Influence of Specimen Design on Maximum Heating Rate and Temperature Variation During Induction Heating in an 805L Dilatometer

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Advanced Steel Processing and Products Research Center

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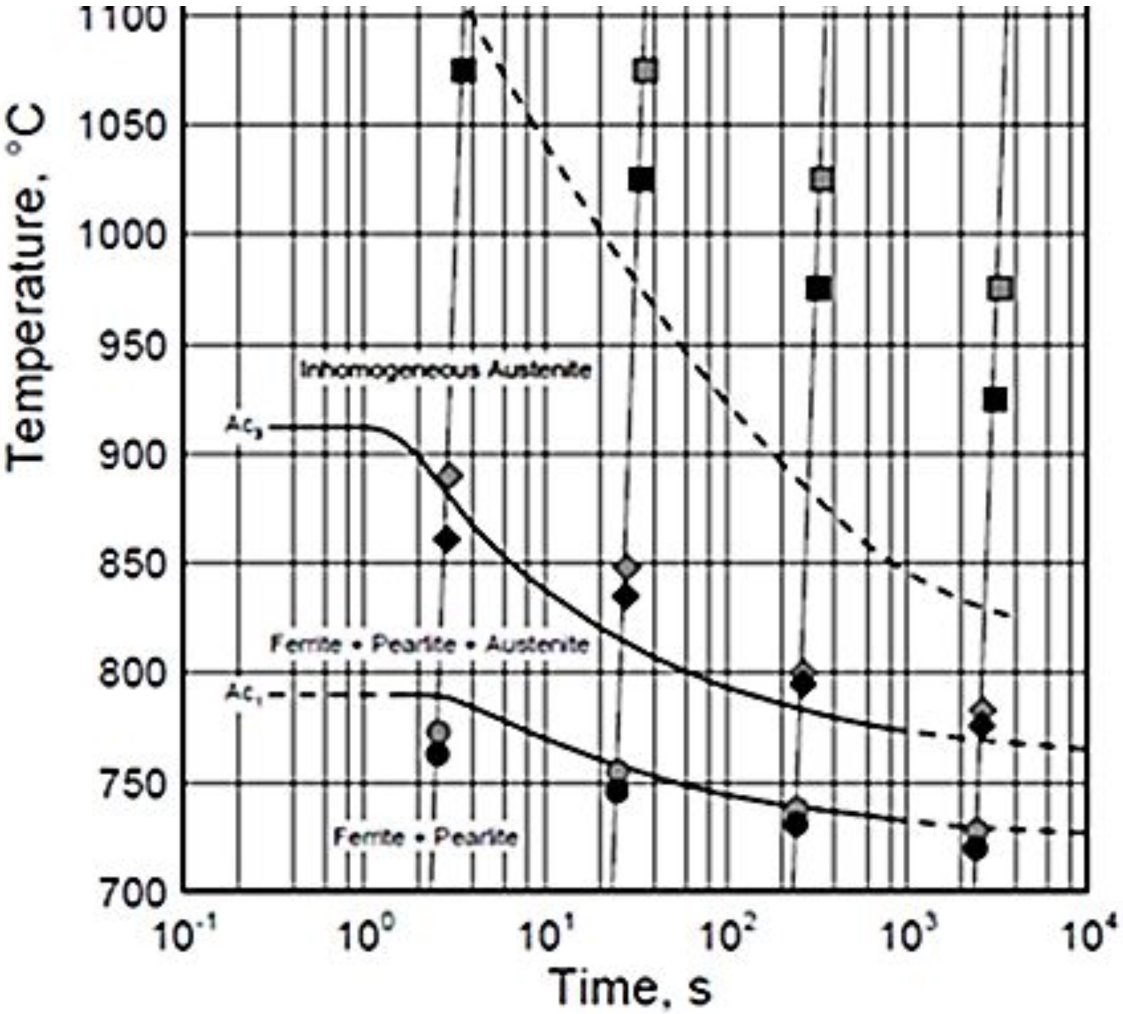
Steel Transformations Change With Rapid Heating Rates



Changes in the microstructure of a Ck 45 (1045) steel with heating rate and peak temperature.

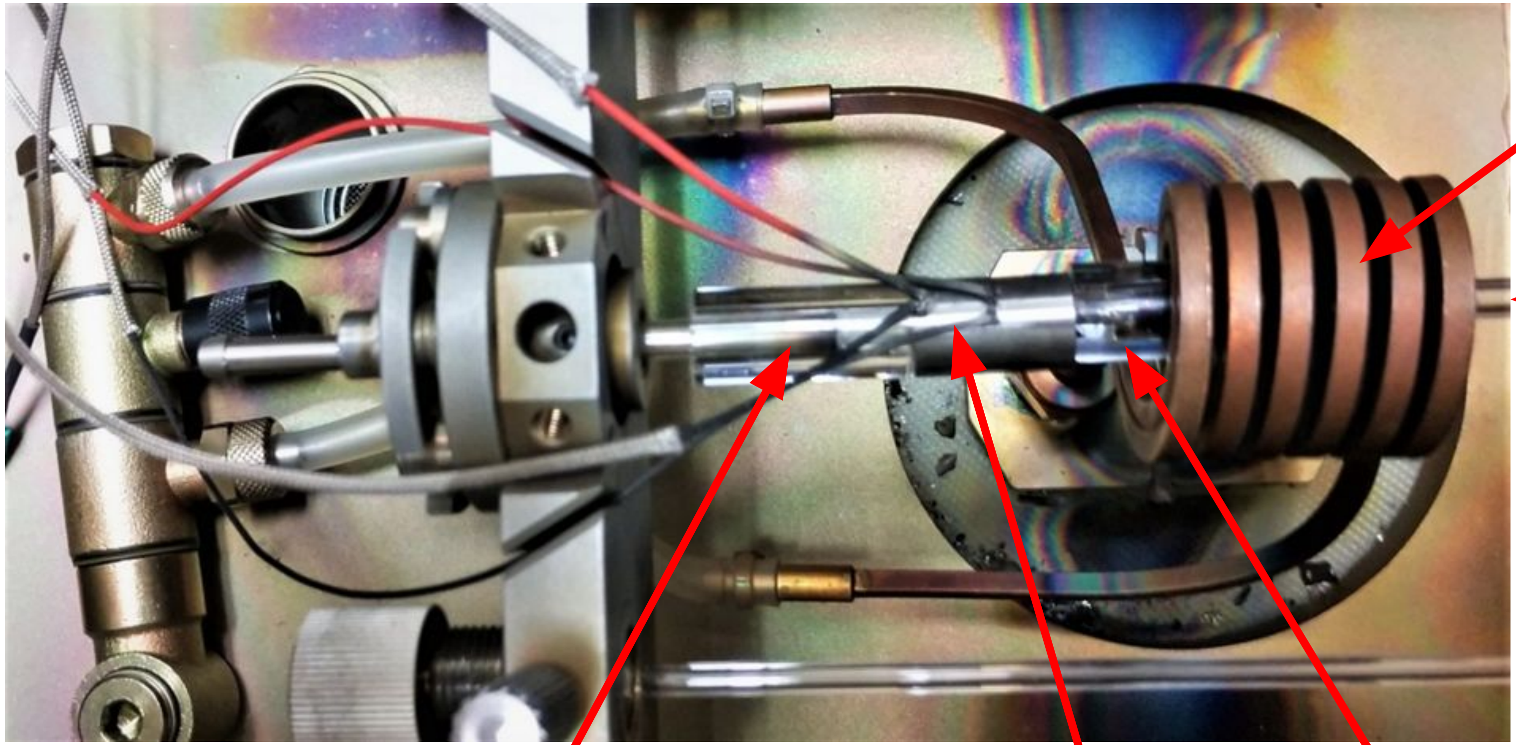
<u>Important to Determine Accurate Transformation Temperatures During Rapid Induction Heating</u>

