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Analysis of the thermal stress state of the ICE piston skirt in critical cases

Topic of Interest: Scientific research, diagnostics, testing, operation and reliability of energy systems

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Scuffing and seizures on the outer surface of the piston skirt on both the pressure and anti-thrust sides

RHEINMETALL KOLBENSCHMIDT

The cause of such damage is considered to be overheating of the piston pin bed in the piston bosses due to:

- mechanical overload of the connecting rod bearing caused by combustion process deviations
- failure of the lubrication due to malfunction of the oil jet nozzle or insufficient pressure created by the oil pump
- insufficient lubrication during the initial engine startup

Ensuring reliable operation of the critical area of a piston skirt

Piston to cylinder liner hot clearance

$$\Delta R(h,\theta,\Xi,\tau)=R_L(h,\theta,\Xi,\tau)-R_S(h,\theta,\Xi,\tau),\quad 0<\tau<P$$

Acceptable change in clearance in operation

$$\Delta R_S(t(h,\theta,\xi_{base}),\sigma(h,\theta,\xi_{base}),\tau)\geq[\Delta R_{\mathrm{creep}}(h,\theta,\xi_{base})],\quad 0<\tau<\Pi.$$

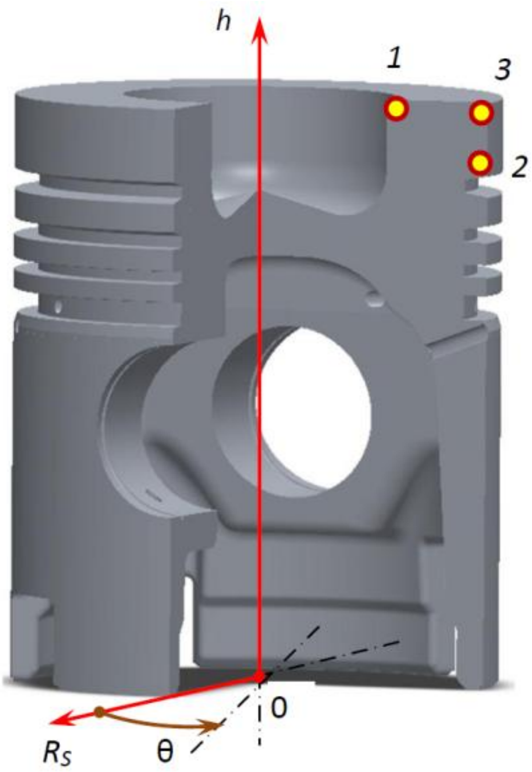
Creep limit at zero creep rate $\quad \dot{\varepsilon}_{creep}=F(t,\sigma)=0$

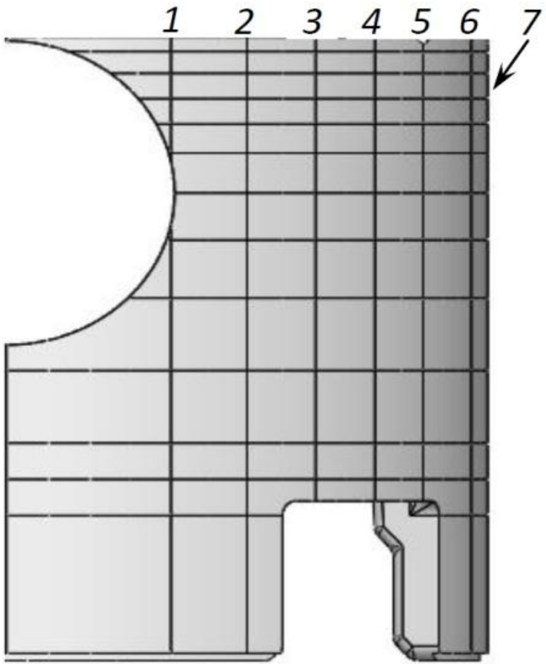
Criterion of the thermally stressed state of the design

$$\sigma(t(h,\theta,\xi_{base}(\tau)))\geq[\sigma_{\max}(t(h,\theta,\xi_{base}(\tau))],\quad 0<\tau<\Pi.$$

