Material Behaviour of 10.9 Bolts under Fire Conditions

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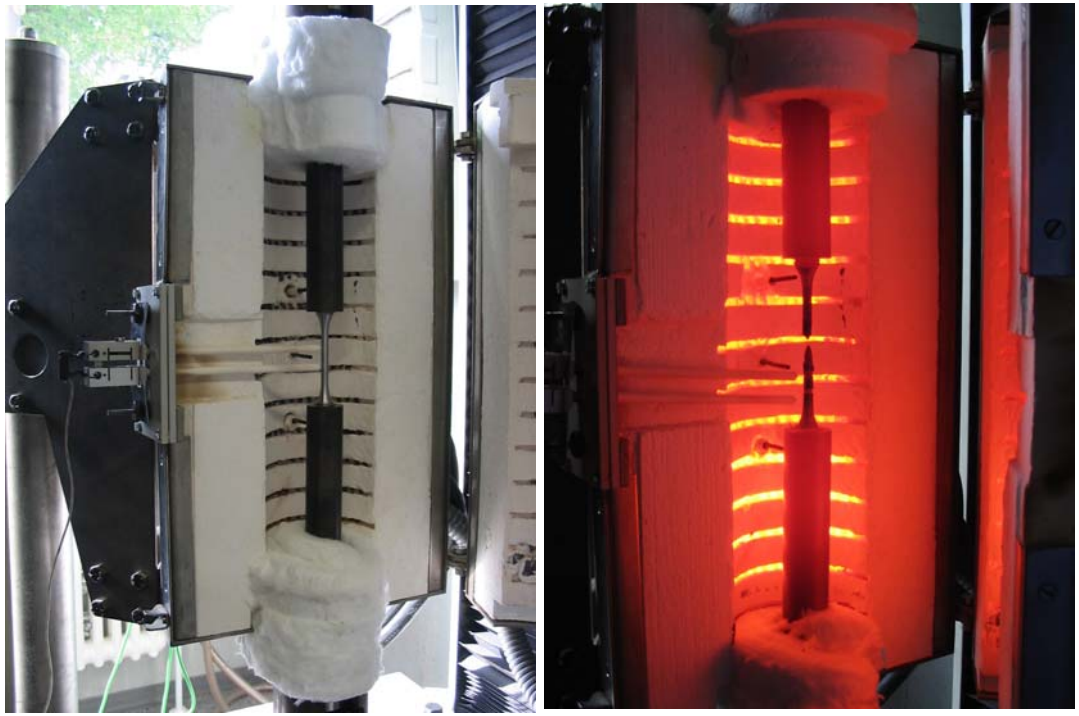
Fernando Gonzalez/Jörg Lange



Connection Design According the EC3 Annex D

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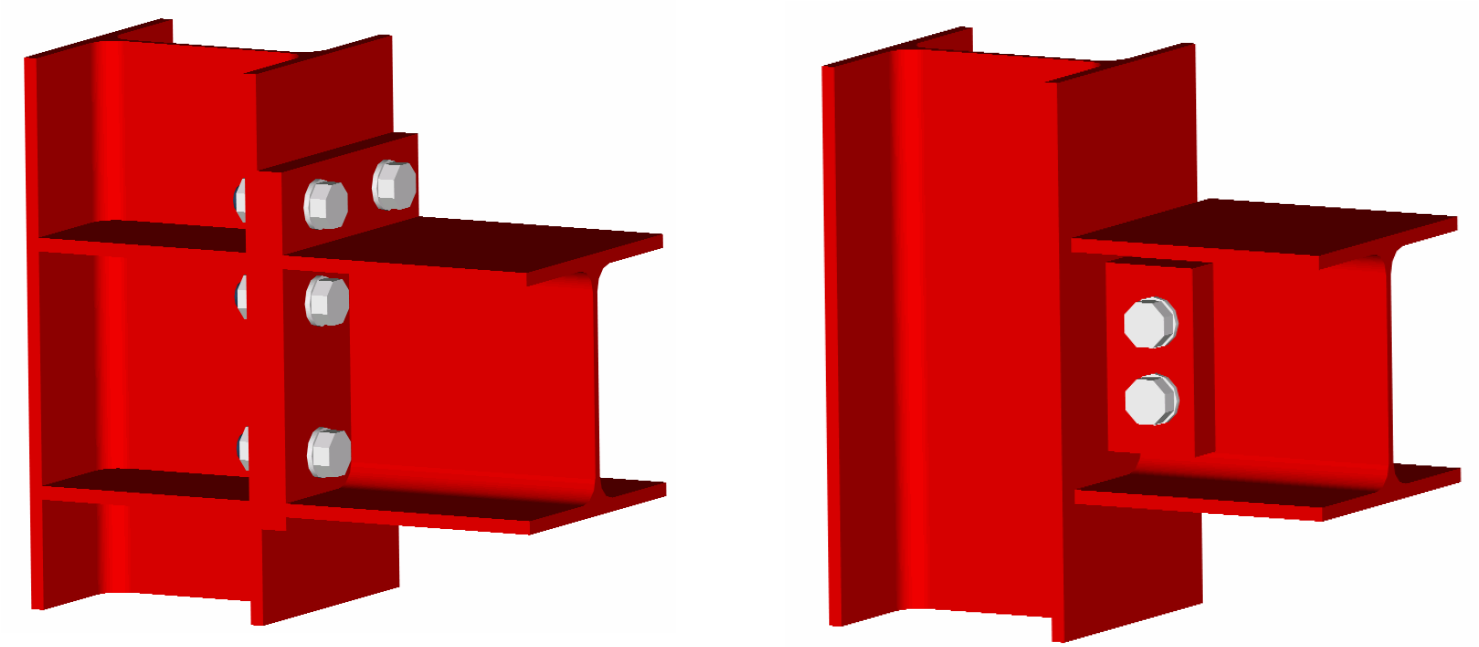

Connection Design According the EC3 Annex D

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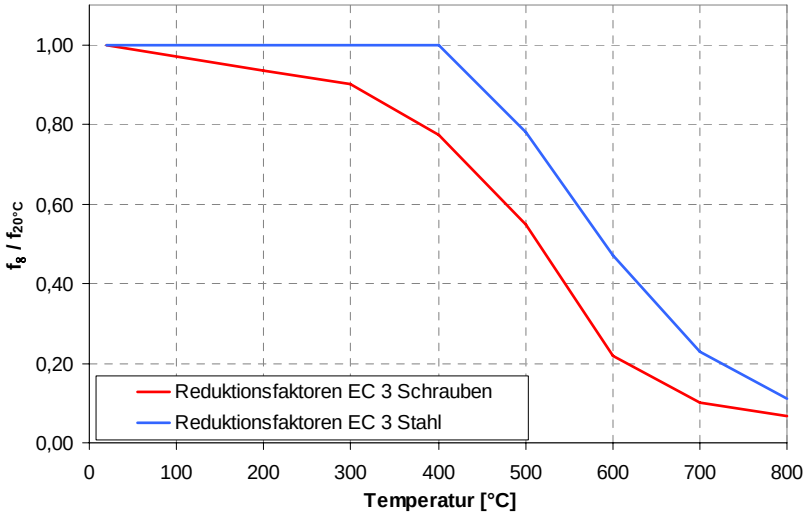
- Step 1: Determination of the steel temperature in the connection

$$\Delta\theta_{a,t} = k_{shadow}\frac{A_m/V}{c_a\rho_a}\dot{h}_{net}\Delta t \qquad \Delta\theta_{a,t} = \frac{\lambda_p\, A_p/V}{d_p c_a \rho_a}\frac{\left(\theta_{g,t}-\theta_{a,t}\right)}{\left(1+\phi/3\right)}\Delta t - \left(e^{\phi/10}-1\right)\Delta\theta_{g,t}$$

