Properties of advanced high strength austenitic alloy Sanicro 25 developed for A-USC plants

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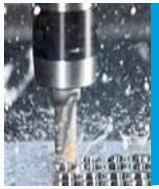
Outline

- Brief presentation of Sandvik
- A-USC Boiler Technology
- Sanicro 25 properties
- Summary

Sandvik Group

Sandvik Construction



Sandvik Machining Solutions

Sandvik Materials Technology

Sandvik Mining

Sandvik Venture

Our Heritage

Founded 1862 in Sandviken, Sweden

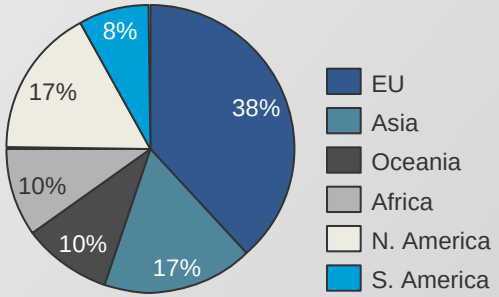
Göran Fredrik Göransson redesigned the Bessemer furnace to mass produce steel

A breakthrough and an innovation started the company 150 years ago

Key figures (2011)

Invoiced sales, B EUR:	11
Worldwide PU's:	140
No. of employees:	50000

Sales by region (2011)



Sandvik Materials Technology – main products

Tube, pipe, fittings and flanges
• Tube and pipe in seamless and welded condition, fittings and flanges

Bar and hollow bar
• Round bar , Free-cutting steel, Hollow bar and hollow drill steel

Welding products
• Welding wire and filler wire/ rods, covered electrodes, strip electrodes and welding flux

Strip steel and strip-based products
• Precision strip steel and strip-based products such as crêping blades and die-cutting products

Wire
• Round wire, flat wire and shaped wire (profiles)

Furnace products and heating systems
• Furnace products, thermal processing equipment and heating systems

Hot isostatic pressed (HIP) products
• Near-net shape metal powder products produced by hot isostatic pressing

Metal powder
• Gas atomized metal powders

Controlled expansion (CE) alloy products
• Products made from controlled expansion alloys

Billets and blooms
• Forging billets, re-rolling billets, extrusion billets and continuous cast blooms

