Measuring Systems
in Tube Mills

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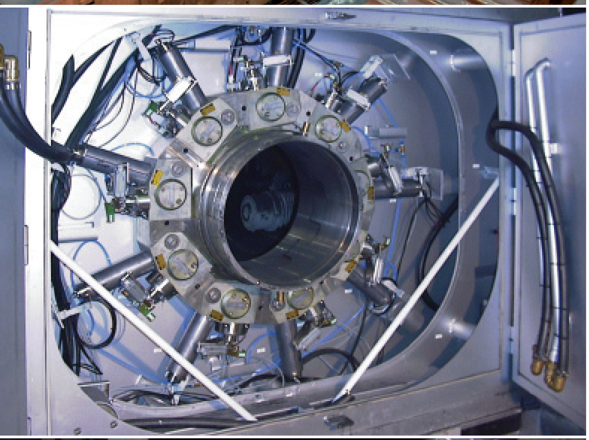
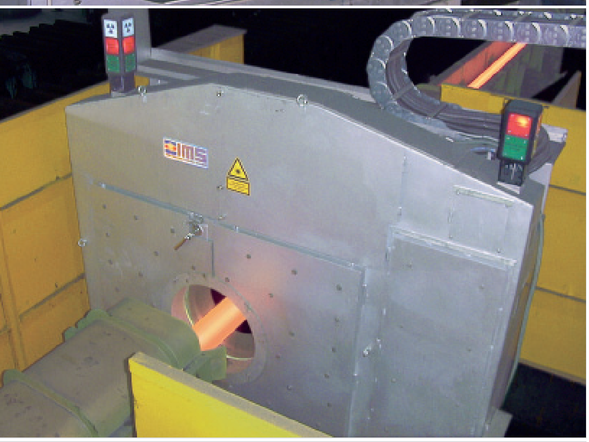
Contents

Tube Production and Metrology





From top to bottom:
Stretch reducing mill – 1-channel system
Internal view sources/detectors – 9-channel system
Exit sizing mill – 9-channel system

In order to ensure economical production of seamless tubes, dating back to an invention of the Mannesmann brothers in 1885, it is necessary today – and will remain so in the future – to know the properties of the product after every single one of the typically three forming stages in the tube production process.

The ever stricter demands being placed on the finished product „tube“ regarding uniformity and compliance with tighter tolerance limits with simultaneous savings in energy and raw materials necessitate a high degree of process reliability, which can only be achieved with precise, operationally reliable and durable measuring equipment.

To verify the quality of the product, also to the users of the tubes, all the product parameters measured are archived, monitored and analysed. In this way it is possible to make information on every single tube produced available both directly during the production process and also months after delivery.

Objectives

- Continuous acquisition and storage of all measured values, production parameters and system events
- Feedback of the measured values to the pilot control and/ or tracking of the control devices of the rolling units
- Targeted error diagnosis to support the operator
- High availability of the measuring system

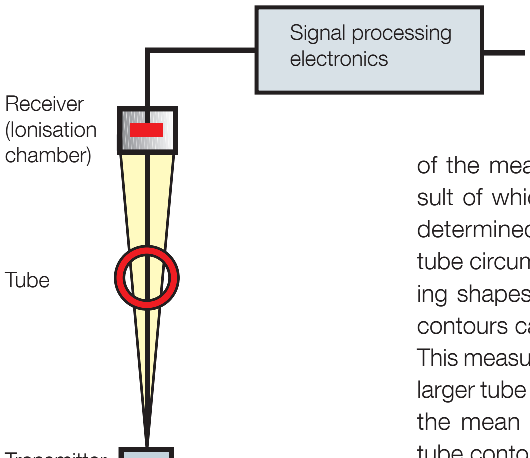
Profitability

- Deliberate utilisation of the lower wall thickness limits with simultaneous equalising of the tube wall profile along the complete length of the tube according to the classifications and special customer require-ments
- Reduction in downtimes after dimensional changes as manual sampling and manual roll adjustment are not necessary
- Increase in material yield with simultaneous savings in feedstock and energy

Measuring Principle
and Physical Influencing Factors

General measuring principle

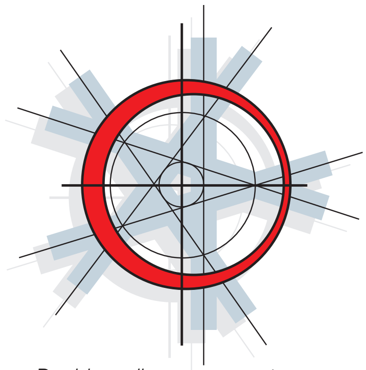
Tube wall thickness measuring systems work by the irradiation principle, where a radiation source (transmitter) is arranged opposite an ionisation chamber (receiver). A measuring object (tube) located between the transmitter and receiver absorbs a part of the radiation. The residual radiation detected by the ionisation chamber generates an electric current, which is processed and digitalised in a measuring transducer and then sent to a central signal processing system for calculation of the tube wall thickness.



Measuring principle

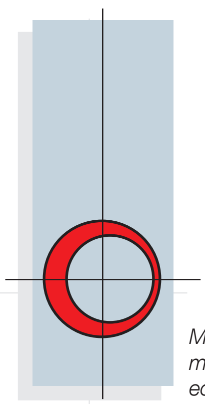
Mass measurement

In the 1, 2 or 4-channel version of the measuring system the complete mass of the tube in the respective measuring plane is measured – the wall thickness indicated corresponds to the mean of the tube cross section.
This measuring geometry is therefore typically used for small tube dimensions, where the tube contour was already determined before the finished tube dimensions were reached or is of little interest.