Geometrical model of the piston

D = 120 mm
S = 140 mm
d_p = 42 mm
h_s = 86 mm
AK12M2MgN

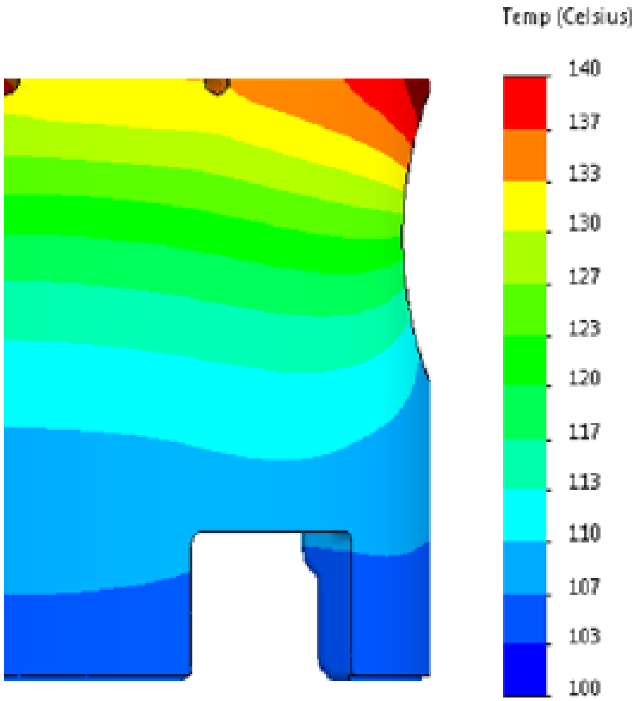




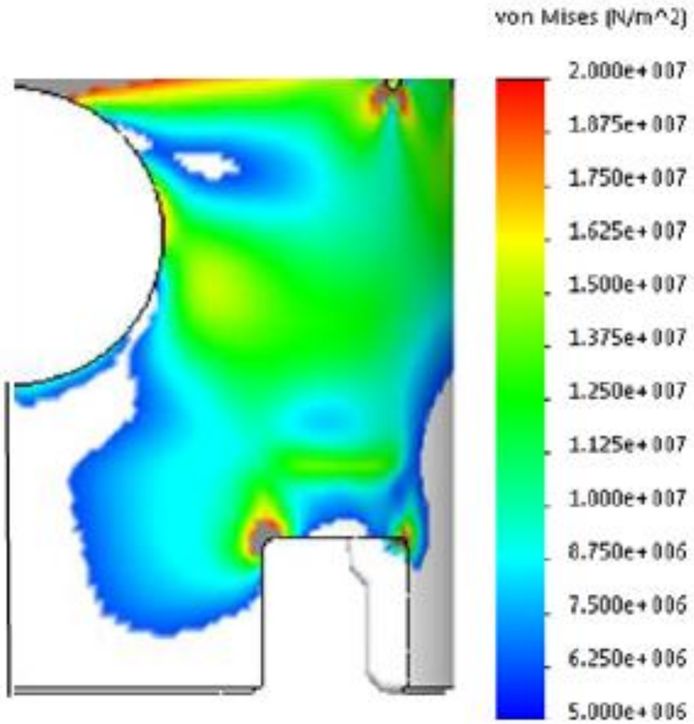
Stage 1 – Regular operation

30 kW per cylinder