Sandvik Materials Technology – key application areas

Oil and gas upstream

Oil and gas exploration
and production

Oil and gas downstream

Oil refining, petrochemicals
and gas reforming

Nuclear power generation

Equipment and components in primary,
secondary and auxiliary systems

Renewable energy

Applications within, for example, solar
energy and fuel cells

Chemical processing

Production and processing
of chemicals

High temperatures

Furnace and boiler tubing and
equipment for industrial heating

Automotive

Automotive systems and
components

Aerospace

Aerospace systems and
components

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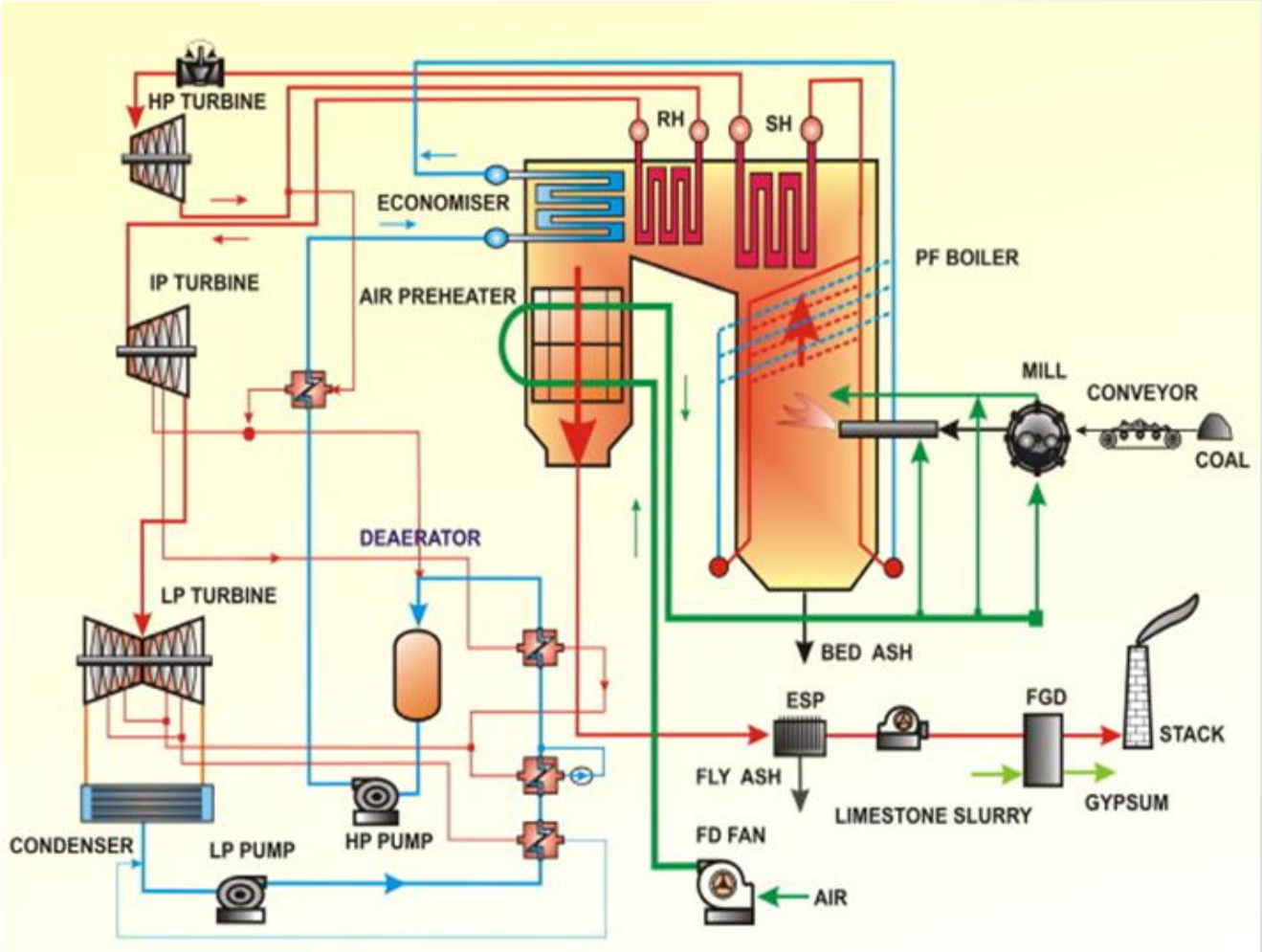
A-USC boiler technology



Process conditions

- T_{steam} /p_{steam} = 700-760°C/300-350bar
- Fuel type variations (ash content)
- Fuel quality variations (within spec.)
- Different boiler designs
- (Intermittent boiler load per 24 h)
- (Co-firing biomass)
- (Oxy fuel firing)

Material requirements

- Creep strength (100Mpa, 100kh)
- Static mechanical strength
- Low cycle fatigue strength
- Structural stability
  - Long term toughness
- Corrosion resistance
  - Fireside corrosion
  - Steamside corrosion
- Fabricability
  - Bending
  - Welding
- Favourable Cost

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Components critically stressed

Headers and Piping

Superheaters and Reheaters

Steam generator components

Sandvik Sanicro 25

- **Development started with an objective to develop new materials for A-USC boilers within the EU-Thermie subgroup – austenitic materials in late 1990**
- **Very high elevated temperature strength**

  Precipitation strengthening
  - Nb or NbCr carbonitrides, Laves (W), Cu-rich precipitates and $M_{23}C_6$

  Solid solution strengthening
  - addition of C, N, Co and W
- **Good protective chromium oxide forming ability**
  - 22-23% Cr

Nominal chemical composition of Sanicro 25

C_{max}	Si	Mn	P_{max}	S_{max}	Cr	Ni	N	W	Co	Cu	Nb
0.1	0.4 max	0.6 max	0.030	0.015	21.5-23.5	23.5-26.6	0.15 - 0.30	2.0 – 4.0	1.0 – 2.0	2.0 - 3.5	0.30 - 0.60