J. Orlich, A. Rose, and P. Wiest, Ed, “Temperatur-Austenitisierung-Schaubilder,” *Atlas zur Warmbehandli-Austeningder Stahle, Vol 3*, Zeit Verlag Stahleisen M. B. H. Dusseldorf Germany, 1973.

Project Background

- TA Instruments (Bahr) 805L Quenching Dilatometer is Commonly Used to Study Steel Transformations.
- Maximum Heating Rate for Austenite Using Standard Specimen Design, 4 mm Diameter by 10 mm Long,
  - Limited to 200 $^{o}Cs^{-1}$
  - Large Temperature Variations with Standard Specimen Heating at 200 $^{o}Cs^{-1}$
- Industrial Induction Heating Rates Can Exceed 1000 $^{o}Cs^{-1}$
- What Are the Effects of Changing to Tubular Test Specimens on
  - Heating Rates in Ferrite Pearlite vs Austenite?
  - Temperature Gradients during Transformation?

TA 805L Quench Dilatometer and Push Rod Modification for Tubes



Induction Heating and Gas Quenching Coils

Spring Loaded 4 mm Diameter Push Rod to LVDT

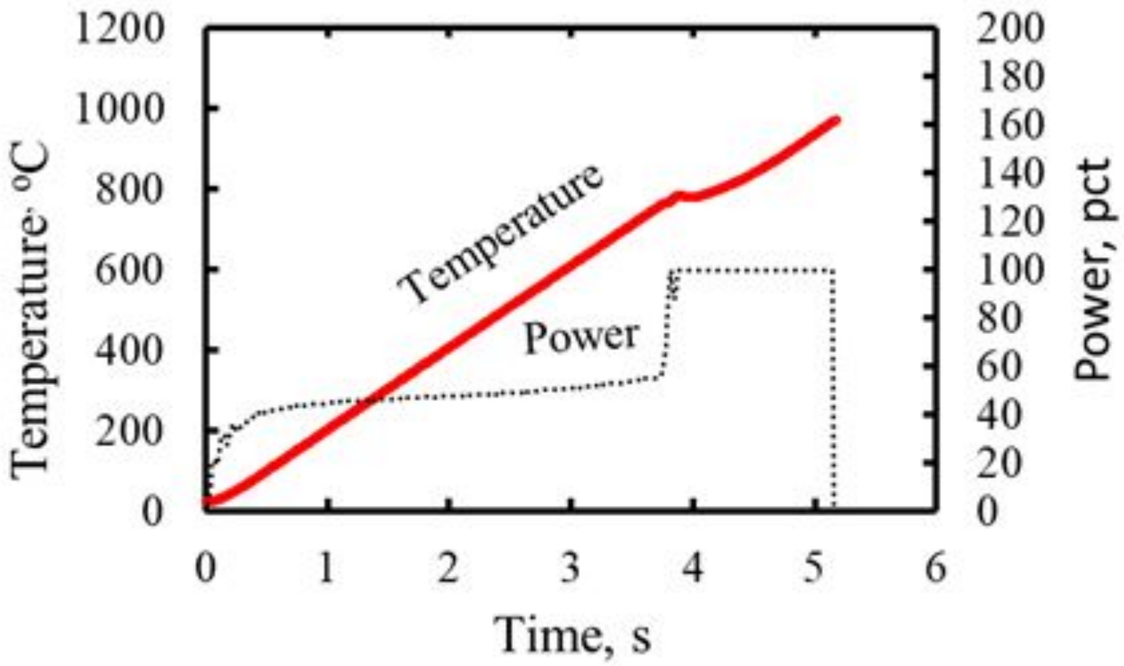
3 kW, 150 – 400 kHz power supply

4 mm ID by 10 mm OD Quartz Shoe

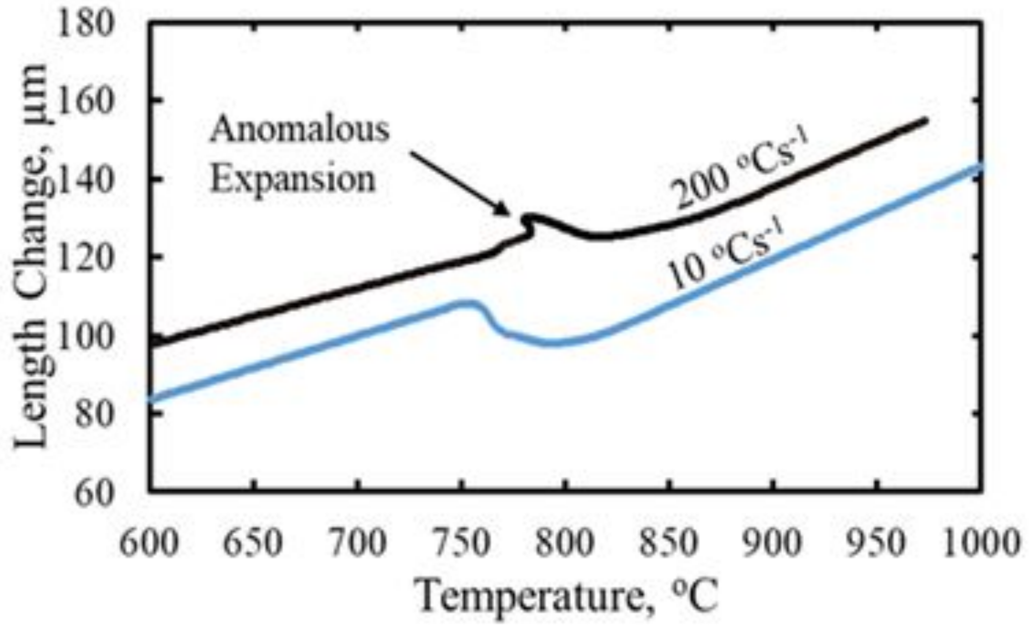
10 mm OD Tube Test Specimen With Thermocouples Attached