creep limit criterion (8) is reached



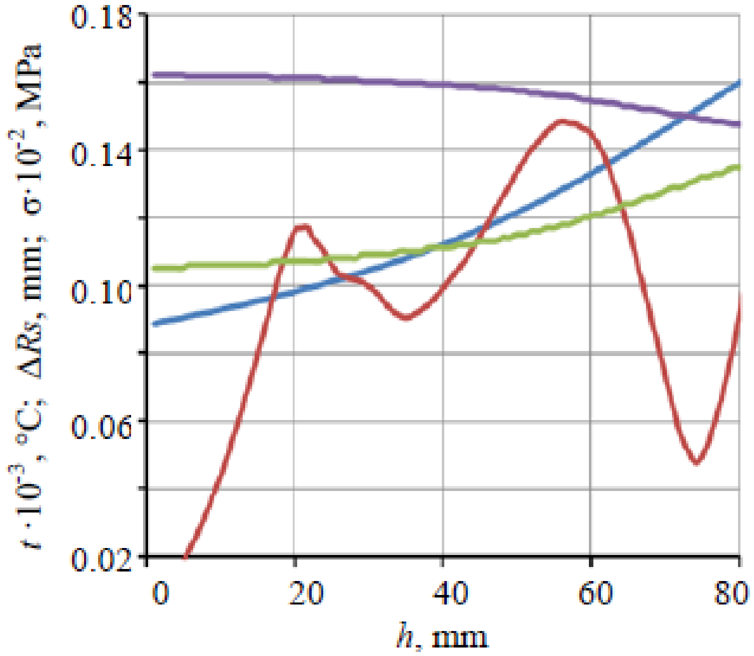
temperature



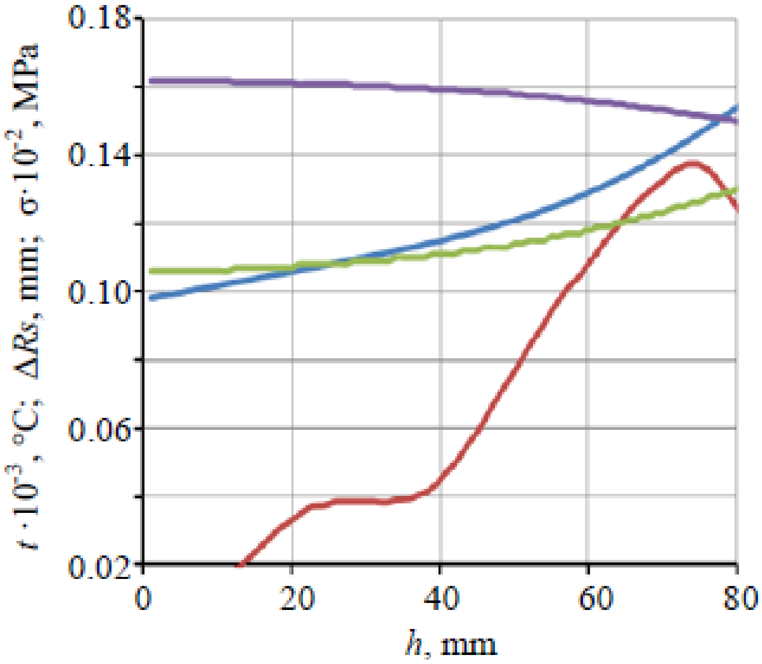
thermal stress

Stage 1 – Regular operation

Angle 30°



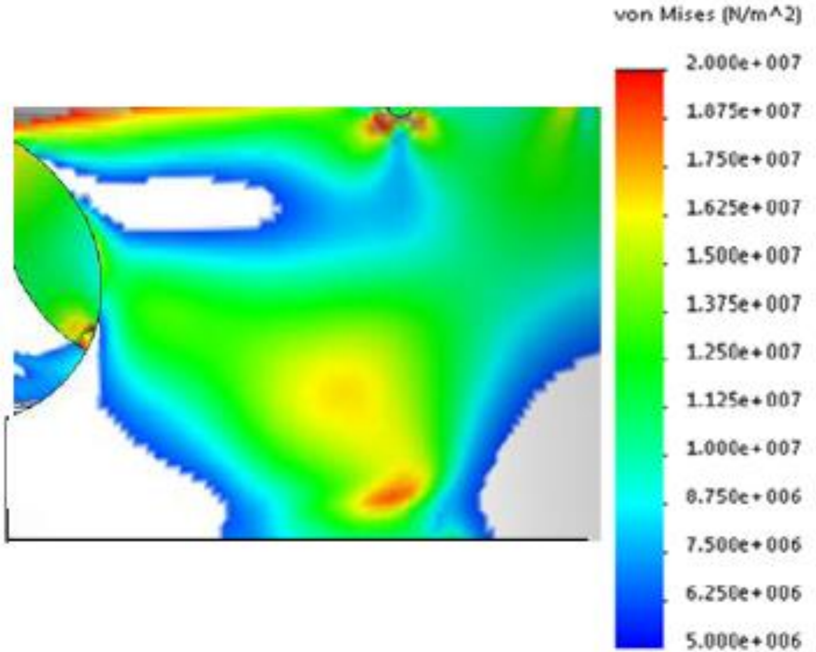