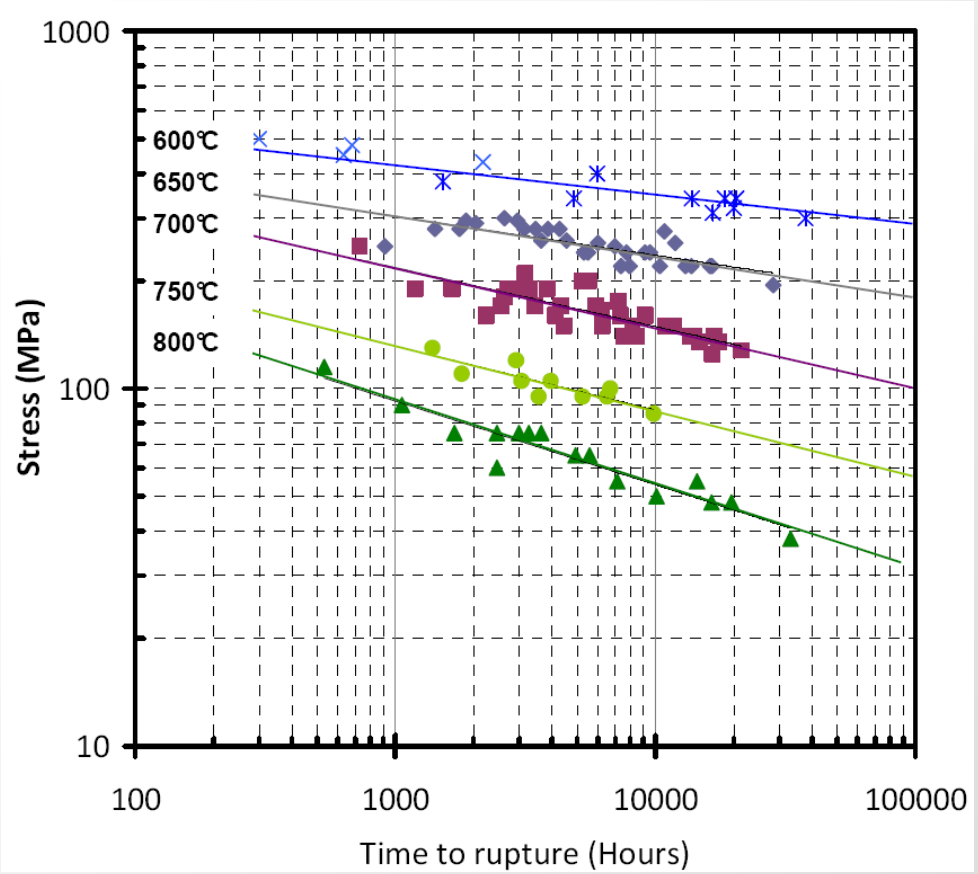
Sanicro 25 – creep rupture strength

97MPa/100kh

@ 700°C

100MPa/100kh

@ 695°C



1. **The creep tests have run up to 76 000h. Some of the tests are still running,**
2. **PED (European Pressure Equipment Directive) approval is available since 2008.**
3. **ASME code case for this material will be available during 2012.**

Development target within EU-Thermie – subgroup austeniic materials; 100Mpa/100kh @ 700°C

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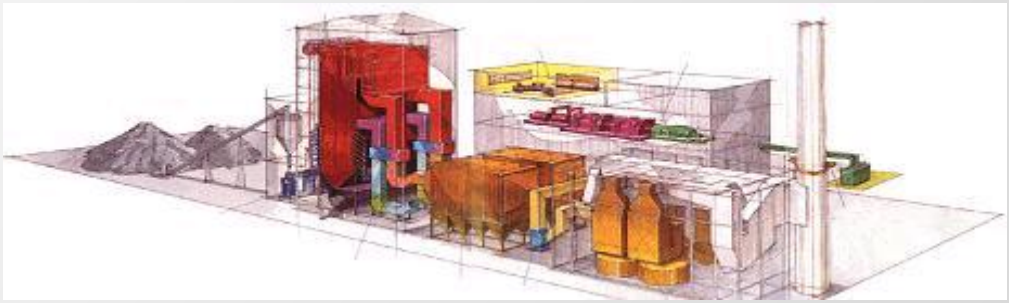
Sanicro25 test loops in coal fired power plants 2004-2009 for metal temperatures ~ 590-645°C

- **The Esbjerg Test Rig, a part of the 700°C Power Plant project (AD700) installed in Dong Energy Esbjerg Power Plant, Dk, Aug 2004,**

  Alstom 670°C/256bar http://www.vgb.org/en/research_project260.html



- **RWE Weisweiler, D, Aug 2004 HitachiPowerEurope, 655°C/169bar**
- **Component Test Facility for a 700 °C Power Plant installed in E.ON Scholven Power Plant, D, July 2005 HitlachiPower Europe, 640°C/212bar** http://www.comtes700.org/index.xhtml
- **Vattenfall Boxberg, D, July 2008, on-going HitlachiPower Europe, in a reheater in lignite fired boiler** 580°C/66**bar**
- **GKW Mannheim, D, July 2009, on-going Alstom Power, in superheater test loop, high efficiency boiler**