- Step 2: Determination of the strength reduction factors for bolts



- Step 3: Design of the connection using the reduction factors

Designing Hot Connections

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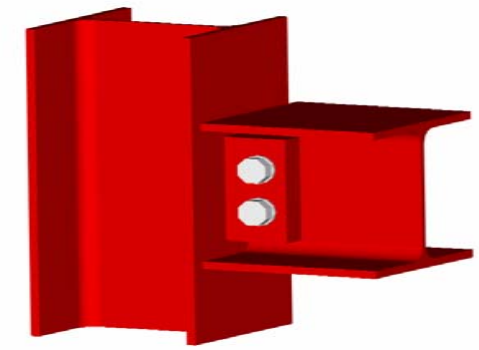
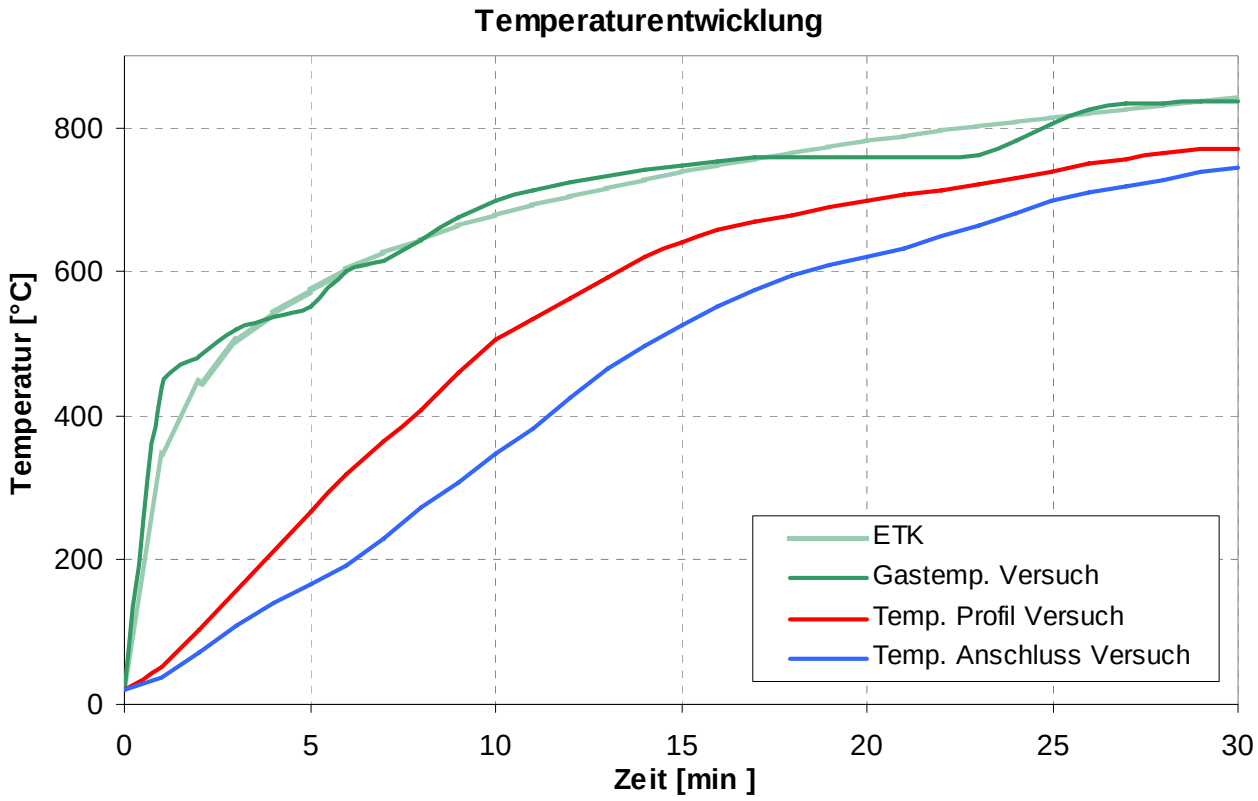
Fin plate connection 135/70/30; HEA 200





Designing Hot Connections

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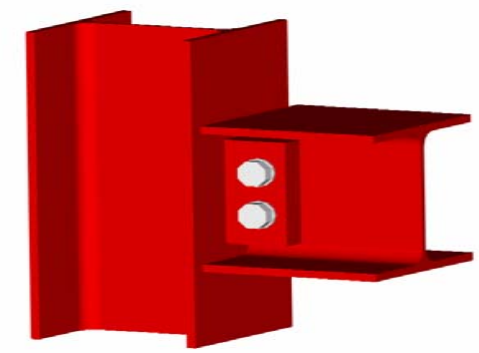
Fin plate connection 135/70/30; HEA 200

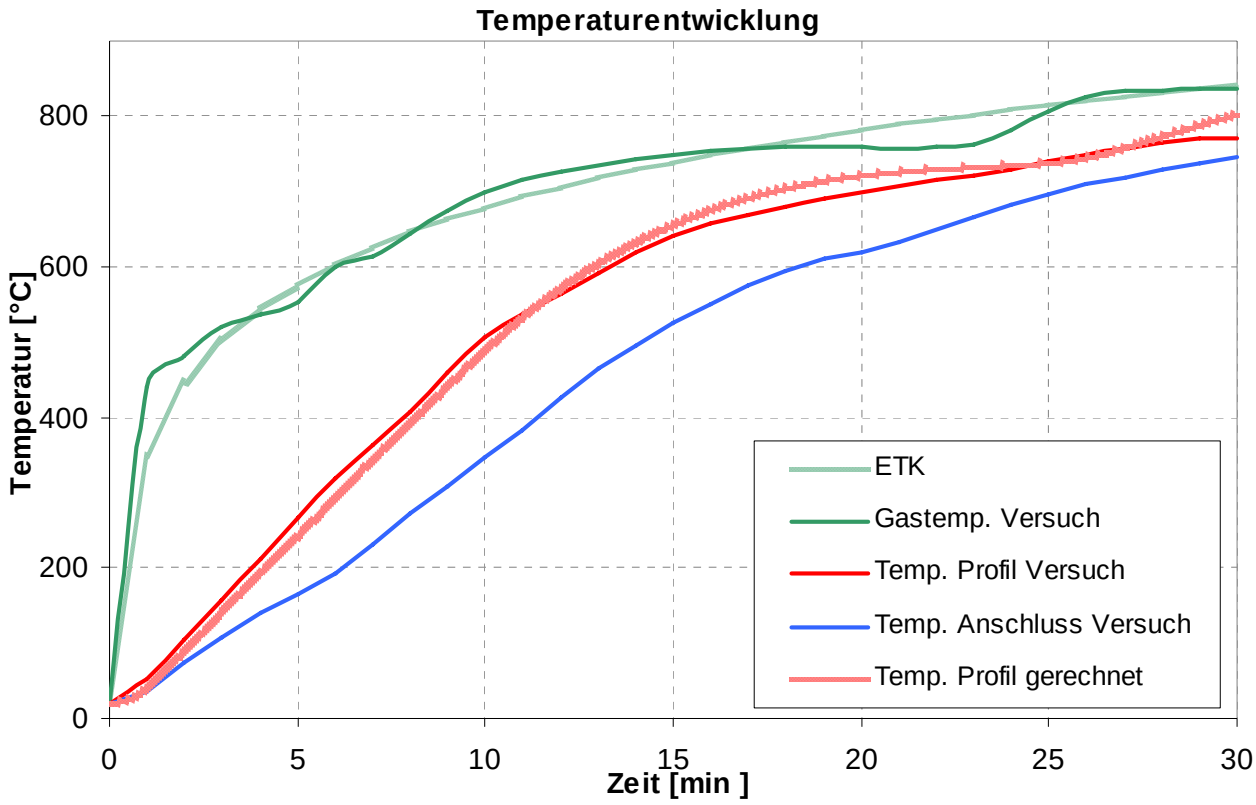


$A_{Trägermitte}$: 53,8 cm²
$U_{Trägermitte}$: 113,6 cm

=> U/A: 211,8m^{-1}
$\Rightarrow k_{sh}$: 0,68

$A_{Anschluss}$: 94,3 cm²
$U_{Anschluss}$: 119,6 cm

=> U/A: 126,8m^{-1}
=> k_{sh}: 0,65



Designing Hot Connections

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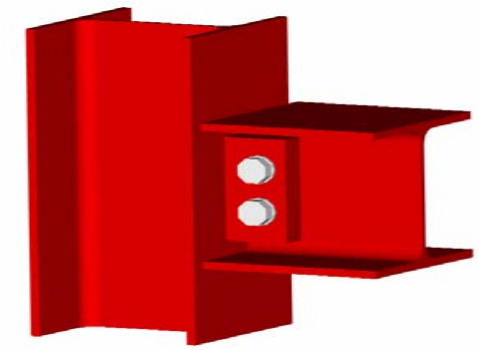
Fin plate connection 135/70/30; HEA 200



