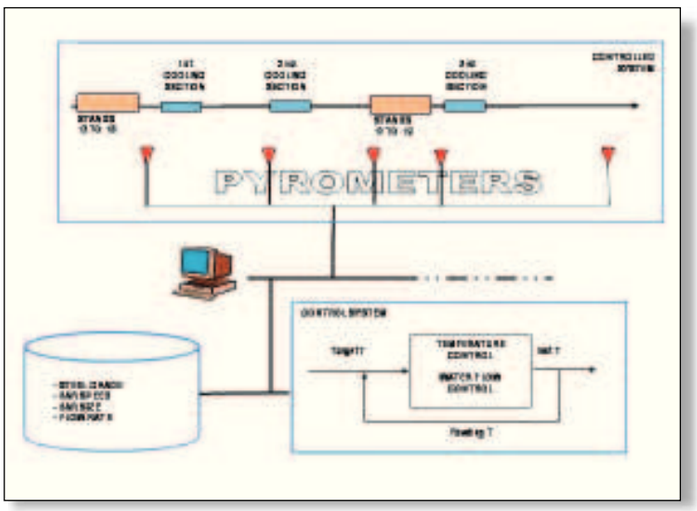

Fig.8 **Cooling control system**

tying machines complete the bar production plant.

Design basis The design basis data of the bar mill is shown in *Table 2*.

Cooling control system A suitable combination of reduction and controlled cooling enables a substantial improvement in product quality to be achieved (see *Figure 8*). The use of low temperature finishing rolling, where controlled deformation applied in the last stands of the mill train within the temperature ranges corresponding to the normalising rolling process or thermo-mechanical rolling, leads to a refinement of the microstructure that consequently improves metallurgical and mechanical properties.

Steel microstructure is determined during the hot rolling sequence and modified as a consequence of the solid state transformations occurring during controlled cooling. Each section is provided with two pyrometers, the first placed before the cooling section entry and the second after equalisation. The automation system is able to guarantee rapid tuning of the cooling rate, taking into account bar speed, bar diameter, entry temperature and equalised exit temperature. If the exit temperature read by the pyrometer is different from the target temperature, the system is able to adjust the water flow rate. The system is tuned not to react to small changes in rolling conditions, thereby avoiding a continuous change water flow closed loop.

Starting billet size, mm-kg	160 x 160 x 12,000 – 2,338 200 x 200 x 12,000 – 3,653
Steel grades	Structural, alloy structural, bolt, spring and bearing steels
Furnace capacity, t/ h	180
Production, t/ y	800,000
Finished products, mm	Rounds Ø 24–55 (65)
	FUTURE
	Flats 50 x 7–100 x 30
Finishing speed, m/ s	15

Table2 **Design data of HZI bar mill**

Pre-stressed Sizing Group (PSG) The PSG can operate in two main modes: precision rolling using two stands when bar tolerances over 1/2 DIN 1013 are acceptable, or precision sizing using three stands when bar tolerances better than 1/3 DIN 1013 are required.

Three main ways are provided to change the product size:

- Free sizing – open or close the stand gap (1–2 minutes)
- Groove change – Along the multi-groove stand barrel length with guides already pre-set on the rest bars (20–30 seconds)
- Quick stand change – change the stand(s) by using quick change device (2–3 minutes). However, during rolling the stands changed must be re-set off-line in the roll shop to be ready for the next size to be produced

After any size change the rolling operation can start immediately without any need for a trial bar. For very tight tolerance requirements the installation of a Precision Rolling Sizing (PRS) unit is additionally foreseen. This application is in response to the automotive industry request for a wide range of stepless rolled product within ultra-precise dimensional tolerances (<1/5 DIN 1013, <1/2 ASTM A29). This four-roll stand features better roundness, no material spread, no overfill and a much larger diameter range within any pass geometry.

The permitted roll separating forces and rolling torques are considerably higher than in conventional Red-Ring stands. This provides the possibility of rolling additional steel grades with higher deformation resistance, and also to apply thermo-mechanical rolling.

For some special bar qualities for the production of automotive parts, such as bearing and spring steel, low and medium alloyed steel and cold heading steel very precise dimensional tolerances are required. These can be obtained at the end of a normal rolling sequence by the use of a new type of hot rolling sizing stands located at the outlet of the mill (see *Figure 9*). The benefits to steel user and producer are:

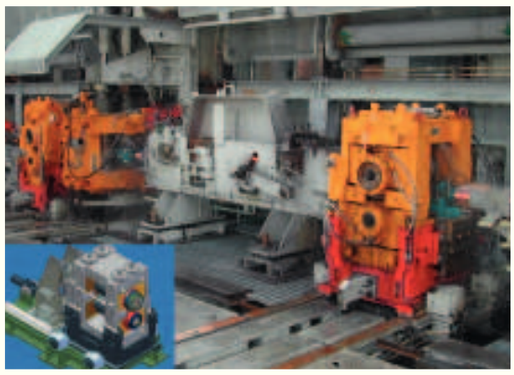

Fig.9 **PSG Pre-stressed sizing group**

Fig.10 **In-line measuring gauge**

- Optimum product dimensions with a consistent head-to-tail tolerance (and hence improved yield)
- No need for further off-line operations such as peeling or cold drawing
- Increased production and better mill utilisation due to the 'one family rolling concept'
- Reduction in production costs and quicker final product delivery on demand
- Possibility of performing thermo-mechanical rolling
- Ability to expand production range to include more added value products
- Achievement of dimensional precision very close to that of cold finished products

In-line product quality testing In today's competitive market, the quality control of the finished products must be performed as much as possible in-line to limit the production of out of tolerance or low quality products. At HZI an eddy current testing device to provide multi-channel, high speed testing, defect marking and documentation of test result, and a measuring gauge (see *Figure 10*) that can guarantee accurate measurement of the bar dimension allowing for equivalent cold bar size calculation and display, will be installed. Bar twist problems are limited by constant 360° rotation of the reading heads around the bar. Accuracy is unaffected by product vibration even at high rolling speed.

Results from an operating mill with in-line product quality testing equipment showed a drop of the rejected production from 3.2% to 1.2% and drop in yield loss from 3.1% to 2.1% in one year of operation.

CONCLUSIONS

The two latest high-productivity bar mills recently commissioned for Xuanhua Iron & Steel Group Co and Tianjin Tiantie Zhaer Steel Production Co exploit the high potential of VAI Pomini equipment, already proven in Shijiazhuang Iron & Steel Co and Maanshan Iron & Steel Co bar mills, in order to meet the increasingly demanding requirements of the market both in terms of output and quality.

The Hangzhou Zijin Industry Co bar mill will represent a benchmark plant for productivity and product quality for a long time to come. MS

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