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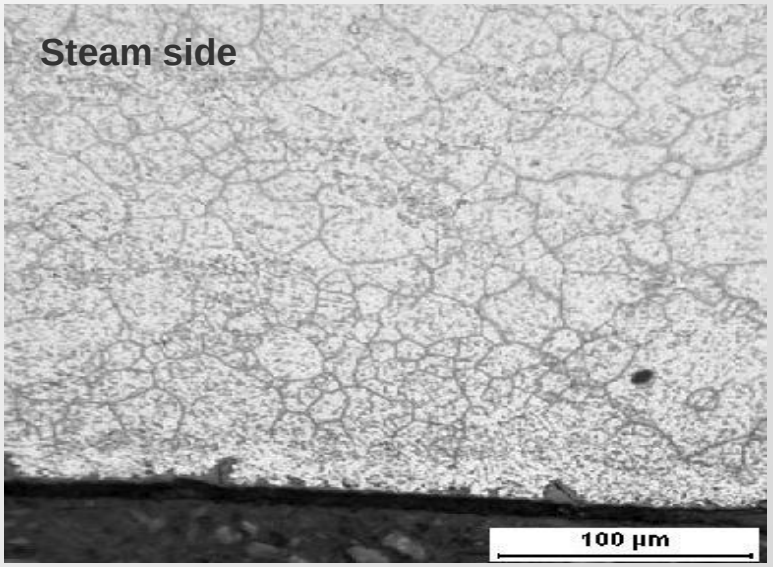
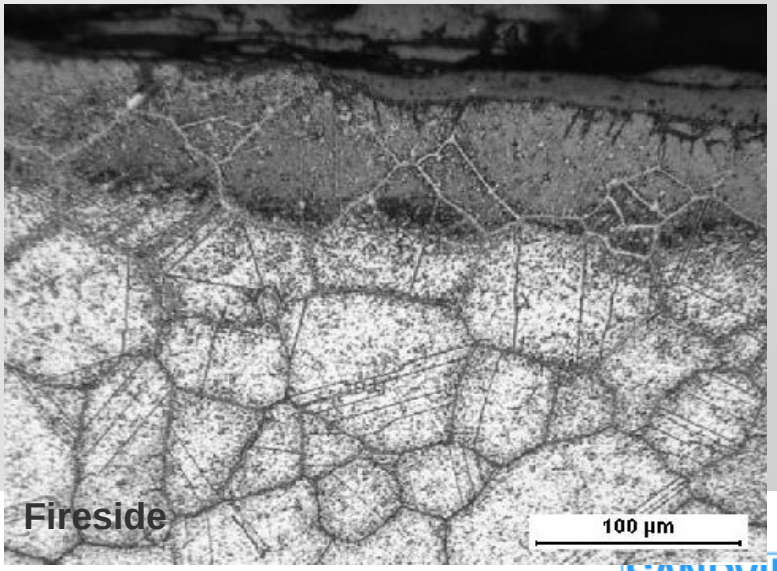
Corrosion resistance – AD700 test loop after > 30000h





The tube was in very good condition. The oxides on the outer and inner surfaces were thin, chromium rich and well adherent. No metal loss could be measured.

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Corrosion resistance in coal fired boilers

- Steam side corrosion is rather non-complex from corrosion mechanism point of view, and easier to a establish ranking for between different candidate alloys

- Fireside corrosion is complex since due to the nature of the fuel (coal) the composition and amounts of corrosive elements, and ash compounds may vary considerably over time

