Thick Cylinder - Shrink Fit Example

A gun barrel has an ID of 150 mm. It is made by shrink fitting an outer sleeve of ID = 190.000 mm and OD of 210.0 mm over an inner sleeve of ID 150.0 mm and OD of 190.125 mm. The maximum pressure seen in the barrel is 50 MPa. The inner sleeve is made from steel with yield strength 320 MPa and the inner sleeve is made from steel with yield strength 670 MPa.

Determine the factor of safety using the von Mises yield criterion.
Determine the minimum temperature difference needed between the sleeves to permit shrink fitting to take place.

Steel properties: E = 205 GPa. Thermal expansion coefficient = 13×10^{-6}/C

a) find the interface pressure:

$P_{int} = 205e9*.000125((0.105^2-0.095^2)(0.095^2-.075^2))/(2x.095^2(0.105^2-0.075^2))$
$P_{int} = 11.29$ MPa

b) find the stresses in each sleeve due to the interface pressure (all axial stresses = 0)

Inner sleeve: $\sigma_{ci} = -11.29x2x0.095^2(0.095^2 - 0.075^2) = -59.94$ MPa (at r = 75 mm)

$\sigma_{co} = -11.29(0.095^2 + 0.075^2)(0.095^2 - 0.075^2) = -48.65$ MPa (at r = 95 mm)

Outer sleeve:

$\sigma_{ci} = 11.29(0.105^2 + 0.095^2)(0.105^2 - 0.095^2) = 113.19$ MPa (at r = 95 mm)

$\sigma_{co} = 11.29x2x0.105^2(0.105^2 - 0.095^2) = 101.90$ MPa (at r = 105 mm)

c) find the stresses in the solid cylinder due to the internal pressure (all axial stresses = 0)

At r = 75 mm $\sigma_c = 50(0.105^2 + 0.075^2)/(0.105^2 - 0.105^2) = 154.17$ MPa
$\sigma_r = -50$ MPa
At r = 95 mm $\sigma_c = 50x0.095^2(1 + 0.105^2/0.095^2)/(0.105^2 - 0.075^2) = 115.71$ MPa
$\sigma_r = 50x0.075^2(1 - 0.105^2/0.095^2)/(0.105^2 - 0.075^2) = -11.54$ MPa
At r = 105 mm $\sigma_c = 2x50x0.075^2/(0.105^2 - 0.075^2) = 104.17$ MPa
$\sigma_r = 0$ MPa

d) find the final stresses in the sleeves due to the internal pressure plus the shrink fit using linear superposition (all axial stresses = 0)

At r = 75 mm on inner sleeve $\sigma_c = 154.17 - 59.94 = 94.23$ MPa
$\sigma_r = -50 + 0 = -50$ MPa
At r = 95 mm on inner sleeve $\sigma_c = 115.71 - 48.65 = 67.06$ MPa
$\sigma_r = -11.29 - 11.54 = -22.83$ MPa

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At r = 95 mm on outer sleeve σ_c = 115.71 + 113.19 = 228.90 MPa

σ_r = -11.29 – 11.54 = -22.83 MPa

At r = 105 mm on outer sleeve σ_c = 104.17 + 101.90 = 206.07 MPa

σ_r = 0 + 0 = 0 MPa