$A_{Trägermitte}$: 53,8 cm²
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=> U/A: 211,8m^{-1}
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=> U/A: 126,8m^{-1}
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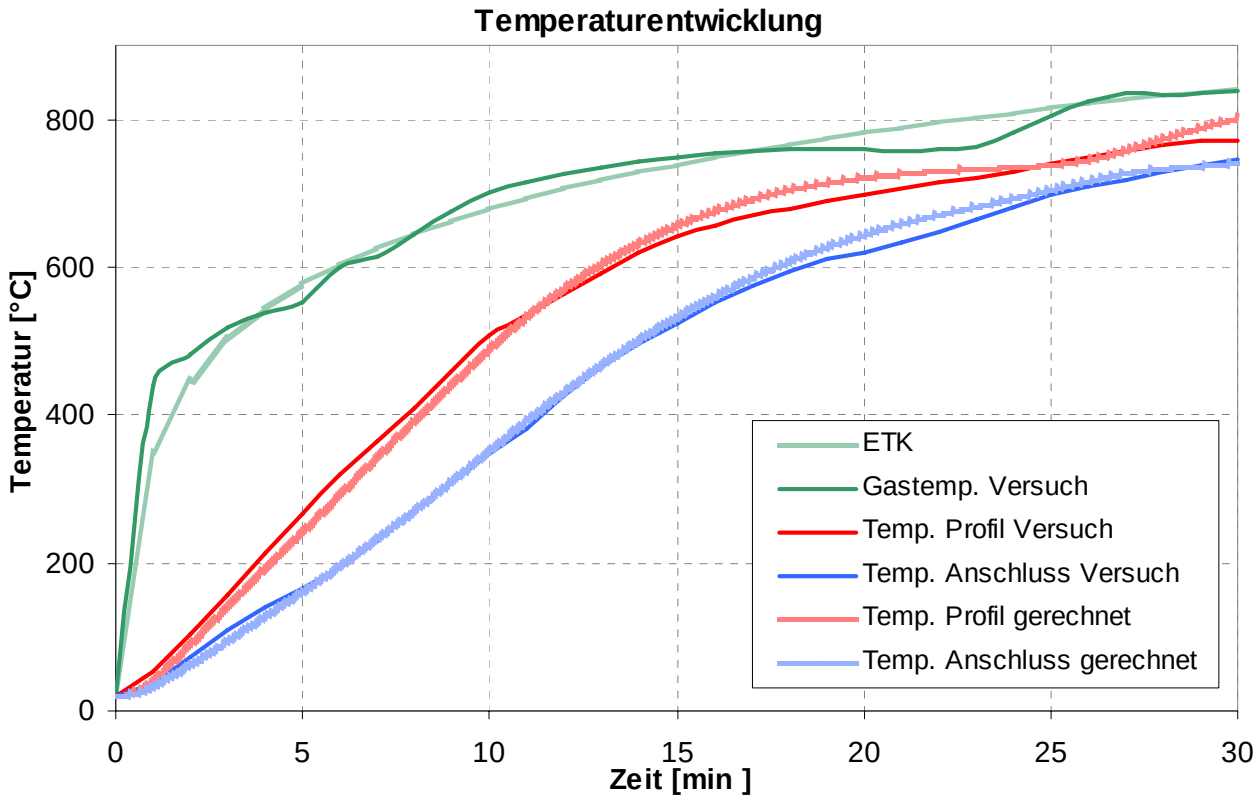

Designing Hot Connections

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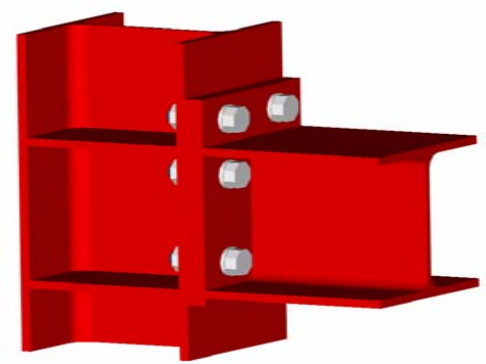
End plate connection