Fabricability - bending

Cold bending **30% CW with good ductility without PBHT**

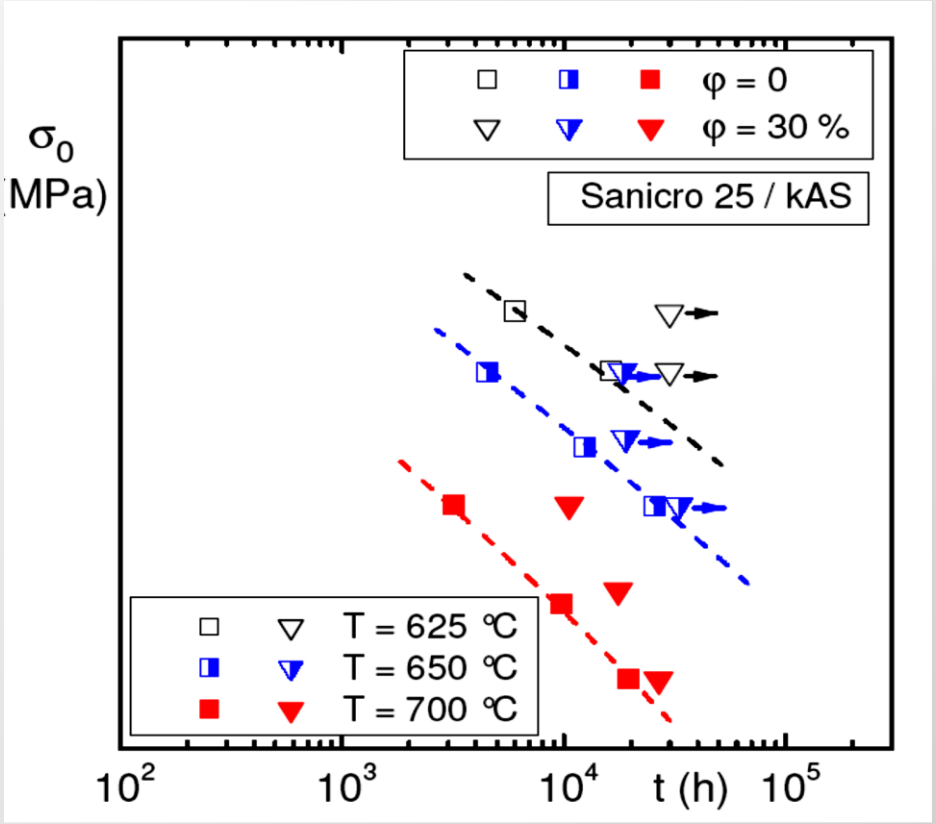
Two different 180° bends

Two different 90° bends

r/D = 2.3 (22%) and r/D = 3.1 (16%)