Double-wall measurement

Double-wall measurement

In the multichannel version (5, 9 or 13-channel version) of the system the tube wall is irradiated respectively at two points, i.e. twice. The beams are arranged uniformly around the center of the measuringsystem, as a result of which the wall thickness is determined around the complete tube circumference and typical rolling shapes of different tube inside contours can be determined.
This measuring geometry is used for larger tube dimensions so that both the mean wall thickness and the tube contour can be determined.


Mass measurement eccentric tube

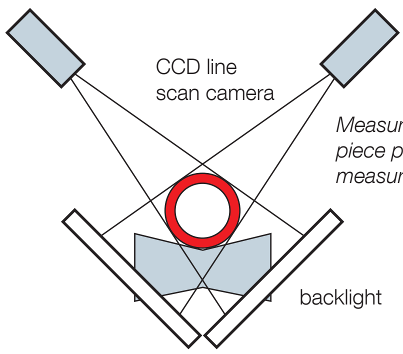
Influencing factors

The measurement of wall thickness, i.e. the measuring effect at the moment of measurement, depends on the following three main influencing factors:

- measuring piece position
- measuring piece temperature
- measuring piece alloy

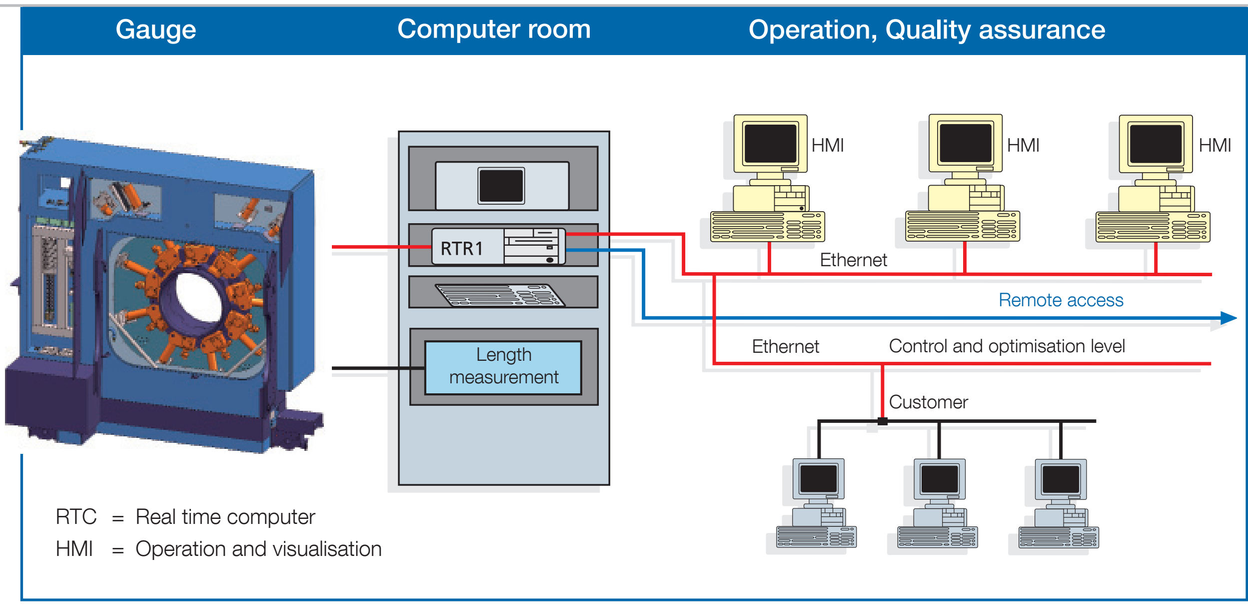
These influencing factors are taken into account either through separate measurement or using customer data specifications.
The measuring piece position is measured with the help of two CCD line scan cameras.
The position information and tube dimensions are then used to calculate the correcting parameters for the wall thickness.

The measuring piece temperature is measured with a colorimetric or ratio pyrometer depending on the production temperature. The correcting parameter for the wall thickness can then be calculated on the basis of dilatometer curves stored in the system.
If grades of steel whose alloys differ from the standard alloysare rolled, the correction values are also calculated here on the basis of data specifications.



Measuring piece position measurement

System Configuration



Configuration

The measuring systems are designed for the particular measuring task and rolling mill configuration in cooperation with the customer. A measuring system usually consists of the following components:

- gauge (measuring frame in C- or O-frame shape with one to 13 measurement axes)
- further sensor measuring systems to determine diameter, ovality, diameter profile, temperature, length and speed
- auxiliary components for the gauge such as power supply and monitoring equipment, cooling systems, etc.
- central signal processing unit with multiprocessor system including operation, visualisation and the necessary network components
- visualisation stations for the operating and maintenance personnel
- quality management system for documentation and archiving of tube and system data over longer periods of time

Disturbance compensation

To obtain exact measured data, the following influences must be compensated:

- dirt, e.g. scale, dust, lubricants, etc.
- measuring piece position changes on the roller table
- measuring piece temperature, for calculation of the cold or hot dimensions
- measuring piece alloys deviating from the standard alloys

The influences of the disturbances are measured with the help of suitable sensors or obtained from data specifications and compensated by mathematical processes or automatic adjustment procedures.

Signal Processing

Signal transmission

The detector signals are digitalised in the C- or O-frame and transferred to the measured value processing unit via an Ethernet network system. Fibre optic transmission components are used in the case of long distances between the gauges and the central signal processing unit.

MEVInet

The powerful multiprocessor system MEVInet is responsible for the complete evaluation of the measured values, monitoring of the measuring system as well as operation, visualisation, data management and quality assurance. The individual components are connected to each other by a fast data network.