4 mm ID by 10 mm OD Quartz Shoe

Dilatometer Heating 4 mm OD by 10 mm Long 1045 Steel Specimen

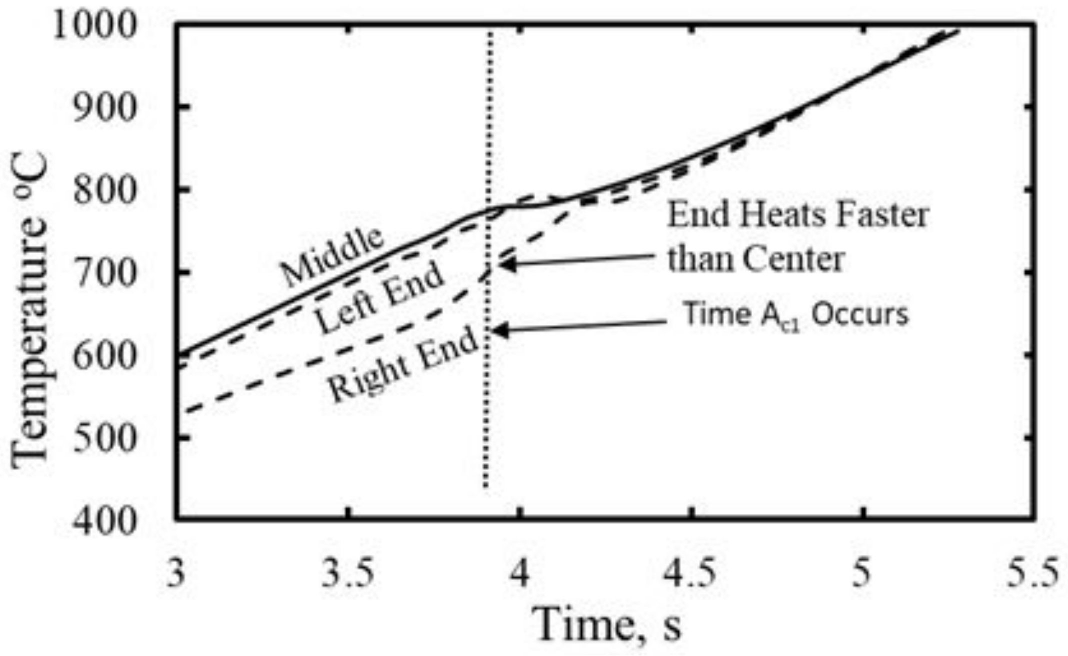


Maximum Heating Rate 200 $^{o}Cs^{-1}$ Above A_{c3}

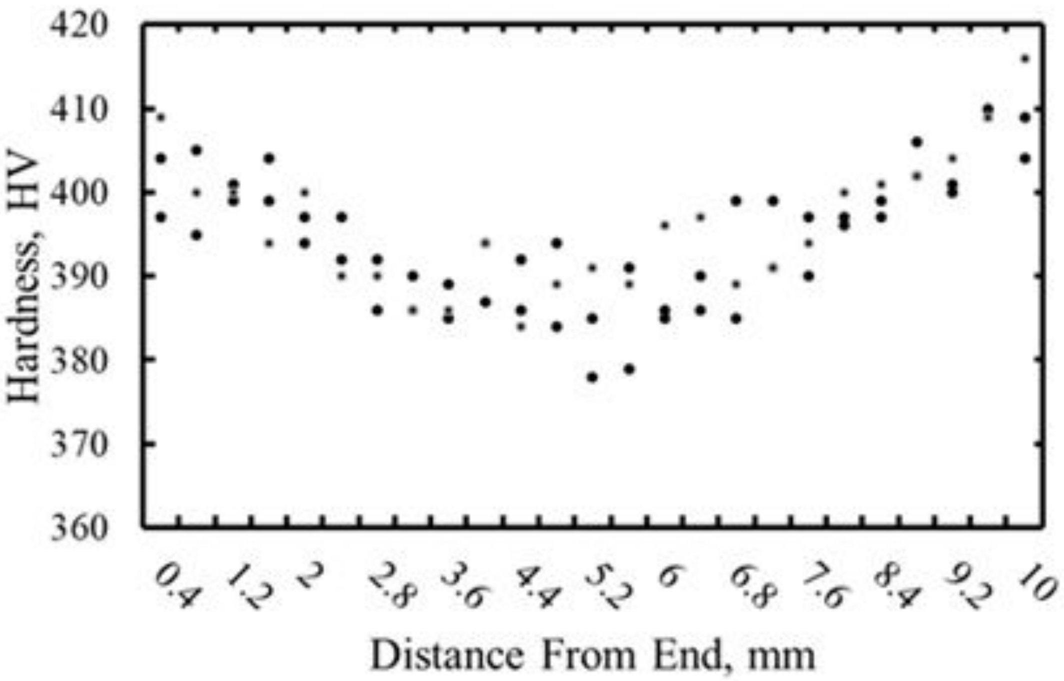


Non Accurate Length Changes at High Heating Rates

Non–Uniform Heating Along Specimen Length – Heating at 200 $^oCs^{-1}$

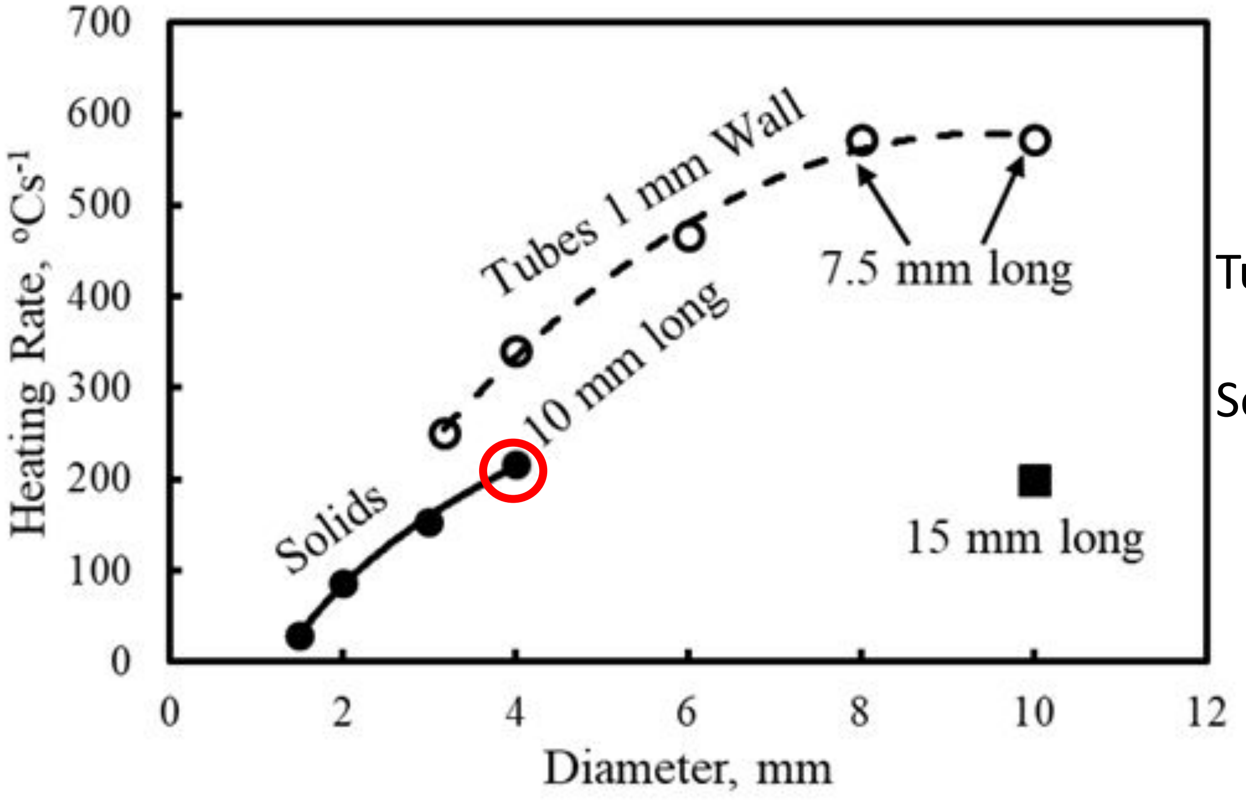