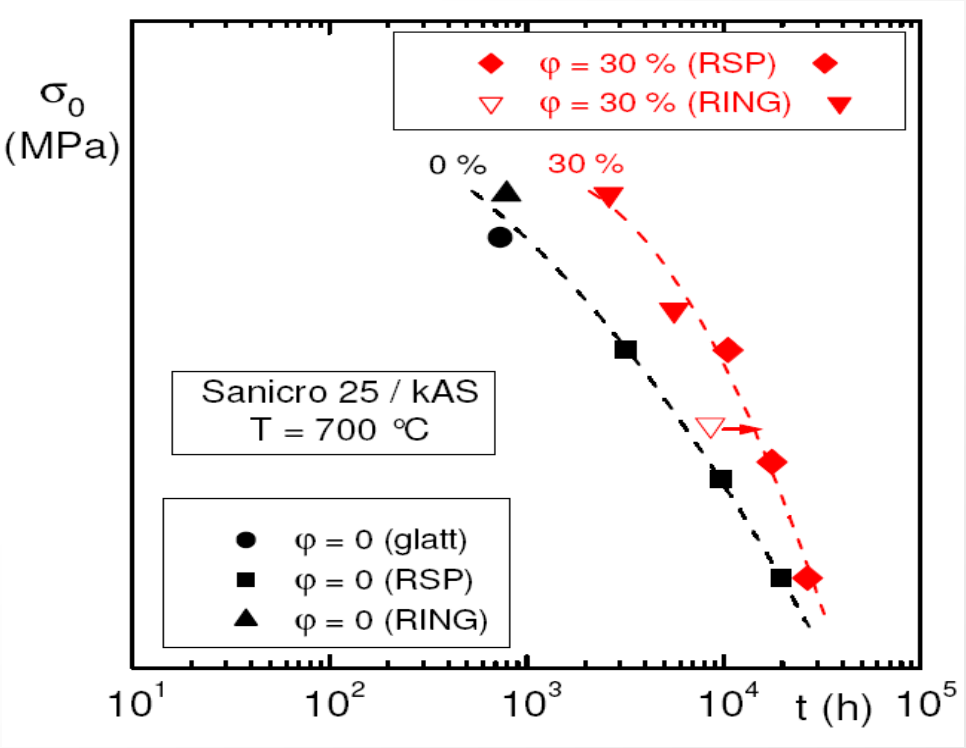
Max measured ovality 1.6%

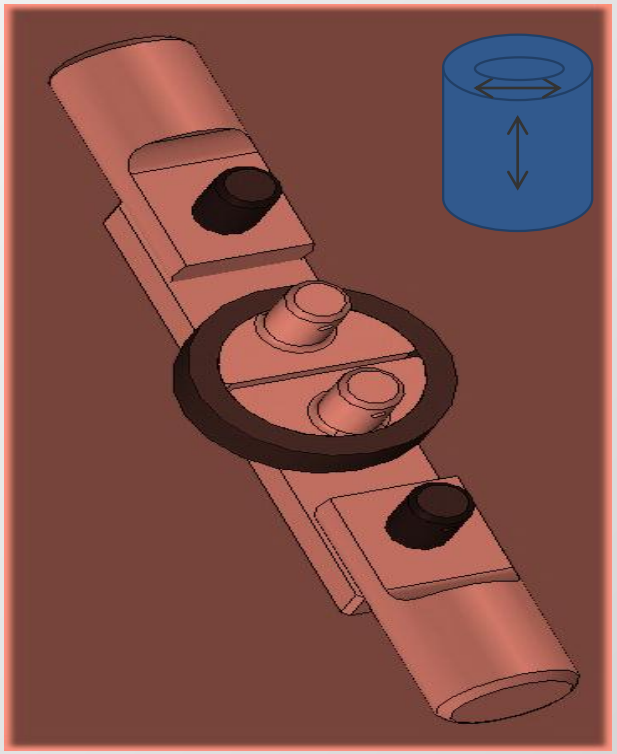
ref. Doosan Babcock Energy Limited



Falk Müller et al. Technische Universität Darmstadt,

Creep properties after cold bending





Falk Müller et al. Technische Universität Darmstadt

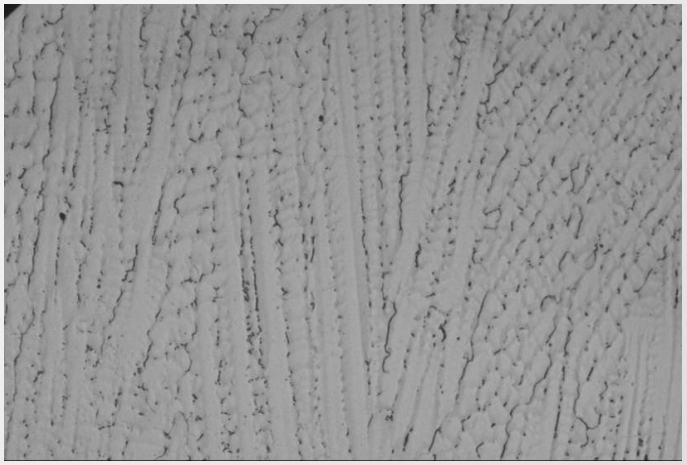
Creep properties in different directions of the tube material after cold deformation are similar

Fabicability - Welding

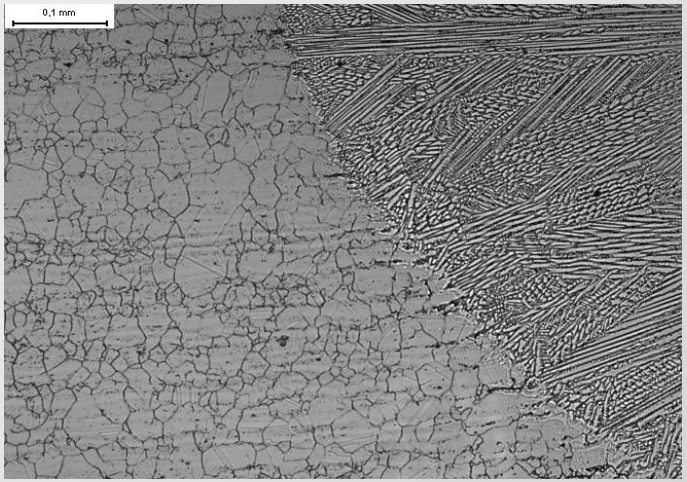
- **Good Weldability**
- **Low thermal conductivity and high thermal expansion requires**
  - Welding with low heat input
  - Interpass temperature below 100°C
- **GTAW with Alloy 617 or Alloy 617 mod filler metal**
  - Wire and rod with ø 1.0- 2.4 mm diameter
- **U-joint or V-joint**
- **No need for PWHT**