The computer system MEVInet consists of the following main components:

- *Real time computer*
  - Operating system Windows
  - Runtime system logiCAD
- *Server, HMI*
  - Operating system Windows
  - MS SQL Server
  - Visual Basic / IMS Dataviewer
- *Project planning system*
  - logiCAD to IEC 1131 (Freely programmable control and regulation system)

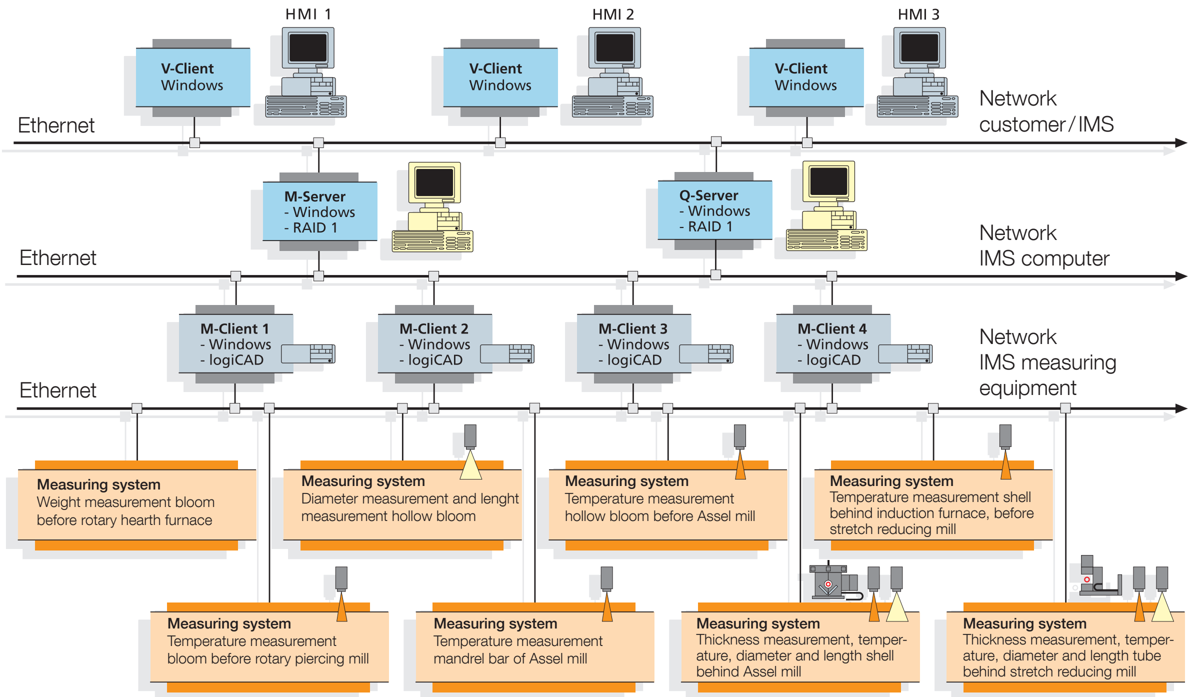
Comprehensive monitor screens enable optimum operation of the measuring system as well as user-friendly service and maintenance work. Optimisation and long-term support of the measuring systems installed around the world are effected by remote maintenance via the internet.

The measured data is evaluated according to customer requirements and sent to master systems.

The tube measuring system determines the following variables:

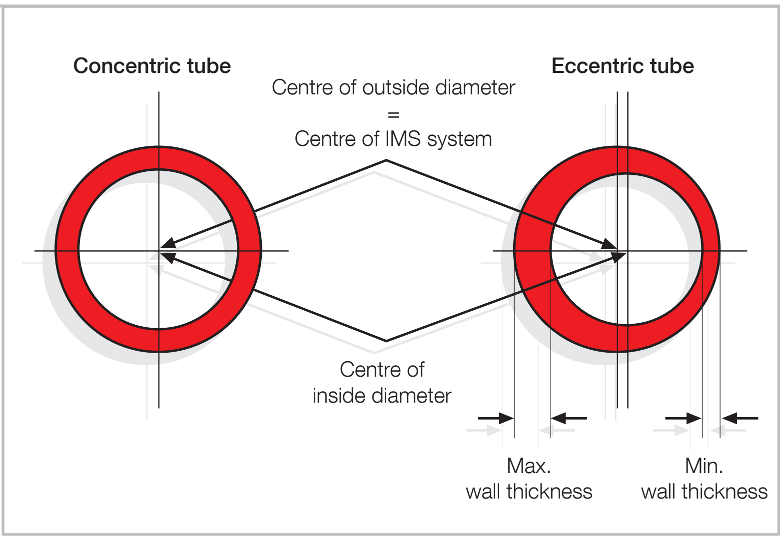
- Mean wall thickness
- Individual wall thickness around the tube circumference *
- Eccentricities of the first to sixth order *
- Tube cross sectional profile *
- Outside diameter, ovality and diameter profil
- Temperature and length
- All measured values are available directly during measurement as online display and are shown at the end of the measurement as profile along the tube length
- Long-term data acquisition and statistical distribution

* Dependent on type of system



Tube Mills

and Typical Tube Contours



Concentric and eccentric tube

Rotary piercing mill and press

In the first forming step in tube production the solid bloom is „pierced", i.e. a rolling or pressing process turns the solid material into hollow material (hollow bloom).

In the rotary piercing method, which is the most widespread process in use today for the first rolling stage, the tensile stresses occurring inside the bloom, caused by the two staggered rolls (skew rolls) running against each other, are used to tear open a hole shortly before the piercing mandrel. The process is therefore less a mechanical „drilling" than a „widening" or „pulling on".

In the pressing method, which is often used in the preliminary stage of pilger mills, a die is pressed into the bloom under high pressure so that a hole is formed in the bloom by transverse impact.