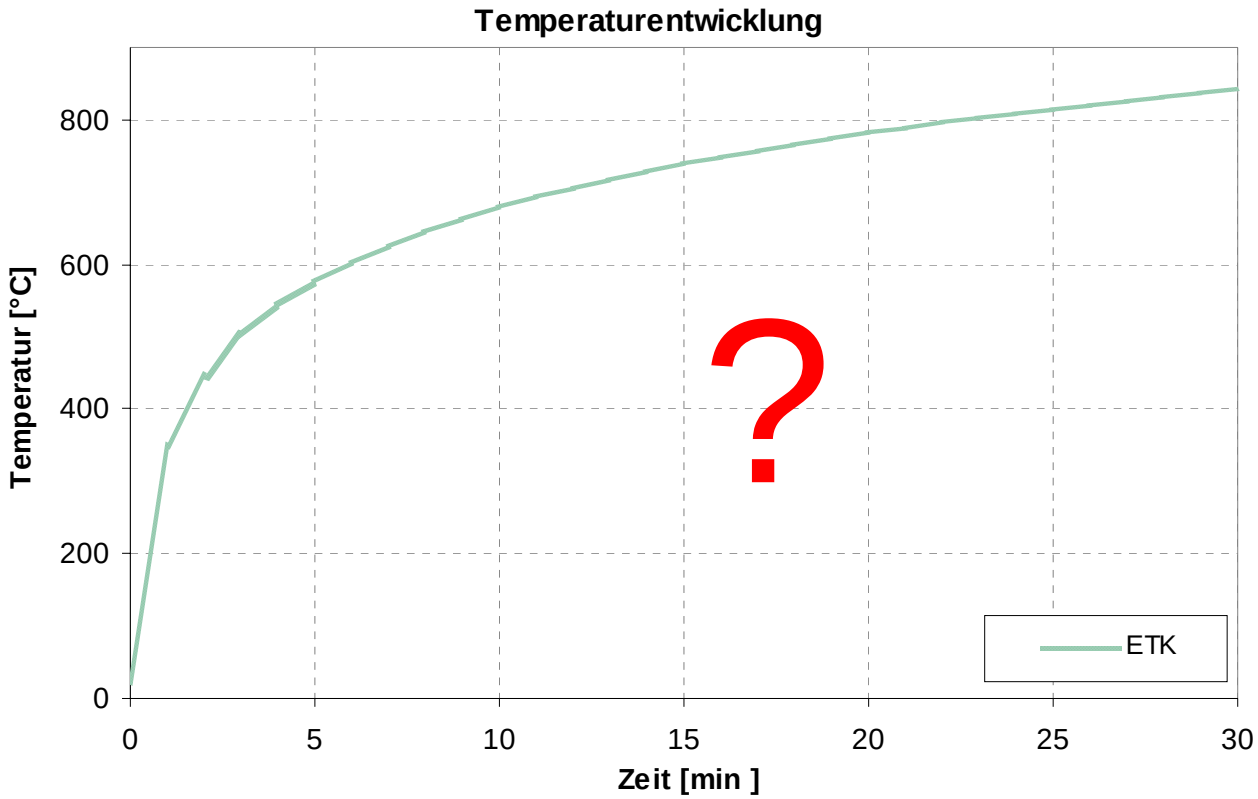


$A_{Trägermitte}$: 53,8 cm²
$U_{Trägermitte}$: 113,6 cm

=> U/A: 211,8m^{-1}
$\Rightarrow k_{sh}$: 0,68

$A_{Anschluss}$: ? cm²
$U_{Anschluss}$: ? cm

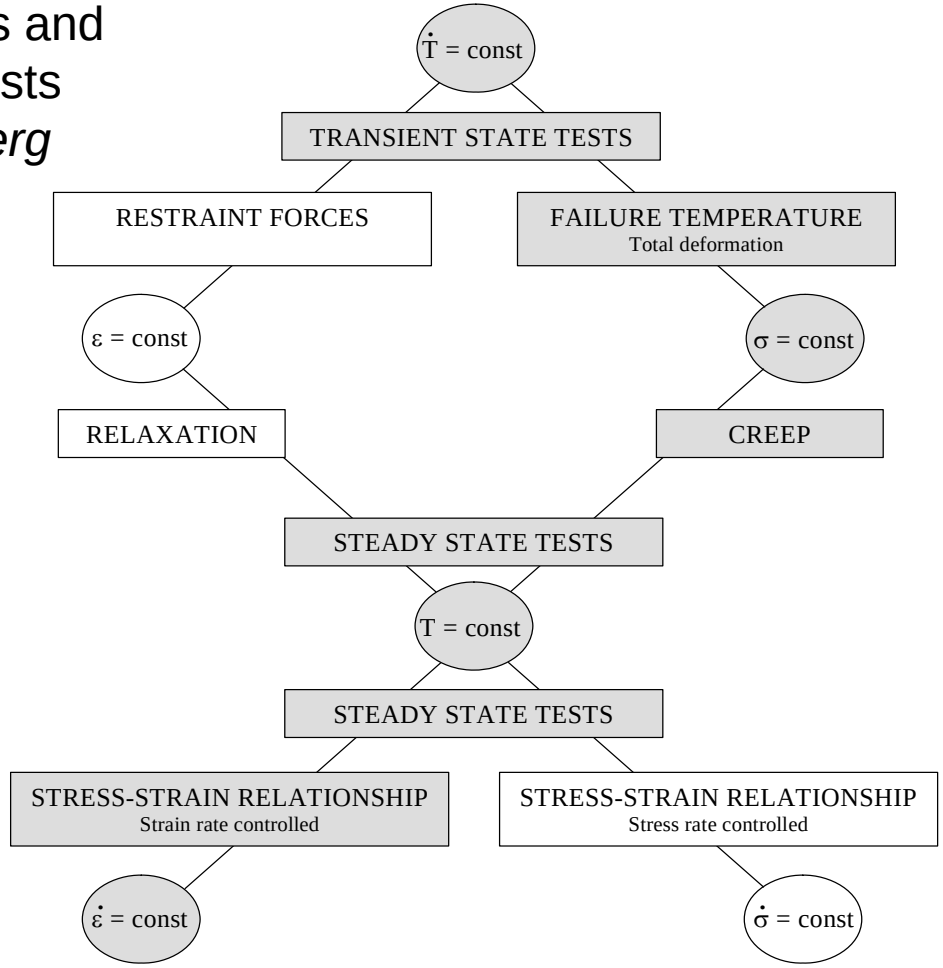
=> U/A: ? m^{-1}



Material Behaviour of 10.9 Bolts under Fire Conditions

Testing Methods

Steady State Tests and
Transient State Tests
according *Anderberg*



Material Behaviour of 10.9 Bolts under Fire Conditions

Testing Methods

Steady State Tests and
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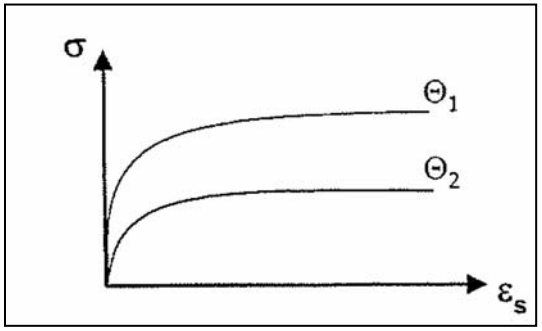
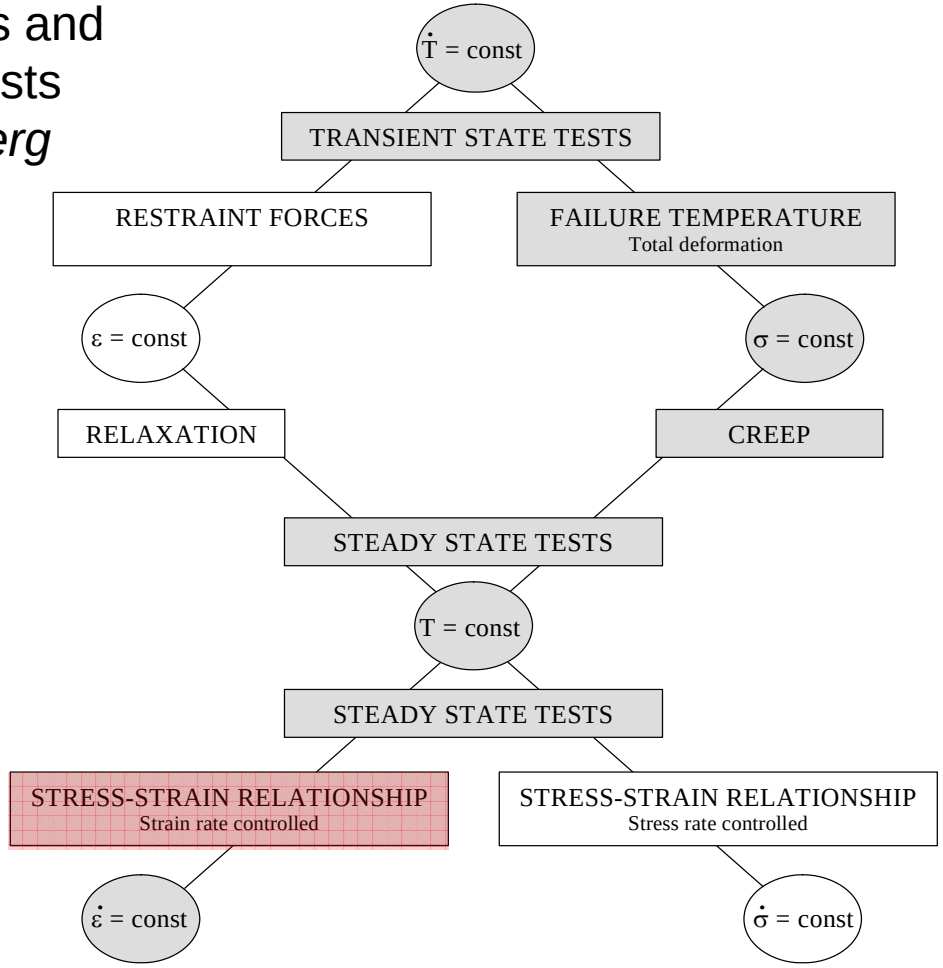