Angle 75°

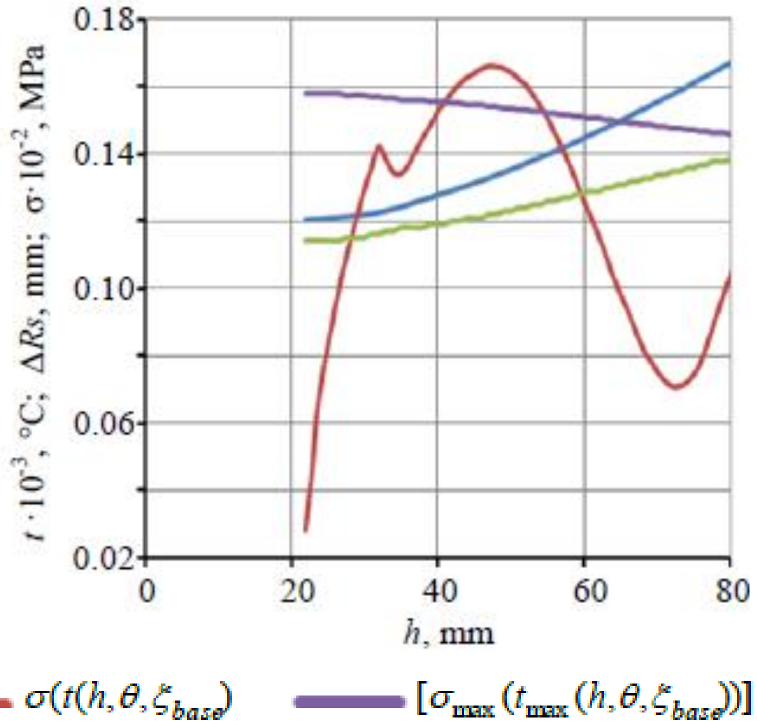


$t(h, \theta, \xi_{base})$ $\Delta R_S(h, \theta, \xi_{base})$ $\sigma(t(h, \theta, \xi_{base}))$ $[\sigma_{max}(t_{max}(h, \theta, \xi_{base}))]$