Eccentricity

In the ideal case both piercing methods should form a concentric hollow bloom, i.e. the centre of the inside radius is simultaneously the centre of the outside radius.
Various external influences, however, cause the two centres to be moved from this ideal position more or less strongly, resulting in an eccentric tube contour.
The following main influences lead to an eccentric tube geometry:

- Unequal temperature distribution in the hollow bloom
- Imprecise centring of the bloom
- Worn or defective piercing mandrels

As a result of the rotation of the bloom during the rolling process, the eccentricity has a spiral shape in dependence on the feed angle of the skew rolls. The eccentricity formed in the bloom press only changes in amplitude, and not in orientation, along the length of the tube.

MPM and sizing mill

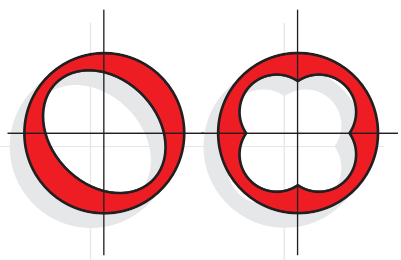
In an MPM (multistand pipe mill) and sizing mill two-roll stands arranged alternately at 90° to each other are used.

In the MPM the rolls roll against a mandrel bar, i.e. the rolls reduce the wall thickness while retaining a constant inside diameter. The outside contour only becomes round in the so-called extractor mill (MPM extractor), which is not reached by the mandrel (held mandrel), but then previous irregularities in the inside contour are moved.

The typical shapes occurring here are an internal oval and/or an internal quadrangle (cloverleaf).
The causes of this are:

- Uneven or offset rolls
- Rolls that are opened too wide or closed too far

The shape is typically constant along the complete length of the tube.



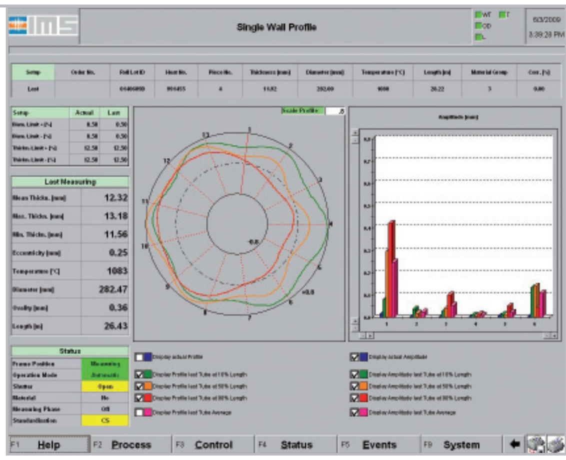
Internal oval and internal quadrangle

Push bench, stretch reducing mill, sizing mill

As an alternative to the aforementioned two-roll mills, three-roll mills are also used. The push bench process differs from the stretch reducing and sizing mill in that the rolls roll against an internal tool, the so-called mandrel bar, similarly to in an MPM mill. The mill stands are not driven – the hollow bloom is pushed.

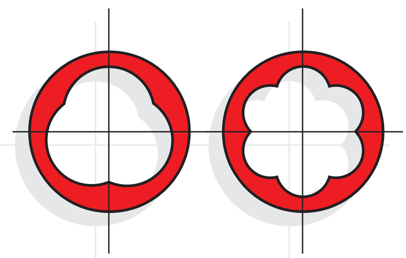
The stretch reducing and sizing mill produce the outside diameter and wall thickness of the finished tube. This is done by arranging numerous three-roll stands, which can be driven jointly or separately, one behind the other. In stretch reducing mills with individual or group drives the wall thickness can be controlled locally using an automation system.

All three mill types produce a typical shape here of an internal triangle or internal hexagon.



Internal tube contour of an PQF® tube

Evaluation "thickened ends"



Internal triangle and internal hexagon

Measured value display

Very different gauge types can be used in the three-stage rolling process depending on the measuring task, which is reflected by the different displays.

In the field of mass measurement the mean wall thickness along the tube length is shown.

As additional functionality the measuring system can determine the lengths of the thickened ends on stretch-reduced finished tubes in order to control a rotary saw with these tube length positions.

Using numerous gauges in the passline, it is possible to monitor the control intervention of the automation system easily.

This is done by comparing the measured data on the shell, which is stored temporarily, with the measured data on the finished tube.

In addition to information on the mean wall characteristic, the multichannel gauges determine the internal contour of the tube up to the sixth order (internalhexagon) depending on the number of channels (5, 9 or 13 channels).

High-resolution
Diameter Profile Measurement

Diameter profile measuring system in a PQF® mill

New rolling technologies in the production of seamless steel tubes such as individually adjustable rollers in three-roller stands in PQF® mills or adjustable end stands in stretch reducing mills have made suitable and cost-efficient measuring systems necessary to meet the stricter demands for transparency in the rolling process and maximum accuracy in measurement.

System features

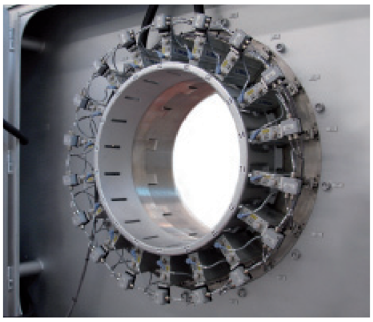
- Equipped with 18 or 24 sensors, other versions on request
- Data transmission via CAN bus at up to 1000 kbit/s
- Installation on water-cooled protective ring and behind protective doors with heat protection shields for measurement in hot environments
- Protection against contamination by pressure blower
- Easy-to-use calibration equipment

This demand can be met optimally using high-precision laser triangulation sensors. For this preferably 18 or 24 sensors are arranged circularly around the circumference of the tube. Through synchronisation of the individual sensors among each other, the measured data of all sensors are outputted simultaneously at measuring rates in the ms range, resulting in a distortion-free representation of the outside profile of the tube.