$\varepsilon = \varepsilon_{el} + \varepsilon_{pl}$



Material Behaviour of 10.9 Bolts under Fire Conditions

Testing Methods

Steady State Tests and
Transient State Tests
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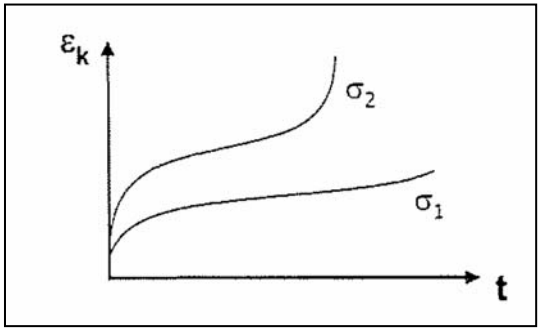
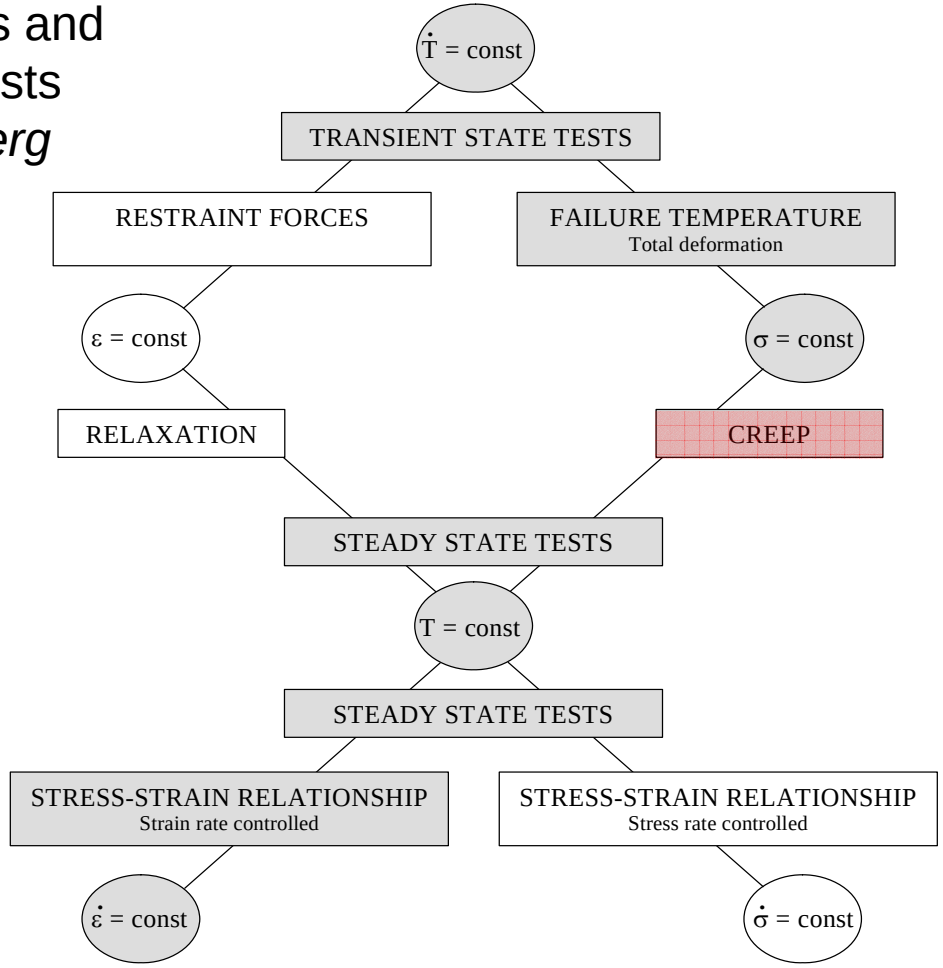


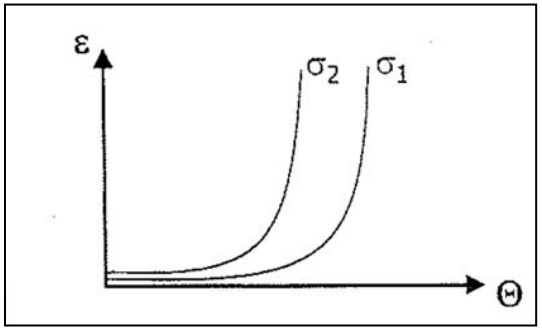
$\varepsilon = \varepsilon_{cr}$



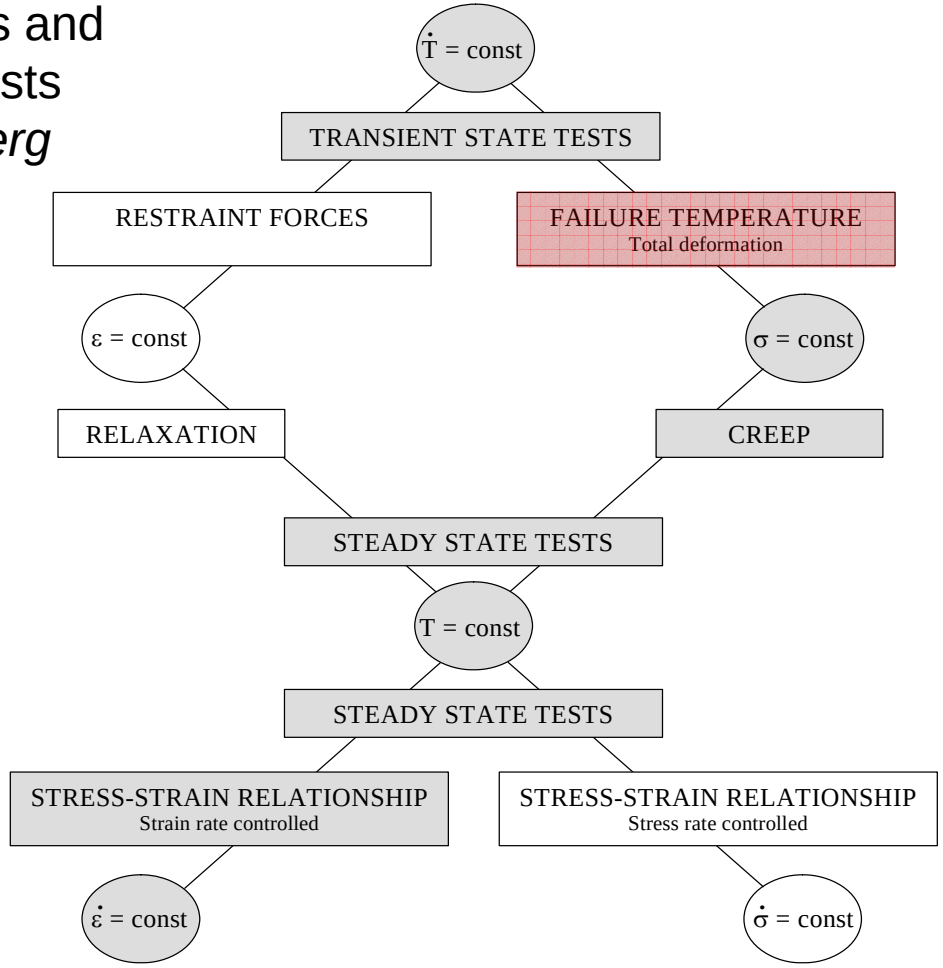
Material Behaviour of 10.9 Bolts under Fire Conditions

Testing Methods

Steady State Tests and
Transient State Tests
according *Anderberg*



$$\varepsilon = \varepsilon_{el} + \varepsilon_{pl} + \varepsilon_{cr} + \varepsilon_{th}$$



Material Behaviour of 10.9 Bolts under Fire Conditions

Material

Bolt type	Minimum tensile strength [N/mm²]	Minimum strength at 0.2% [N/mm²]	Min. ult. strain [%]	Necking [%]	Vickers hardness, HN; F ≥ 98 N
10.9	**1040**	**940**	**9**	**48**	**min 320; max 380**