1045 Steel Ends Heat Slower Than Center Below A_{c1}



Quenched 1045 Steel Center Softer Than Ends When Induction Tempered at 740 ^oC

Effect of Specimen Design on Heating **Austenite** at Maximum Power

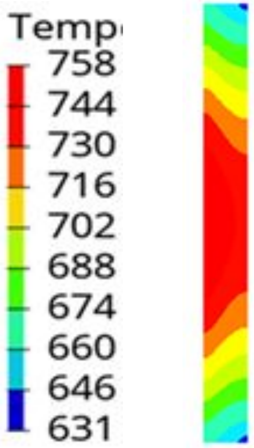


Tubes – Austenitic Stainless Steel

Solids - O1 Tool Steel above A_{c3}

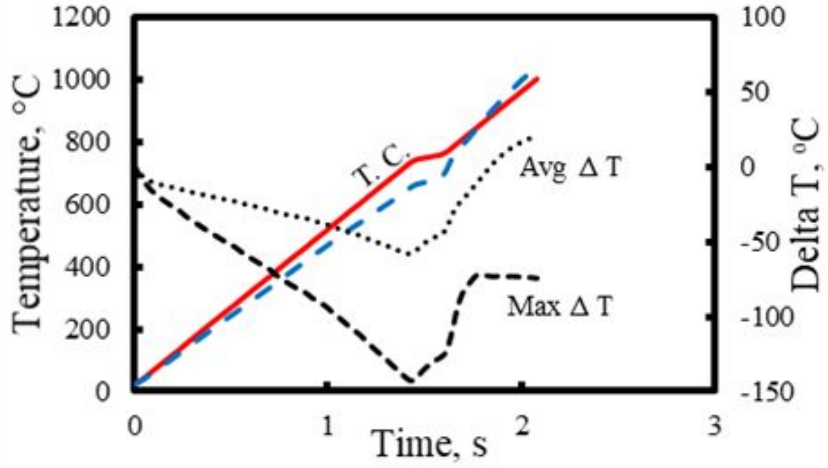
Tubes and Larger Diameters Heat Faster