This configuration is particularly interesting in combination with a multi-channel wall thickness measuring system because it represents a fully integrated solution for measurement of all geometric parameters on hot tube requiring only one complete gauge.

A version as independent gauge without wall thickness measuring system is also available.

IMS has been using laser triangulation sensors from the Swedish company LIMAB, based in Gothenburg, since 2007 to determine tube position as an alternative to CCD camera systems. The business relationship between LIMAB and IMS was upgraded to a partnership in the field of diameter measurement in 2009 with integration of high-resolution diameter measurement by means of LIMAB measuring heads into the IMS multi-channel tube wall measuring system.



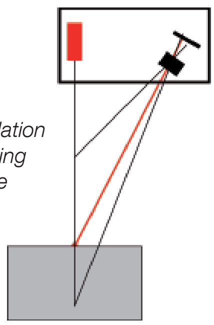
18-channel diameter profile measuring system

LIMAB laser triangulation sensor

Measuring principle and configuration

The measuring principle used by the individual measuring heads is based on a distance measurement by means of optical triangulation.

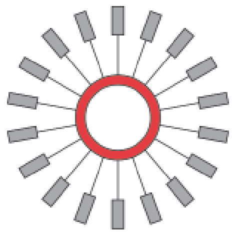
A laser point is dropped on to the surface of the material to which the distance is to be measured. The laser point is reflected diffusely by the surface. The light of the laser point is imaged within the measuring range of the measuring head on a CCD line (charge coupled device) via an optical system. The axis of the optical system is locked on a fixed angle to the outlet direction of the laser beam.



Triangulation measuring principle

By analysing the position with the highest light intensity on the CCD line and based on the fixed geometrical relationship (triangulation), the position can be converted to a distance with the help of the calibration curve stored in every measuring head.

The configuration for high-precision determination of the outside diameter and the profile consists of several individual sensors arranged in pairs opposite each other.



Configuration with 18 sensors

Simultaneous determination of the distances of all sensors to the surface of the material supplies the basic information needed for further calculation of the tube profile.

At the end of the processing chain the following parameters are displayed and process correcting variables derived as result:

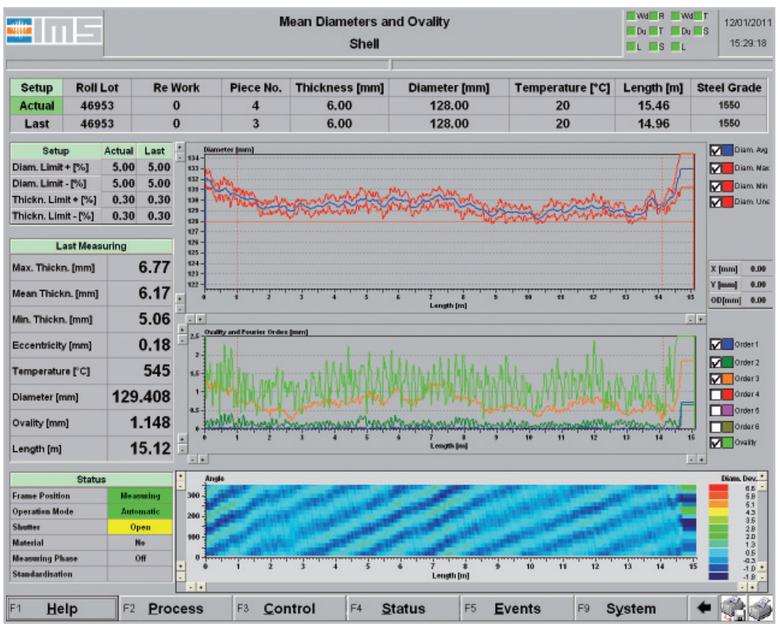
- mean diameter
- minimum and maximum diameter and their directional position
- ovality and evaluation of certain structures such as triangular or hexagonal shapes

Technical data single measuring head

- Measuring head measurement range 200 mm (standard version)
- Stand-off distance 100 mm
- Resolution 10 µm
- Measuring frequency 2000 1/s
- Wavelength 635 … 670 nm (visible red)
- Laser class 3R/3B

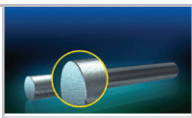
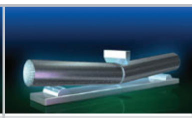
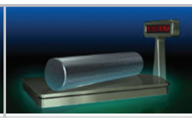
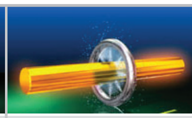
Technical data profile measurement

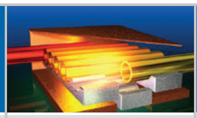
- Minimum diameter > 20 mm
- Diameter range with up to 400 mm diameter change possible (freely configurable)
- Measuring accuracy diameter < ± 25 µm
- Measuring accuracy ovality < ± 50 µm

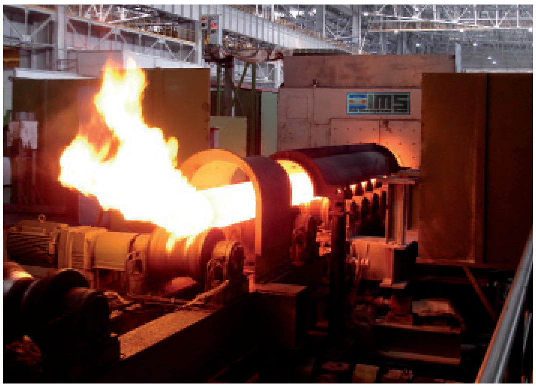


Diameter, ovality and false-colour profile

Tube Measuring Systems in a Seamless Tube Mill
PQF© / FQM™ Mill

					T [°C]
Optical bloom identification (barcode)	Bloom division for optimum finished tube length utilisation	Bloom weight measurement	Bloom heating in rotary hearth furnace	High pressure bloom descaling	
Laser scanner		**Roller table weigher**			**Ratio pyrometer**
Takeover data specifications		Takeover bloom weight			Temperature measurement bloom

