

# A typical Case from the Practice, Explained Step by Step for Beginners:

# Understanding of Material Failure in a Heat Exchanger by Means of Thermal and Structural Analysis

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# ABSTRACT

Some leaking tubes due to surface flaws in welding of the tube plate were detected recently in an evaporator of a chemical plant. Aiming to clarify, whether such a failure can be explained by the transient three-dimensional state of stresses occurring during an unplanned rapid cooling process, a start-up with sharp temperature gradients, thermal and mechanical FE simulations have been performed using a simplified finite element model. This model consisted of cut off sections of a single tube of the complete tube bundle and representative parts of the tube plate as well as of the cylindrical vessel shell (casing). Following the heat transfer analysis, structural loads due to gravity and pressure were superimposed on the thermal stresses expected due to thermoshock, in a second phase of investigation.

Based on the equivalent (von Mises) stresses resulting under combined loads, it could easily be concluded that the allowable stress limits are almost exhausted at the welds and consequently the occurrence of local flaws must not be surprising.

The presentation discusses the significant steps of modelling and analysis procedure focusing on easy understanding and reproducibility.



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 Understanding of the function of the component and of the specific problem as part of a complex process







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Representative FE model containing parts of

≻Tube

- ➤Tube plate
- Casing
- 3096 Hexa/brick elements of type 43 & 44 for heat transfer analysis (MSC.Marc Version 2000 is used)





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## Thermal loading / boundary conditions



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 Thermal loading /boundary conditions: heat transfer coefficients, prescribed timedependent temperatures for the media in contact with surfaces of the model

 Thermal material properties: heat conduction coefficient, specific heat, density





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 Results of heat transfer analysis: Transient temperatures at selected nodes (history plots)





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# Results of heat transfer analysis: Temperature distributions for selected times (path plots)



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 Results of heat transfer analysis: Temperature distributions for selected times (contour plots)





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- Mechanical 3D-model consisting of hexa/brick elements of type 7 & 21 for structural analysis using MSC.Marc
- Mechanical material properties

   (i.e. Young's modulus of elasticity,
   Poisson's ratio, coefficient of thermal expansion)
- Appropriate boundary conditions taking the symmetry into account where applicable





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 Results of postprocessing: displacements under combined load "thermoshock + differential pressure" (mm)





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 Results of postprocessing: equivalent (von Mises) stresses due to "thermoshock"





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 Results of postprocessing: equivalent (von Mises) stresses due to

"differential pressure"





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 Results of postprocessing: equivalent (von Mises) stresses under combined load "thermoshock + differential pressure"





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 Results of postprocessing:
 xy-plot of the equivalent (von Mises) stress distribution
 under combined load
 "thermoshock + differential
 pressure", from the gap tip to
 the surface of the tube plate





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## Conclusions

- The investigation has shown that significant stresses can occur during a fast start-up
- The thermally induced stresses are of the same order of magnitude as those due to differential pressure
- Similar transients should be avoided by operational regulations in the future
- A simple FE model could enable to simulate and understand the phenomenon causing the material failure & cracks
- The step by step procedure applied helps to explain different aspects influencing the verification and animates to reproduce it as a case study



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