Modeled Temperature Variations in 10 mm Tube Heating at Maximum Power



1045

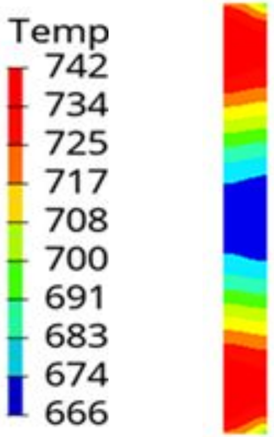
TC



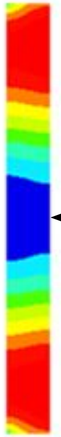
Ferrite-Pearlite

Center Heats Faster than Ends

Negative ΔT



Austenitic Stainless



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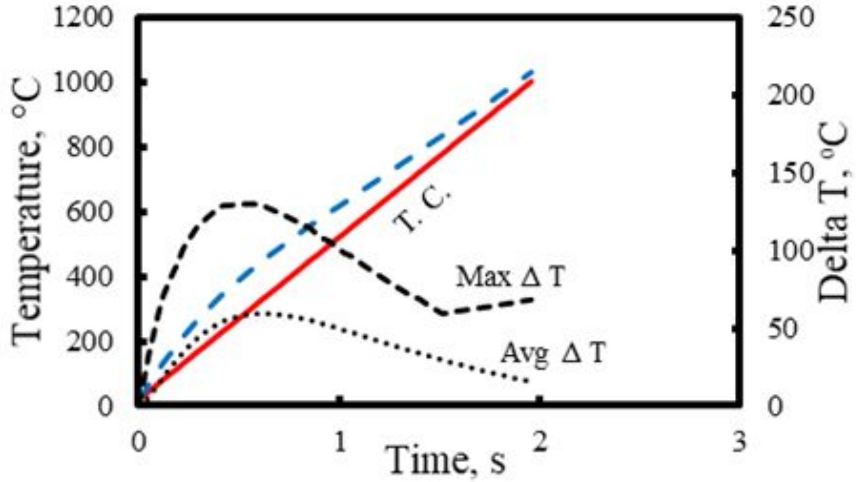
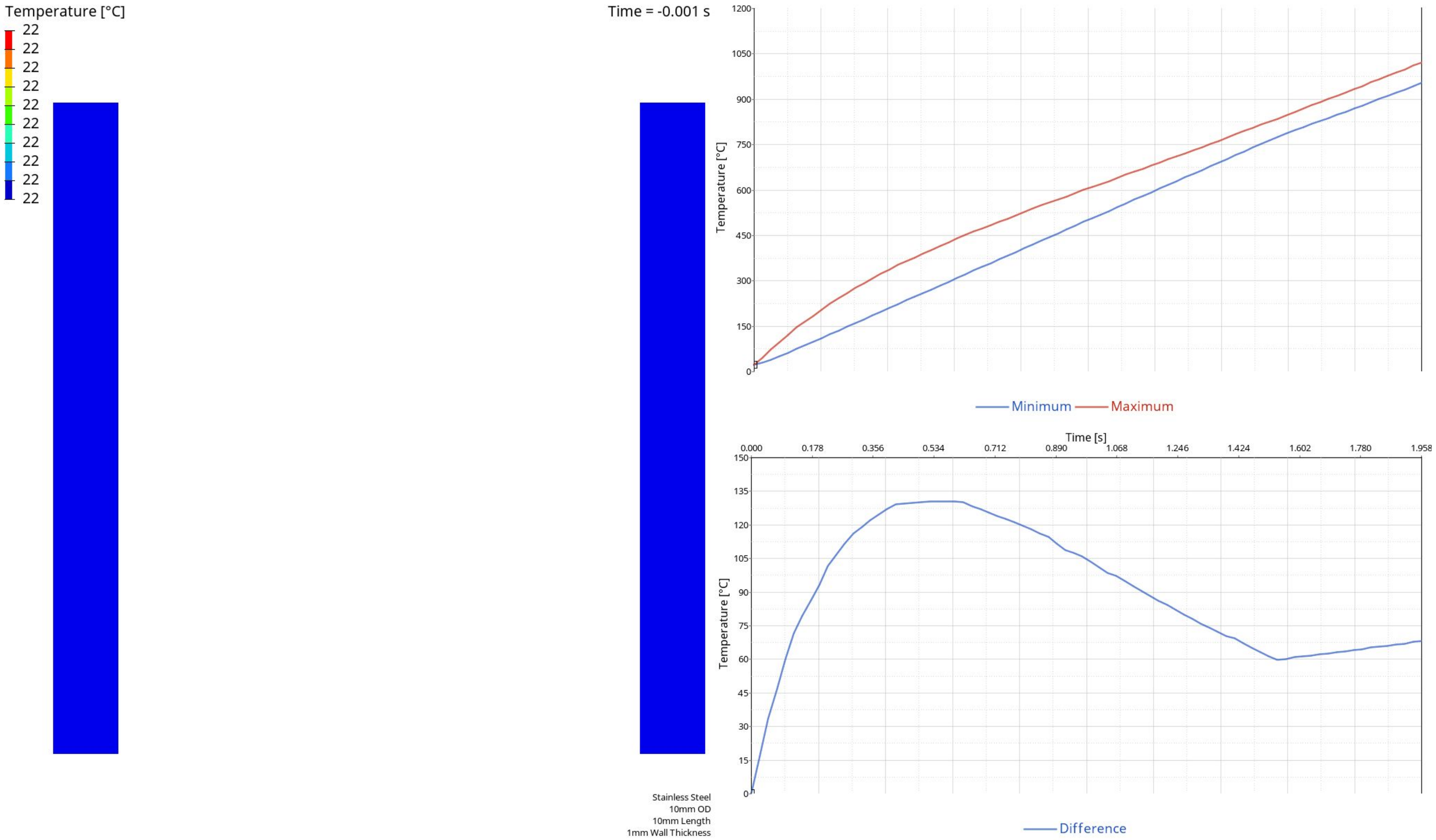