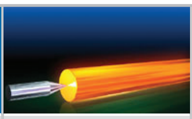
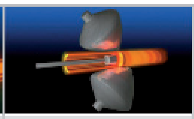
S [mm]	D [mm]	T [°C]	L [m]		T [°C]
Multi-channel measuring system (5- , 9- or 13-channel system)				Intermediate heating of shells in walking beam furnace	
Multi-channel thickness gauge	**Laser triangulation gauge**	**Radiation pyrometer**	**Laser length gauge**		**Ratio pyrometer**
Wall thickness measurement shell	Diameter and outside profile measurement tube blank	Temperature measurement shell	Length measurement shell		Temperature measurement shell after intermediate heating

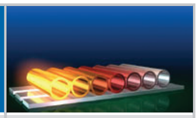


Multi-channel measuring system at entry to walking beam furnace

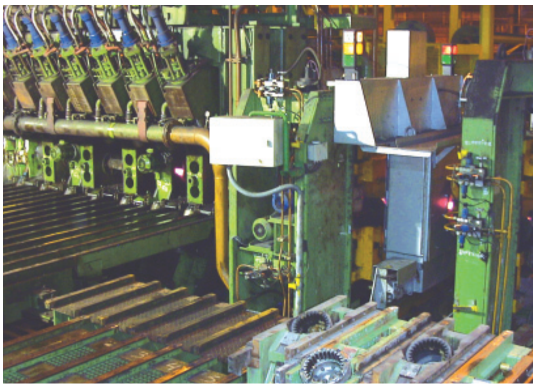
PQF®- or FQM™-Mill
(**P**remium **Q**uality **F**inishing Mill or **F**ine **Q**uality **M**ill).

The flowchart shows an example of the measuring equipment of a modern seamless tube mill. The material is formed in three stages: after heating of the bloom in a rotary hearth furnace in a rotary piercing mill (piercing), a PQF® or FQM™ mill (elongation) and a stretch reducing mill (finishing).

			T [°C]	D [mm]	L [m]	
	Bloom centring	Piercing of bloom in rotary piercing mill				Rolling of hollow bloom to shell in PQF® and FQM™ mill
			Ratio pyrometer	**CCD camera (infrared)**	**CCD camera (infrared)**	
			Temperature measurement hollow bloom	Diameter measurement hollow bloom	Length measurement hollow bloom	

→		S [mm]	D [mm]	T [°C]	L [m]	
	Stretch reduction of shells to finished tube dimensions	2- or 4-channel measuring system				Air cooling of finished tubes on cooling bed
		Thickness gauge	**Laser triangulation gauge**	**Ratio pyrometer**	**Laser length gauge**	
		Wall thickness measurement finished tube	Diameter and outside profile measurement finished tube	Temperature measurement finished tube	Length measurement finished tube	

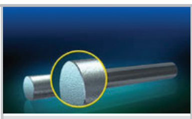
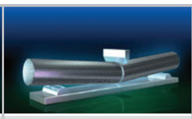
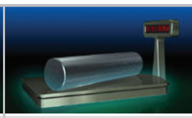
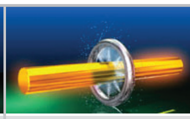
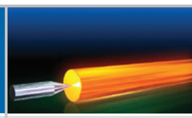
Characteristic for a PQF® or FQM™ mill in comparison to a conventional MPM mill (multi-stand pipe mill) is use of hydraulically adjustable three-roller stands and a held mandrel. Thereafter the shells are rolled to the respective finished tube dimensions required in a stretch reducing mill comprising up to 28 stands. Adjustable end stands can also be used here.

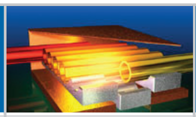


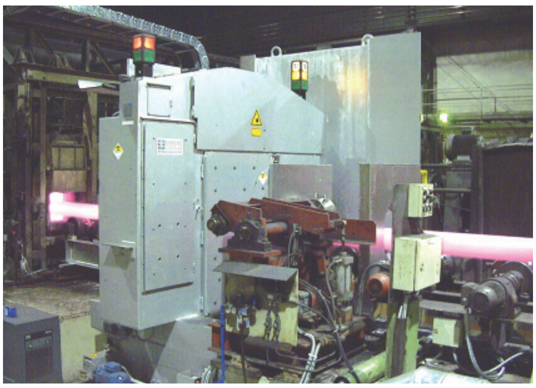
2-channel measuring system behind SRM

Tube Measuring Systems in a Seamless Tube Mill

CPE Mill

					T [°C]	
Optical bloom identification (barcode)	Bloom division for optimum finished tube length utilisation	Bloom weight measurement	Bloom heating in rotary hearth furnace	High pressure bloom descaling		Bloom centring
Laser scanner		**Roller table weigher**			**Ratio pyrometer**	
Takeover data specifications		Takeover bloom weight			Temperature measurement bloom	

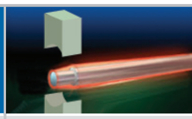
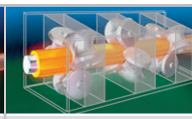
	S [mm]	D [mm]	T [°C]	L [m]		T [°C]
Mandrel bar extraction	Multi-channel measuring system (5- , 9- or 13-channel system)				Intermediate heating of shells in walking beam furnace	
	Multi-channel thickness gauge	**CCD cameras (backlight, stereoscopic)**	**Radiation pyrometer**	**Laser length gauge**		**Ratio pyrometer**
	Wall thickness measurement shell	Diameter measurement shell	Temperature measurement shell	Length measurement shell		Temperature measurement shell after intermediate heating