Material Behaviour of 10.9 Bolts under Fire Conditions

High Temperature Test

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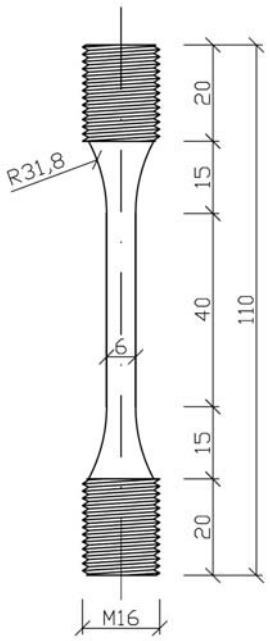
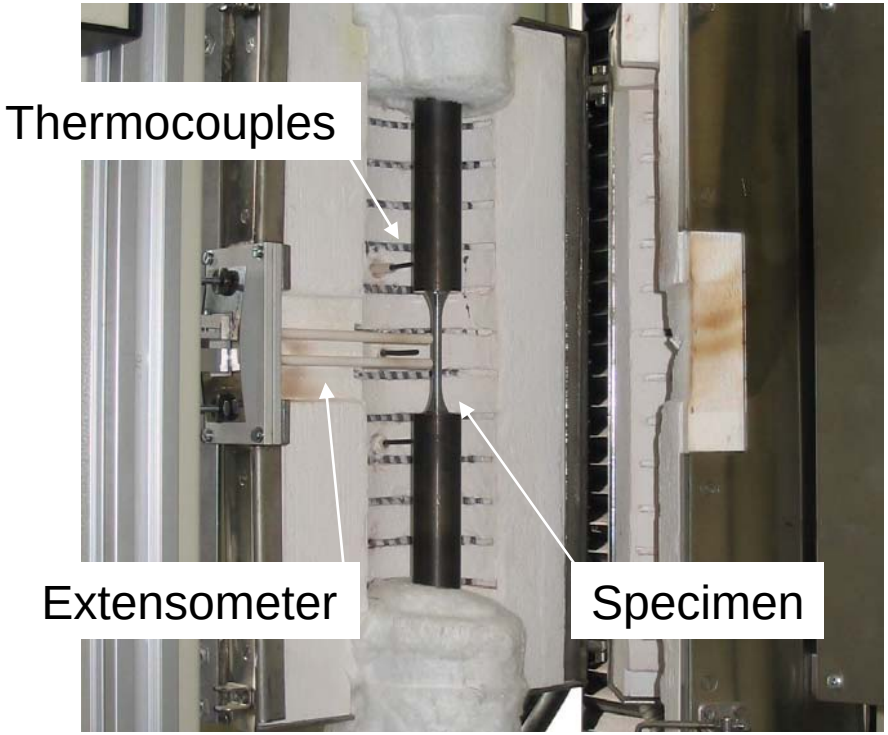
Testing device





Material Behaviour of 10.9 Bolts under Fire Conditions

High Temperature Test

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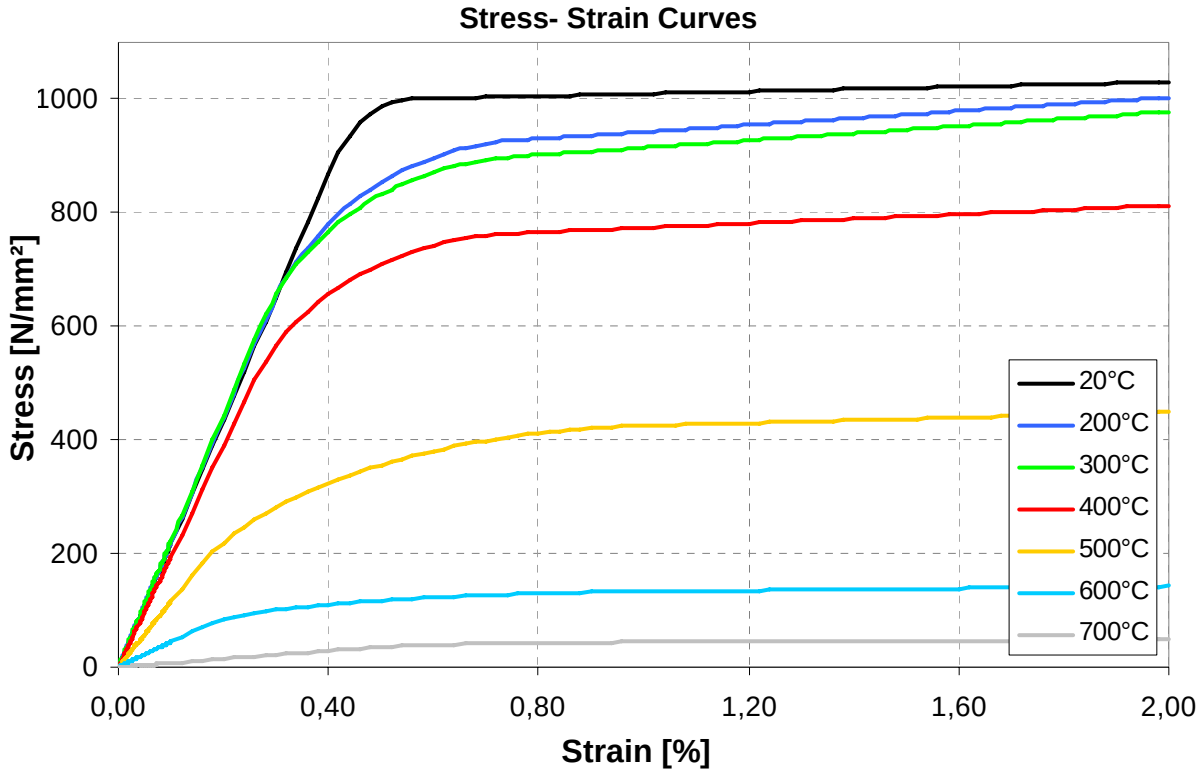
Results of the steady state tests



Strain rate: 0,001 min^{-1} Heating rate: 10 K/min

Material Behaviour of 10.9 Bolts under Fire Conditions

High Temperature Test

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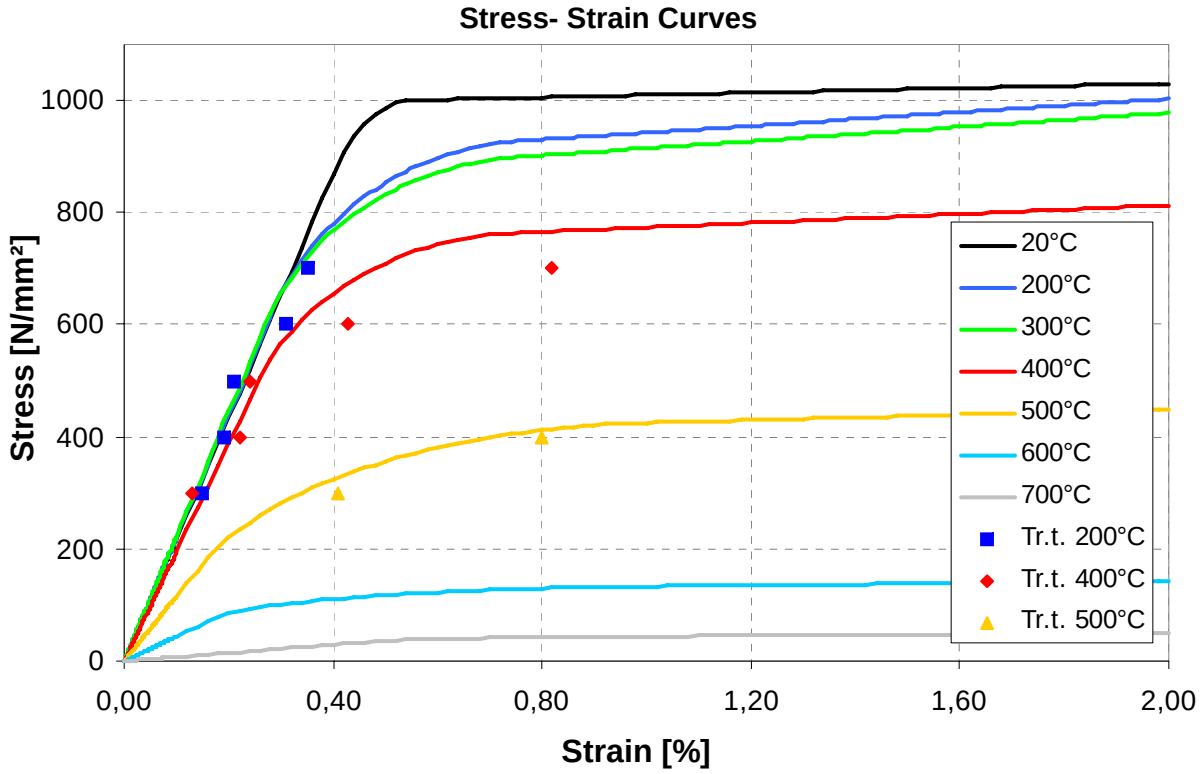
Results of the steady state and transient state tests