Austenite

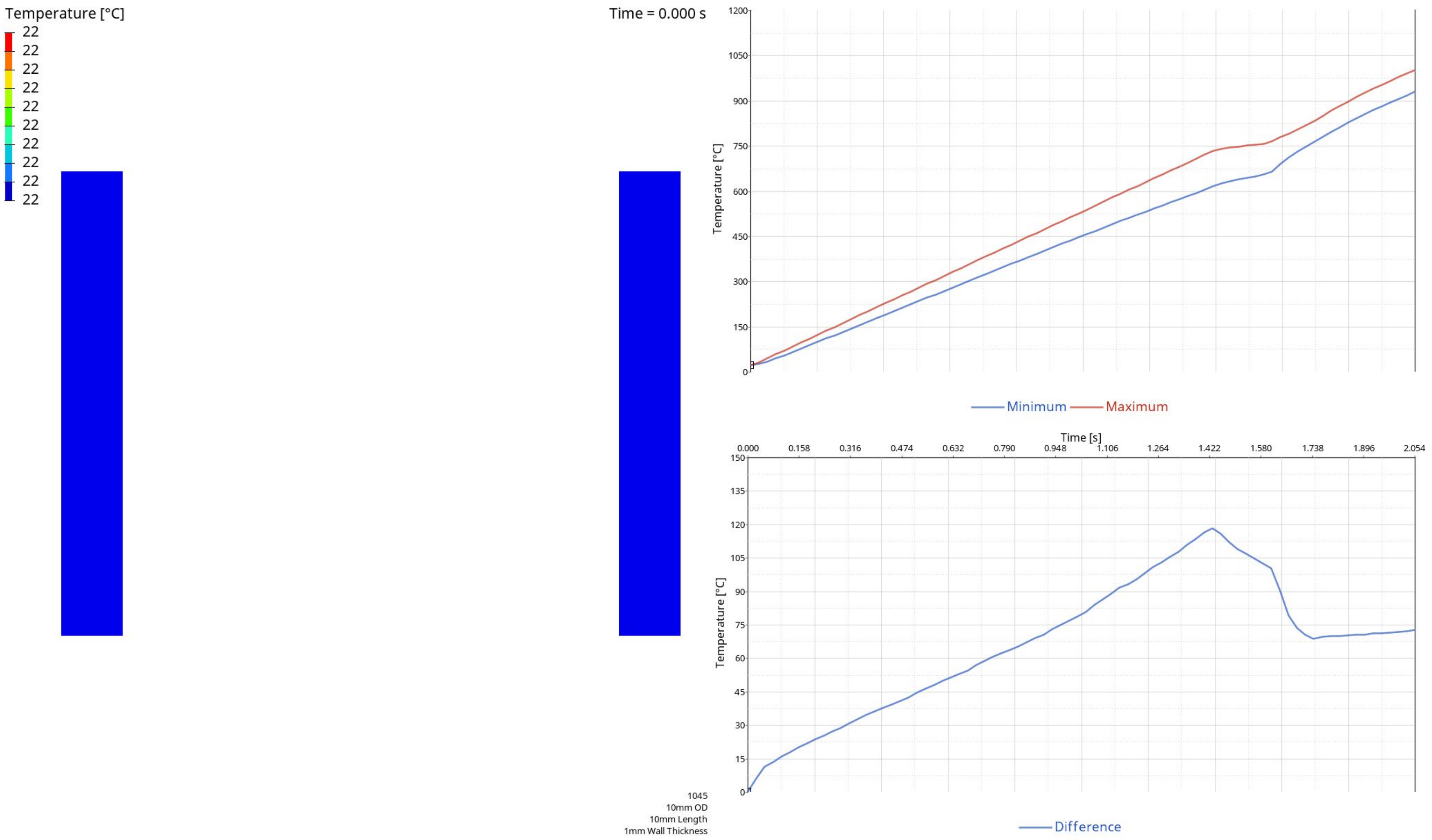
Ends Heat Faster than Center

Positive ΔT

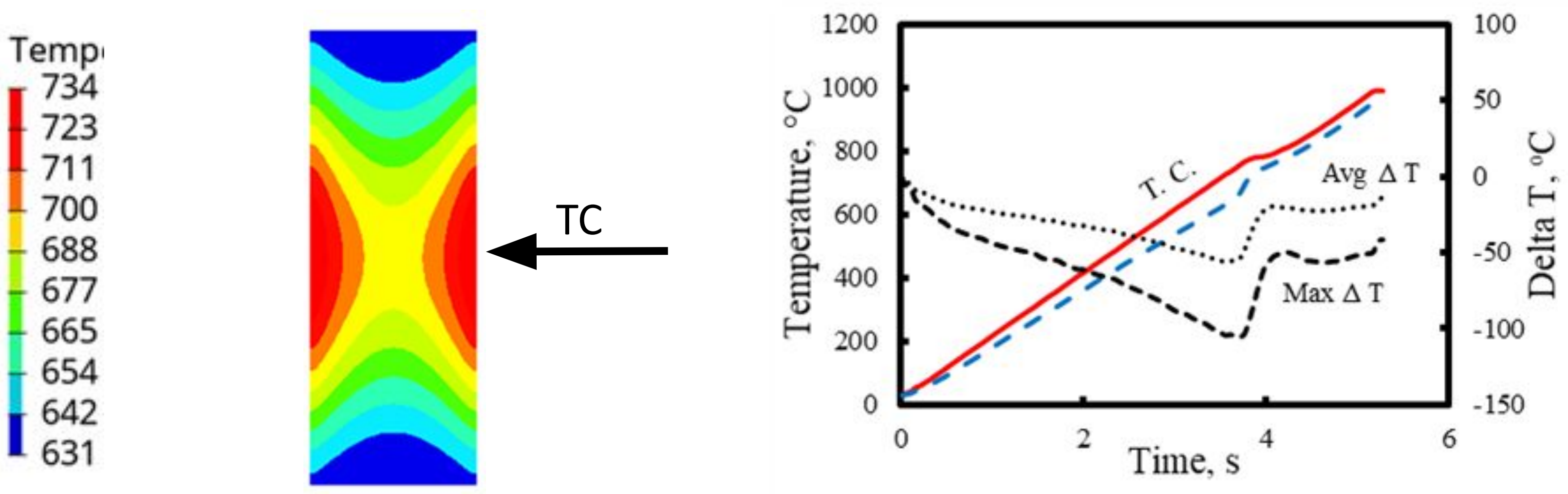
10 mm Stainless Steel Tube



1045 10 mm Tube



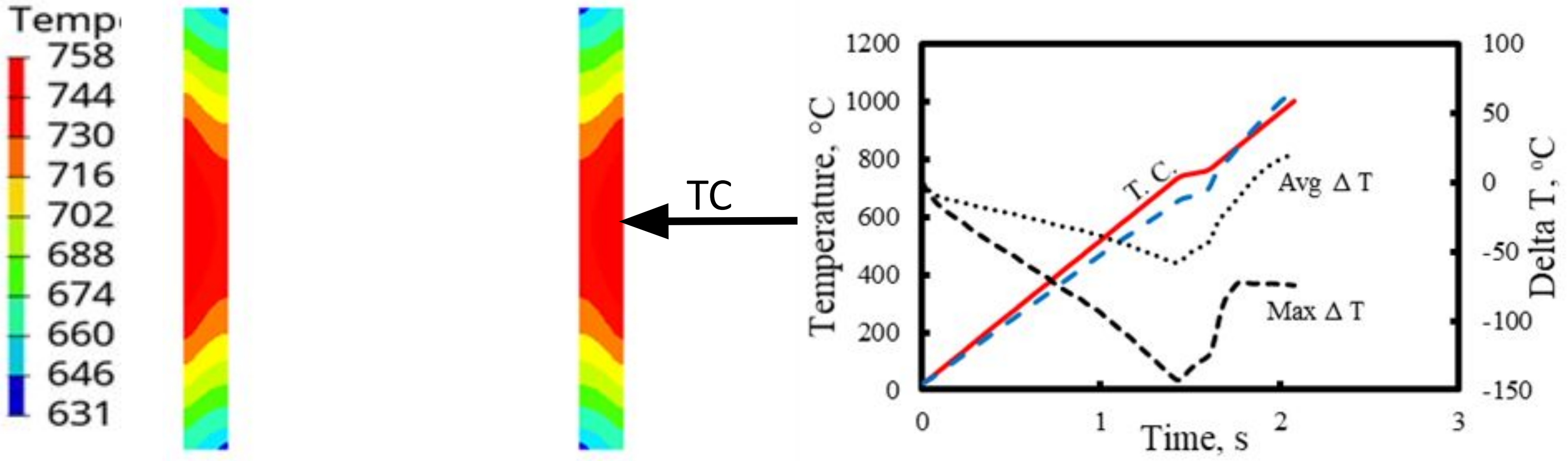
Modelled Temperature Variations in Tube Versus Solid 1045 Steel at Maximum Power