Macro and microstructure as welded

Weld joints with Sandvik Sanicro 25 welded with Sandvik 23.25.HT (TIG), Alloy 617 (TIG+MMA) and Alloy 617 mod (TIG)

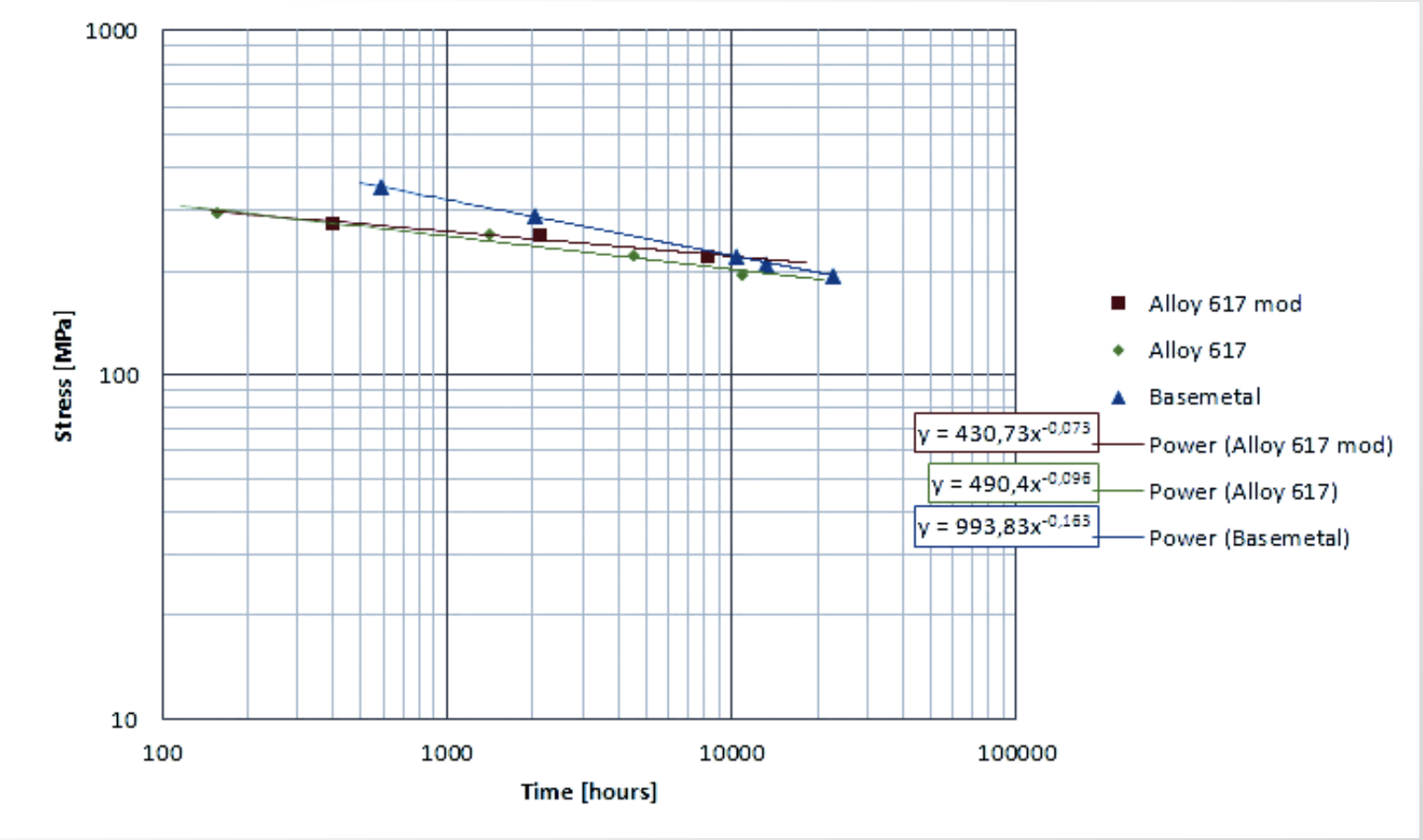


Weld metal in OD38x6.3 mm weld joint(X200)