Material Behaviour of 10.9 Bolts under Fire Conditions

High Temperature Test

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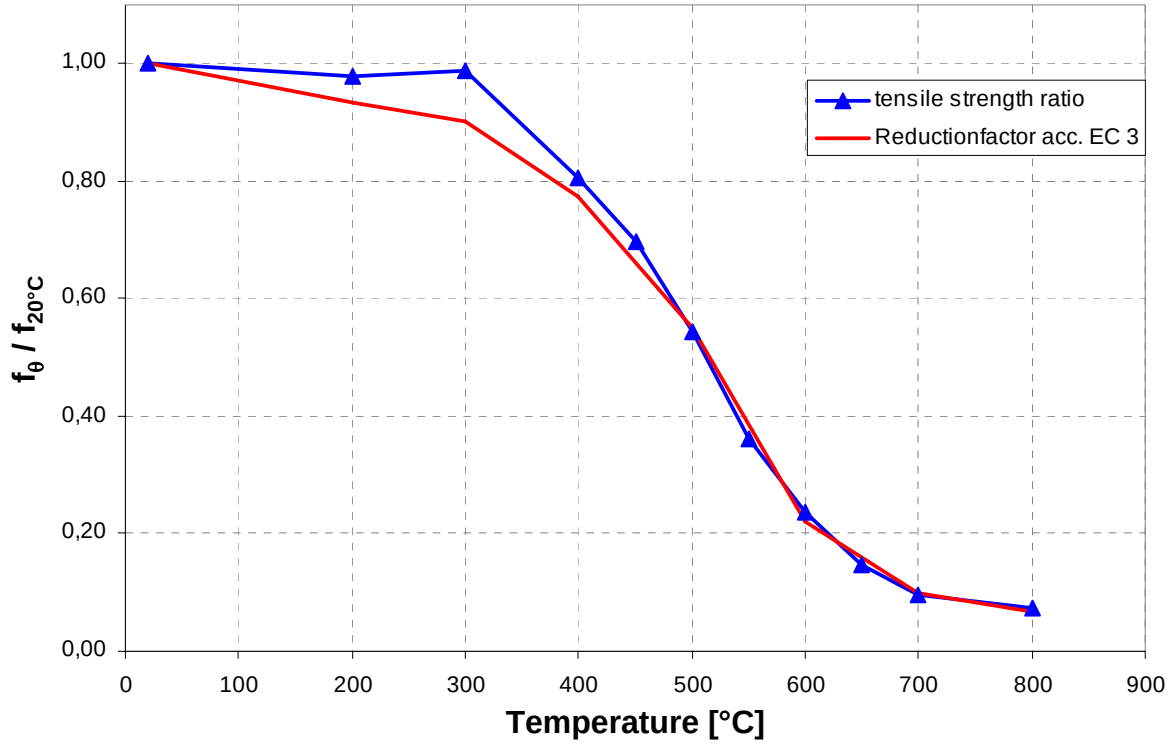
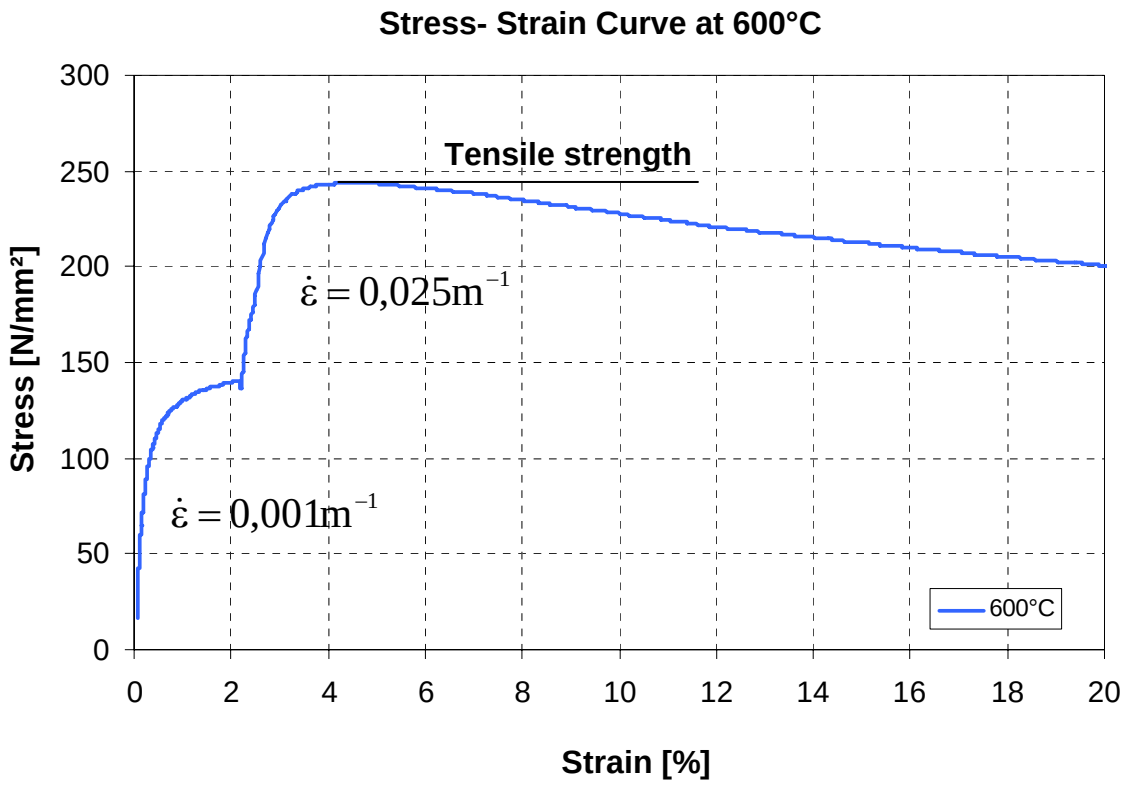
Comparison of the results