4 mm Solid

Heating in 5 s

Maximum $\Delta T = -120\ ^{o}C$

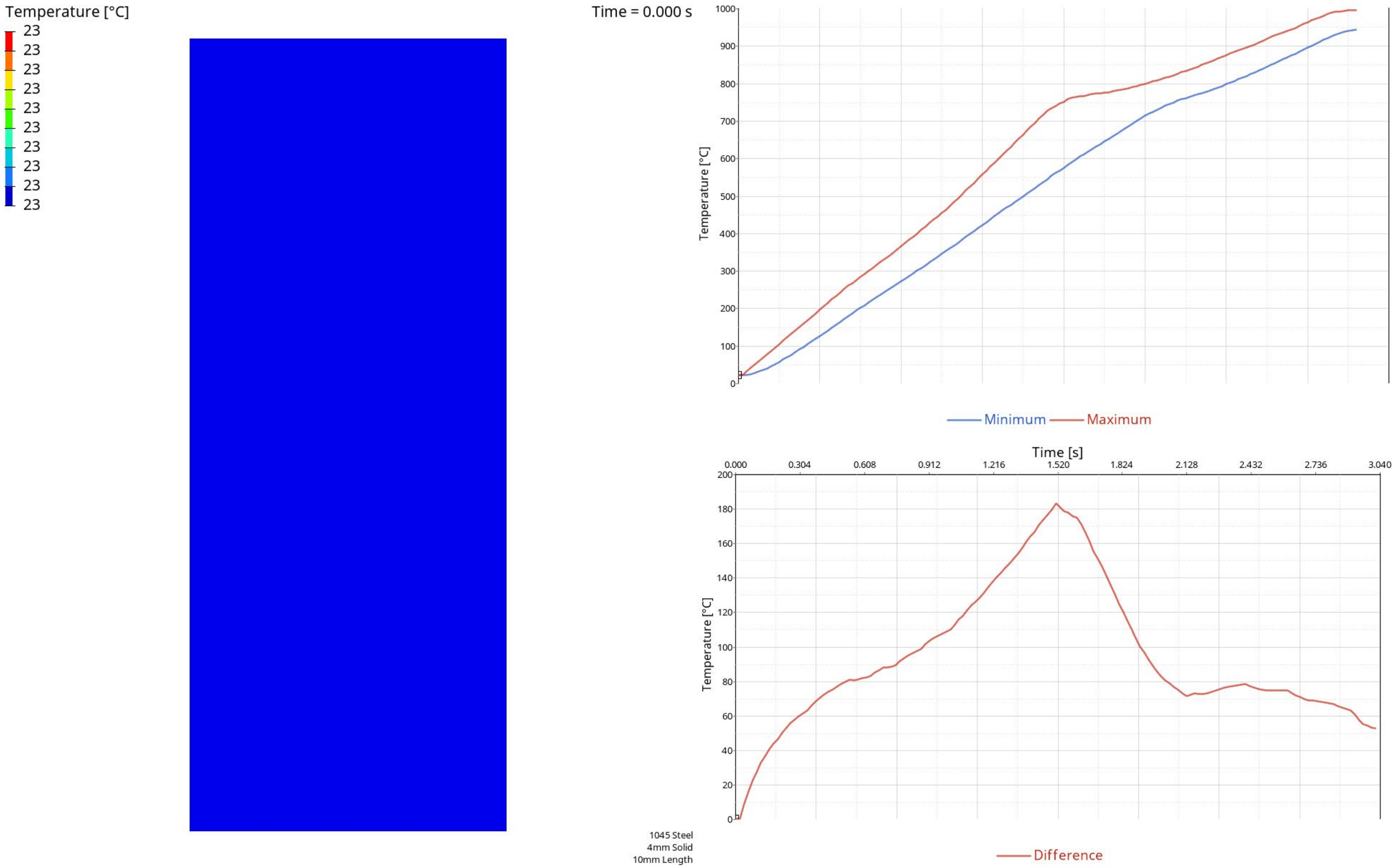


10 mm Tube

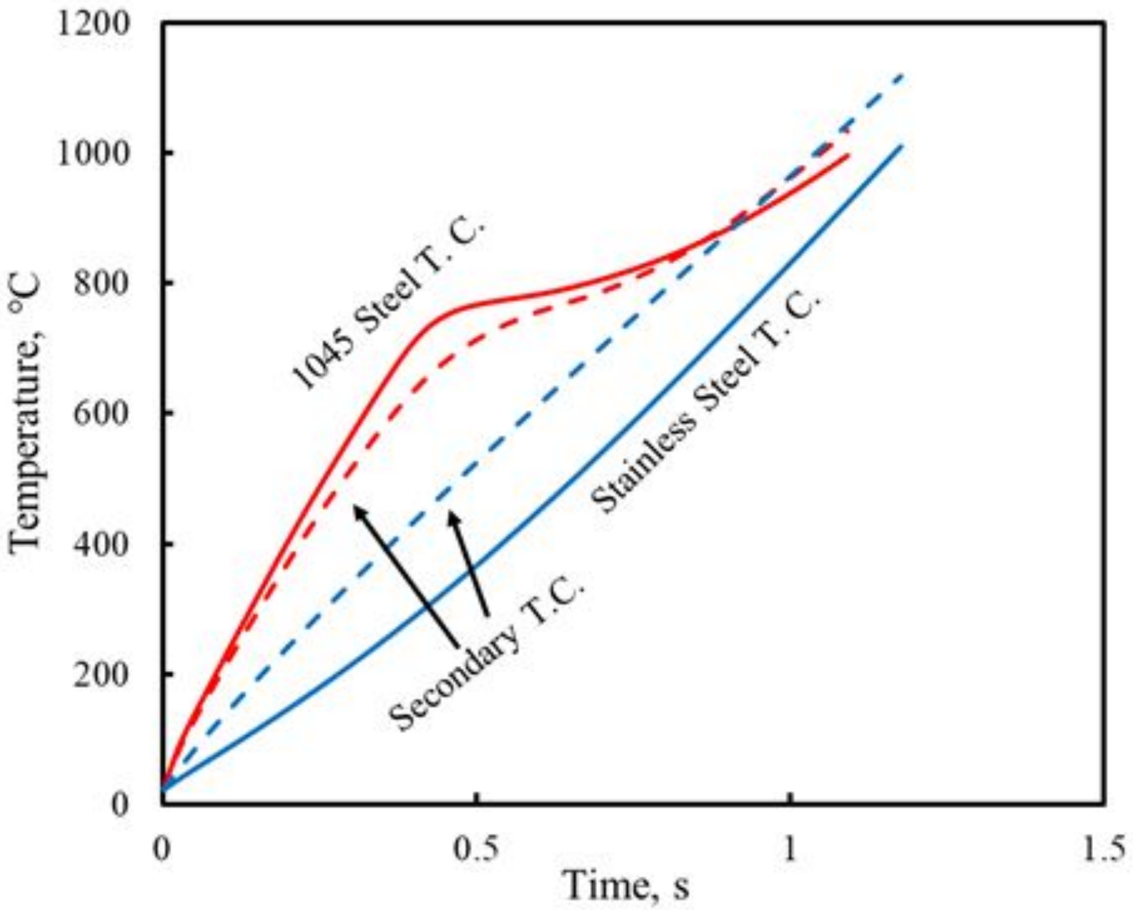
Heating in 2 s

Maximum $\Delta T = -150\ ^{o}C$

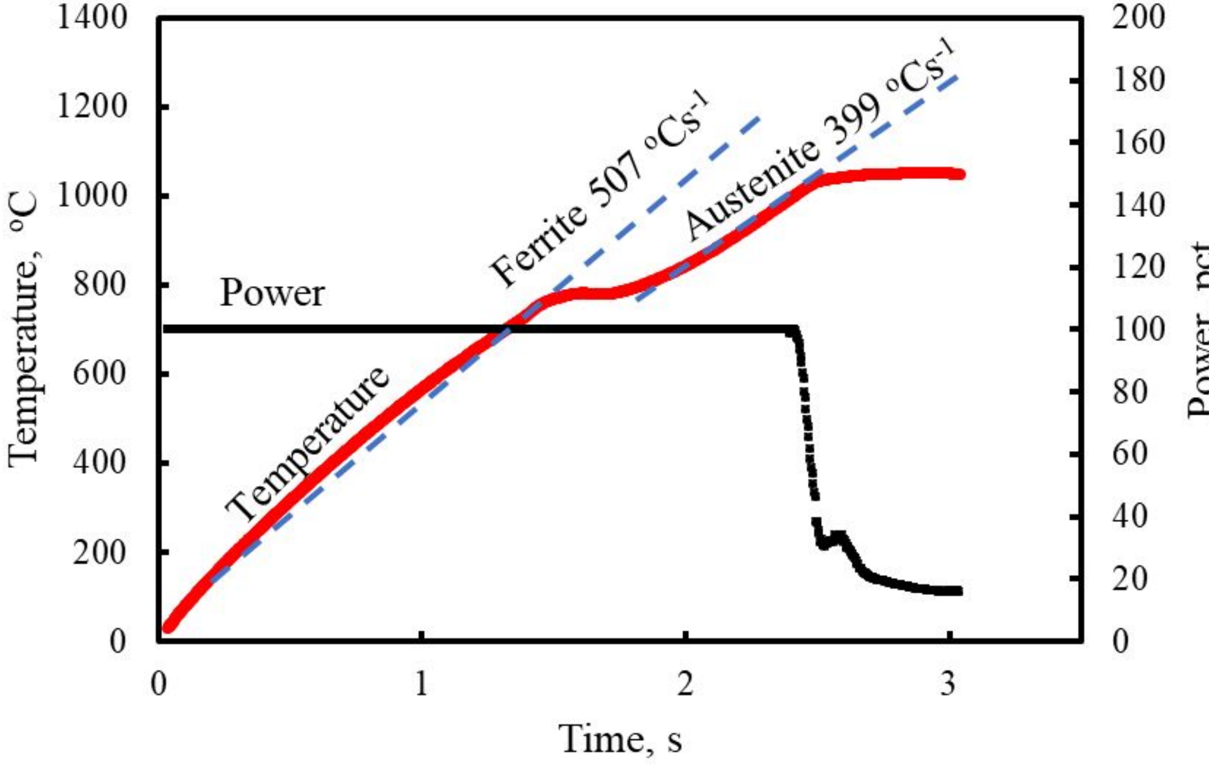
1045 4 mm Diameter by 10 mm Long Solid Cylinder

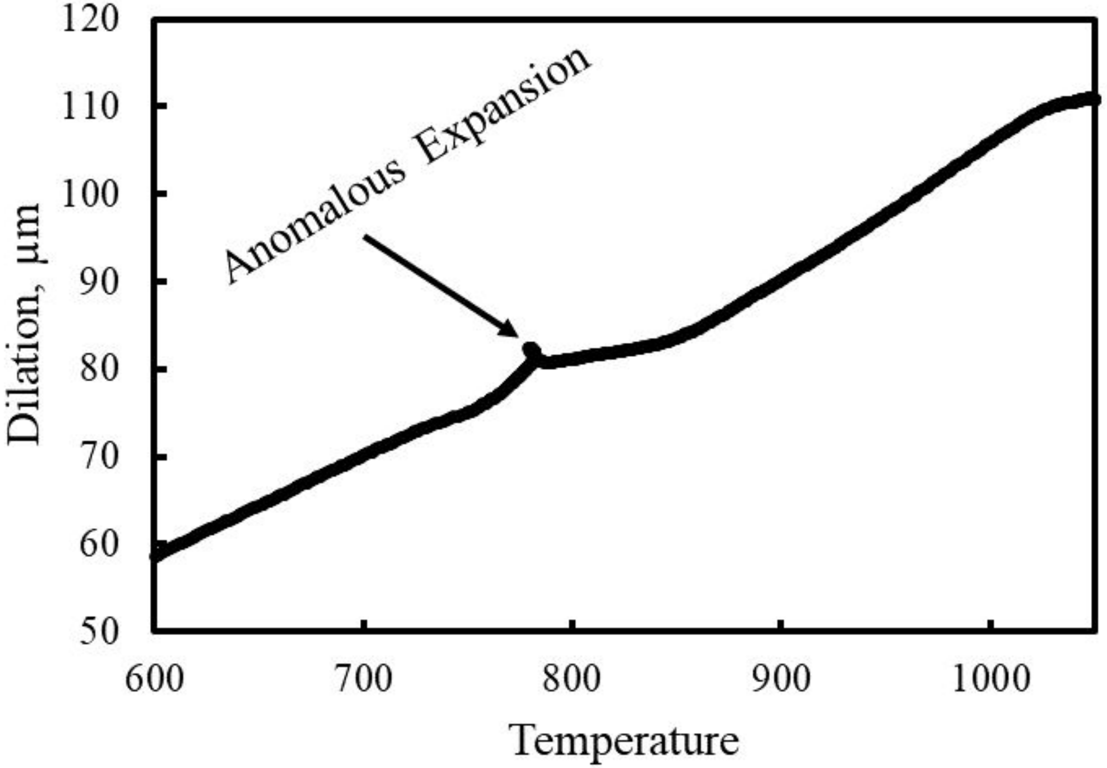


Modelled Heating Curves Showing Deviations Between Center Control and End Temperatures of 10 mm Diameter Tubes at Maximum Power



Actual Heating Test for 10 mm diameter by 7.5 mm long by 0.1 mm wall thickness 1045 steel at maximum power.





Conclusions

- With a TA 805 L Dilatometer it is possible to increase the maximum heating rate for 1045 steel up to about 400 $^oCs^{-1}$ as austenite and over 500 $^oCs^{-1}$ as ferrite-pearlite by changing the specimen design to a 10 mm diameter by 1 mm wall thickness by 7.5 mm long tube.
- The temperature gradient is approximately the same for the 4 mm diameter solid and the 10 mm diameter tubular specimens heated with the maximum power input
- A_{c1} temperatures are not accurately determined for either specimen type at maximum heating rates due to thermal gradients causing anomalous expansion during the transformation.

THANK YOU!

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