Stage 2 – Disruption of heat transfer on the surfaces of the piston pin bed

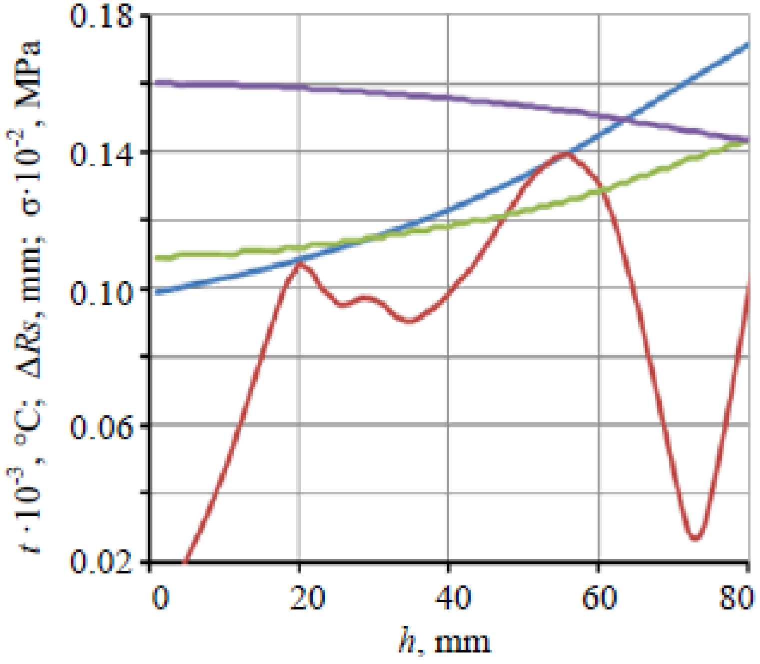
Angle 50°



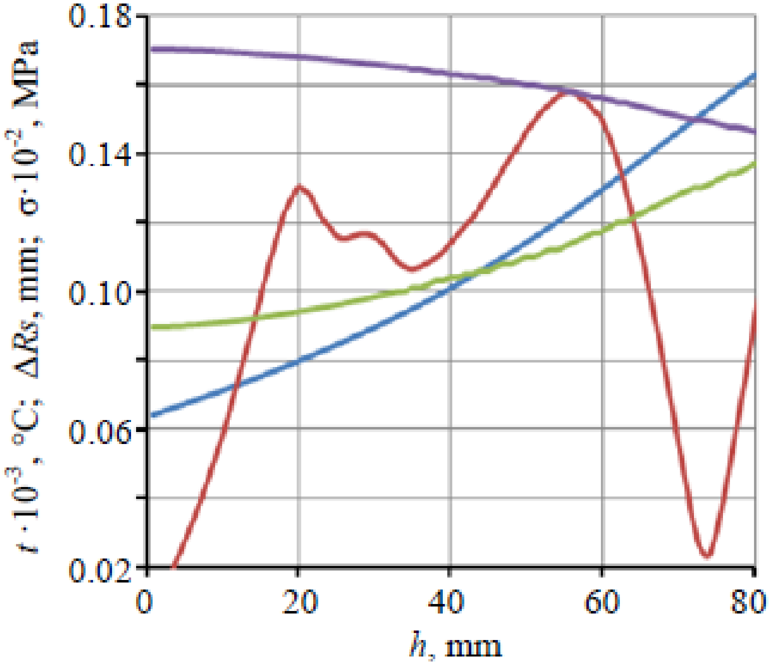


Stage 3 – Impairment of oil cooling, at angle 30°

Oil temperature 95°C



Oil temperature 50°C



$t(h,\theta,\xi_{base})$ $\Delta R_S(h,\theta,\xi_{base})$ $\sigma(t(h,\theta,\xi_{base}))$ $[\sigma_{max}(t_{max}(h,\theta,\xi_{base}))]$

The criterion of exceeding the creep limit is proposed to be used in case of malfunction of ICE systems for analysis of a piston skirt reliability .

The determining parameter according to the criterion of exceeding the creep limit is thermal stress. It is shown that there is no correlation between the radial thermal deformations of the piston skirt and thermal stresses.

The location of critical areas of the skirt in the event of a fault emerging has been determined. Simulation results are in full correlation with the observations in ICE maintenance practice regarding the places of occurrence of scuffing and seizures on the piston skirt, as well as with the proposed explanation of the reasons for the loss of reliability.

THANK YOU FOR YOUR ATTENTION !