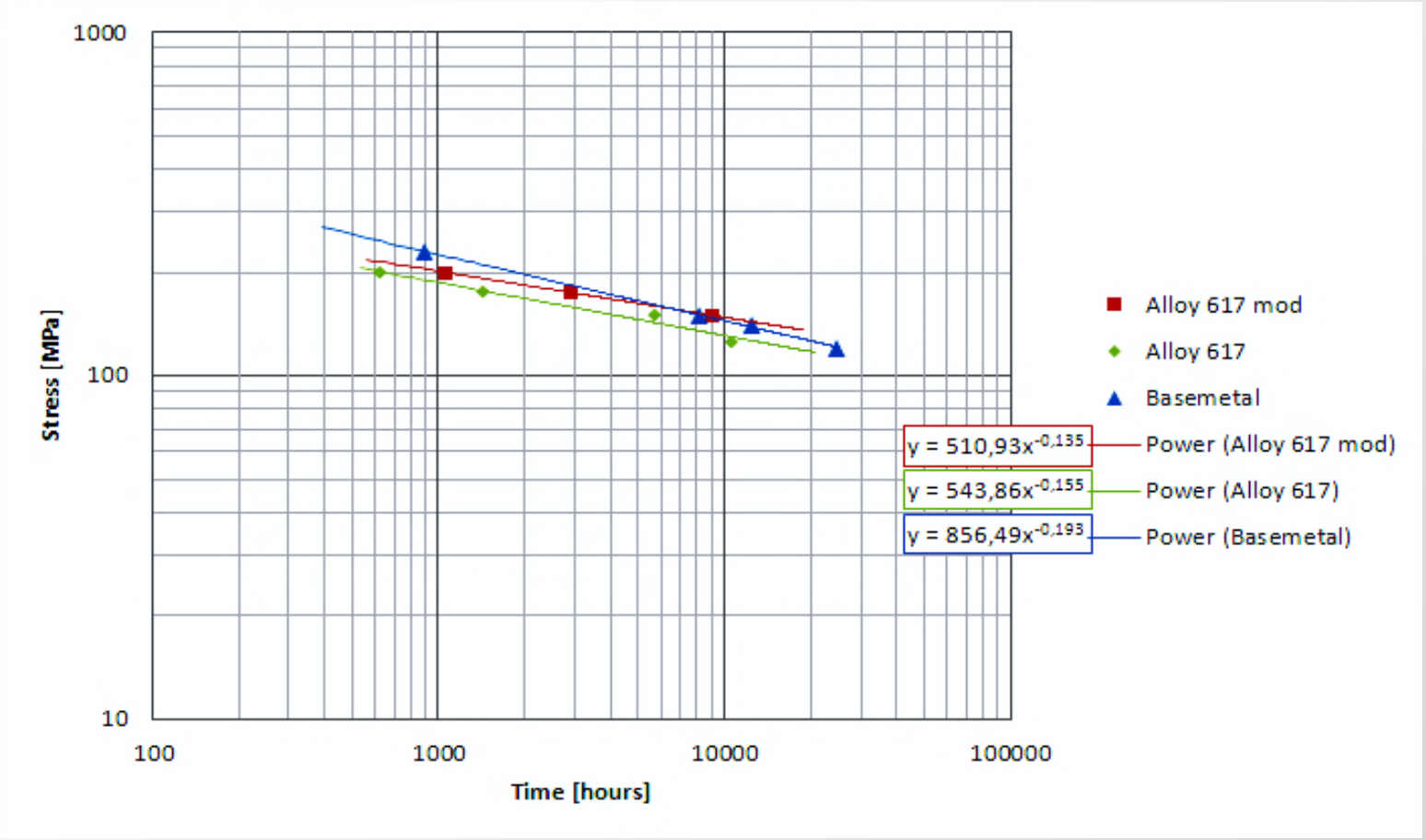


HAZ in OD38x6.3 mm weld joint (X200)

Creep testing over weld at 650°C



Creep testing over weld at 700°C



Summary

A new austenitic stainless steel grade Sandvik Sanicro 25 has been developed intended for superheater and reheaters in advanced coal fired power boilers.

- **The new grade has higher creep rupture strength than other austenitic stainless steels available today.**
- **The creep strength is related to intragranular precipitates and nano particles acting as obstacles for dislocation movement.**
- **Sanicro 25 shows a good bendability, and weldability using 617mod filler metals and similar creep strength to the matrix.**
- **Steamside corrosion resistance testing show good results both in laboratory and field test loops within the AD700 programme.**
- **Fireside corrosion resistance has shown very good results in one AD700 field test loop, with no corrosion at all but local corrosion in another loop test. In laboratory, the results are variying between very low rates to somewhat higher**

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Thank you for your attention