Material Behaviour of 10.9 Bolts under Fire Conditions

High Temperature Test



Material Behaviour of 10.9 Bolts under Fire Conditions

High Temperature Test

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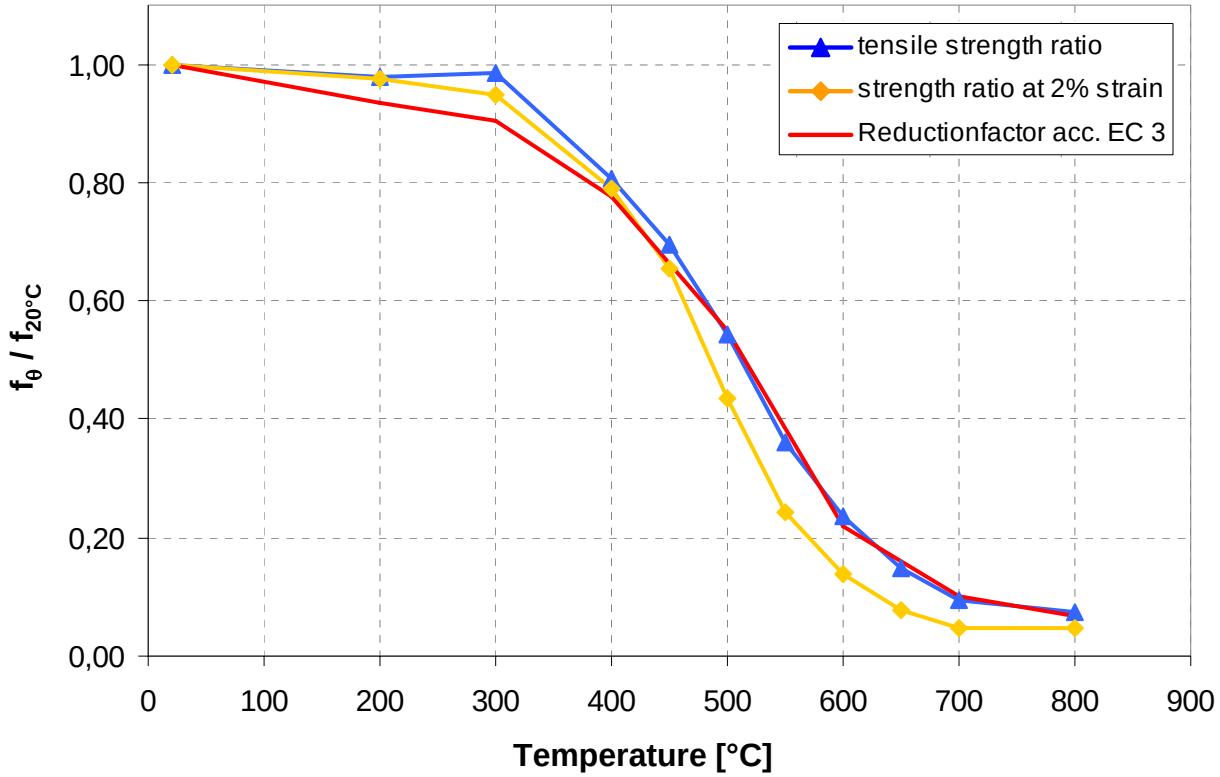
Comparison of the results



Material Behaviour of 10.9 Bolts under Fire Conditions

High Temperature Test

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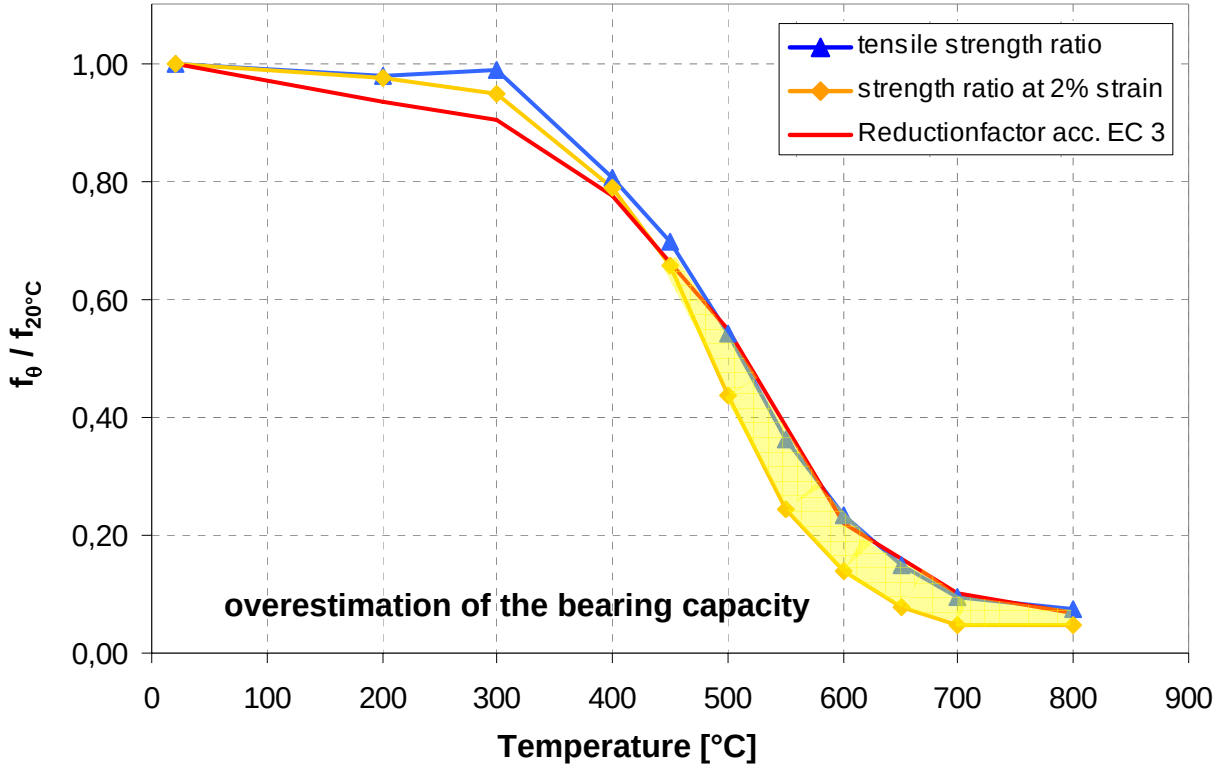
Comparison of the results



Material Behaviour of 10.9 Bolts under Fire Conditions

Tests on Bolts

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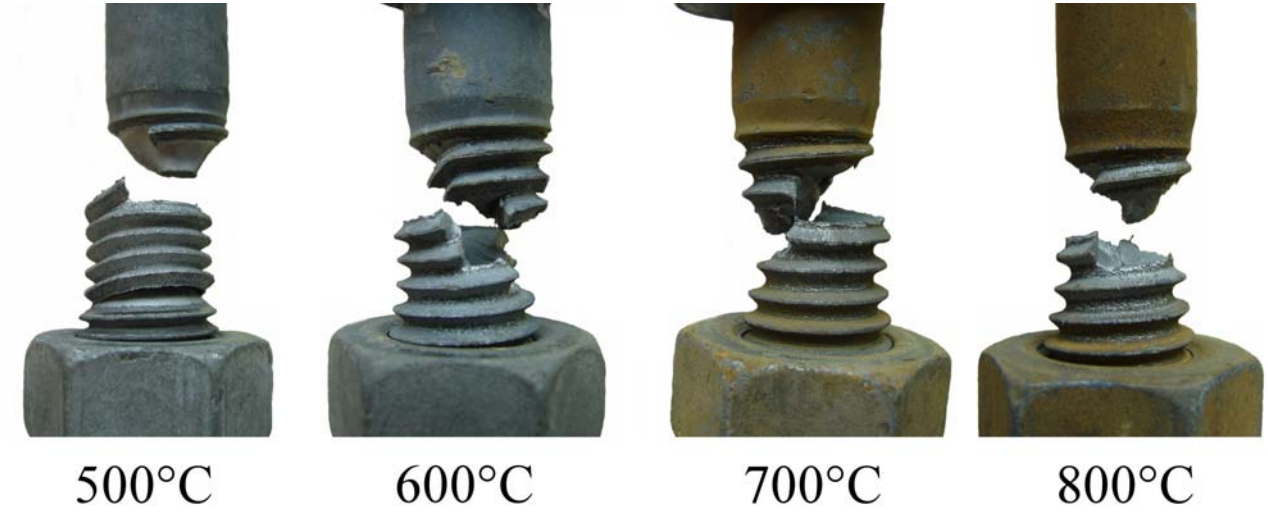
Thread failure at room temperature



Bolt failure at high temperatures

Material Behaviour of 10.9 Bolts under Fire Conditions

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Thank you for the attention !!!