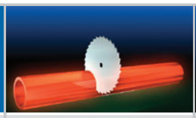
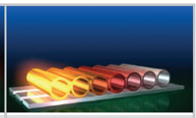


Multi-channel measuring system at entry to walking beam furnace

CPE mill

(**C**ross-roll **p**iercing and **e**longation)
The following mill layout is representative of the material flow in the hot forming section of a seamless tube mill. The three-stage material forming process takes place after heating of the bloom in a rotary hearth furnace on a rotary piercing mill (piercing), a push bench (elon-

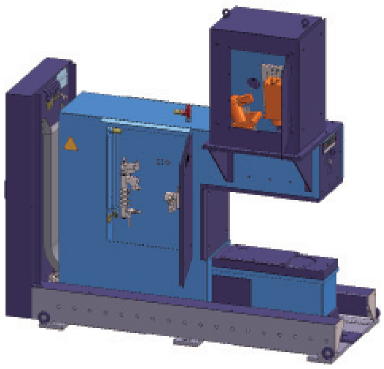
→		T [°C]	D [mm]	L [m]			
	Piercing of bloom in rotary piercing mill				Forming of hollow bloom head by Kümpel press	Rolling of hollow bloom to shell on push bench	Expansion of shell in detaching mill
		Ratio pyrometer	**CCD camera (infrared)**	**CCD camera (infrared)**			
		Temperature measurement hollow bloom	Diameter measurement hollow bloom	Length measurement hollow bloom			

→		S [mm]	D [mm]	T [°C]	L [m]		
	Stretch reduction of shells to finished tube dimensions	1-channel measuring system				Online separation of "thickened ends" on finished tube and cutting to length	Air cooling of finished tubes on cooling bed
		1-channel thickness gauge	**CCD camera (infrared)**	**Ratio pyrometer**	**Laser length gauge**		
		Wall thickness measurement finished tube	Diameter measurement finished tube	Temperature measurement finished tube	Length measurement finished tube		

gation) and a stretch reducing mill (finishing). Characteristic for the CPE method is forming from solid bloom to shell without intermediate heating. Thereafter the shells are rolled to the respective finished tube dimensions required in a stretch reducing mill comprising up to 28 stands.

1-channel measuring system in feed roller table to cooling bed

Gauge Types –
Mass Measurement



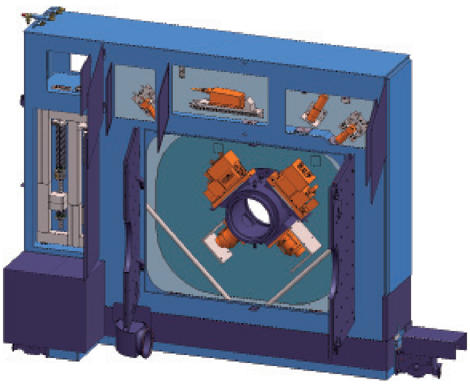
1-channel system

Measuring equipment:

Wall thickness measurement:	1-channel, vertical to tube axis
Diameter measurement:	1-channel, infrared
Temperature measurement:	Radiation or ratio pyrometer
Length measurement:	Laser Doppler velocimeter

Measured values:

Wall thickness:	Mean value, minimum value, maximum value per tube
Diameter:	Mean value, minimum value, maximum value per tube
Temperature:	Mean value, minimum value, maximum value per tube
Length:	Total length, length of thickened ends



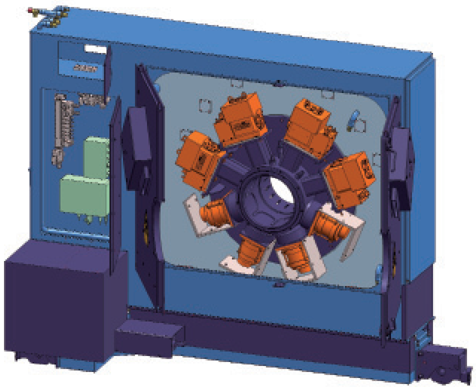
2-channel system

Measuring equipment:

Wall thickness measurement:	2-channel, +/- 45° to tube axis
Diameter measurement:	2-channel, infrared or backlight; multi-channel by laser triangulation
Temperature measurement:	Radiation or ratio pyrometer
Length measurement:	Laser Doppler velocimeter

Measured values:

Wall thickness:	Mean value, minimum value and maximum value per tube
Diameter:	Mean value, minimum value, maximum value per tube, diameter difference (pseudo oval) or diameter profile
Temperature:	Mean value, minimum value, maximum value per tube
Length:	Total length, length of thickened ends



4-channel system

Measuring equipment:

Wall thickness measurement:	4-channel, ± 22,5° and ± 67,5° to tube axis
Diameter measurement:	2-channel, infrared or backlight; multi-channel by laser triangulation
Temperature measurement:	Radiation or ratio pyrometer
Length measurement:	Laser Doppler velocimeter

Measured values:

Wall thickness:	Mean value, minimum value and maximum value per tube, plus wall thickness difference odd/even channel pairs
Diameter:	Mean value, minimum value, maximum value per tube, diameter difference (pseudo oval) or diameter profile
Temperature:	Mean value, minimum value, maximum value per tube
Length:	Total length, length of thickened ends

Gauge Types –
Double Wall Measurement

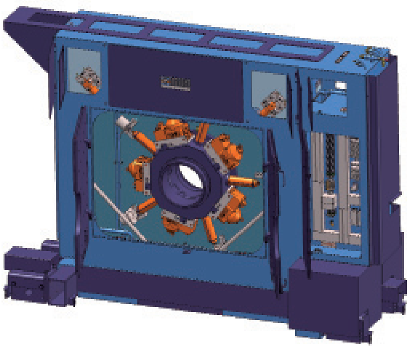
5-channel system

Measuring equipment:

Wall thickness measurement:	5-channel, 5 x 72° offset
Diameter measurement:	2-channel, infrared or backlight; multi-channel by laser triangulation
Temperature measurement:	Radiation or ratio pyrometer
Length measurement:	Laser Doppler velocimeter

Measured values:

Wall thickness:	Mean value, minimum value and maximum value per tube, plus wall thickness characteristic of first and second order
Diameter:	Mean value, minimum value, maximum value per tube, diameter difference (pseudo oval)
Temperature:	Mean value, minimum value, maximum value per tube
Length:	Total length



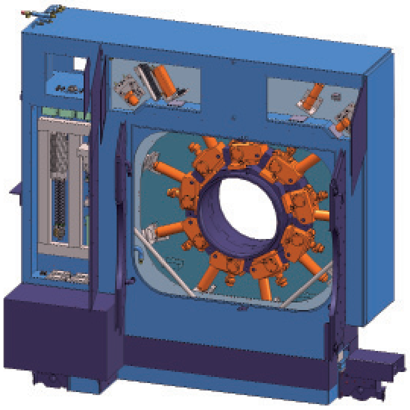
9-channel system

Measuring equipment:

Wall thickness measurement:	9-channel, 9 x 40° offset
Diameter measurement:	2/4-channel, infrared or backlight; multi-channel by laser triangulation
Temperature measurement:	Radiation or ratio pyrometer
Length measurement:	Laser Doppler velocimeter

Measured values:

Wall thickness:	Mean value, minimum value and maximum value per tube, plus wall thickness characteristic of first to fourth order
Diameter:	Mean value, minimum value, maximum value per tube, diameter difference (pseudo oval in 2-channel version)
Temperature:	Mean value, minimum value, maximum value per tube
Length:	Total length



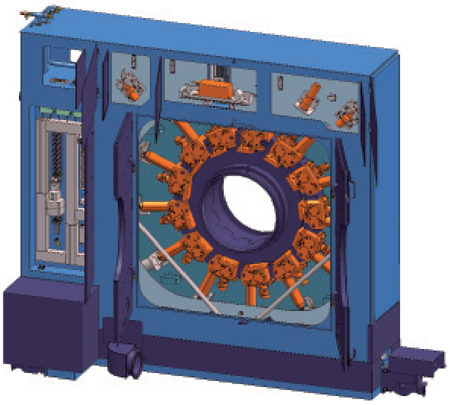
13-channel system

Measuring equipment:

Wall thickness measurement:	13-channel, 13 x 27.7° offset
Diameter measurement:	2/4-channel, infrared or backlight
Temperature measurement:	Radiation or ratio pyrometer
Length measurement:	Laser Doppler velocimeter

Measured values:

Wall thickness:	Mean value, minimum value and maximum value per tube, plus wall thickness characteristic of first to sixth order
Diameter:	Mean value, minimum value, maximum value per tube, diameter difference (pseudo oval in 2-channel version)
Temperature:	Mean value, minimum value, maximum value per tube
Length:	Total length



Technical Data

Tube data	
Tube wall thickness:	< 50 mm individual wall thickness
Tube outside diameter:	16 to 750 mm
Tube temperature:	< 1300 °C
Tube speed:	< 15 m/s
Material:	Alloyed and unalloyed steels, stainless steels, non-ferrous metals on request

Gauge data	
Gauge:	Traversing C- or O-frame, special design on request
Cooling:	Closed cooling circuit, supplied by customer cooling medium
Drive unit:	Pneumatic or electric
Radiation source:	Isotope Cs 137 (185 or 370 GBq per source), X-ray on request
Number of sources/detectors:	1 to 13 per gauge
Ionisation chamber:	KG 126 or KG 60
Measuring point size:	OD 80 to 100 mm (mass measurement), approx. 15 x 60 mm (double-wall measurement)

Measuring dynamics	
Analog measuring time constant:	< 30 ms
Cycle time data acquisition:	500 µs
Cycle time data processing:	5 ms
Cycle time data output:	10 ms

Measuring accuracy	
Tube wall thickness:	Application-dependent < ± 0,3 %
Tube diameter, position:	Application-dependent < ± 0,4 % of measuring range end value or < ± 25 µm
Tube temperature:	< ± 0,75 % of measuring range end value
Tube length:	< ± 0,1 % of total length plus ± 20 mm end detection

Type Table / Configuration Range

Additional components / Gauge version	**C-frame 1-channel** (mass measurement)	**C-frame 2-channel** (eccentricity measurement)	**O-frame 2-channel** (mass measurement)	**O-frame 4-channel** (mass measurement)	**O-frame 5-channel** (1st & 2nd order double wall measurement)	**O-frame 9-channel** (1st & 4th order double wall measurement)	**O-frame 13-channel** (1st & 6th order double wall measurement)
Temperature measurement	●	●	●	●	●	●	●
Keller	●	●	●	●	●	●	●
Land	○	○	○	○	○	○	○
Ircon	○	○	○	○	○	○	○
Diameter, Position and profile measurement	●	●	●	●	●	●	●
1-camera system infrared	●	–	–	–	–	–	–
2-camera system infrared	○	○	○	●	○	○	○
1-camera system backlight	○	–	–	–	–	–	–
2-camera system backlight	○	●	●	●	●	–	–
4-camera system backlight	–	–	–	○	○	–	–
2+2-camera system backlight	–	–	–	○	○	●	●
4+2-camera system backlight	–	–	–	○	○	○	○
Laser triangulation (diameter)	*	–	○	○	○	○	○
Laser triangulation (position)	–	–	○	○	○	○	○
Length measurement	○	○	○	○	○	○	○
Polytec	○	○	○	○	○	○	○
Beta Lasermike	○	○	○	○	○	○	○

● = Standard ○ = Option – = Not available * = On request

Manufacturer for example

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