Thermal Simulation of Heated PMMA Rear Windows

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1. Introduction

1. Introduction

- Automotive: Poly(methyl metacrylate) (PMMA) as a glass substitution
  - Motivation: weight reduction, easy forming, etc.
- Additional thermal requirements for rear windows
  - Heating behavior
  - Visibility
  - Defrosting
- Simulation
  - Calculation of optimal proportion of heating lines and input power

Image: Evonik Industries AG

2. FE-Modeling and Simulation

2. FE-Modeling and Simulation

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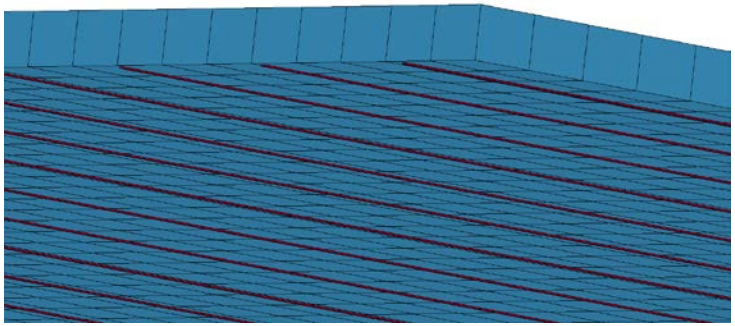
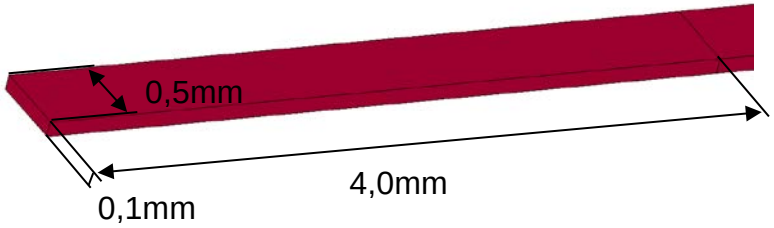
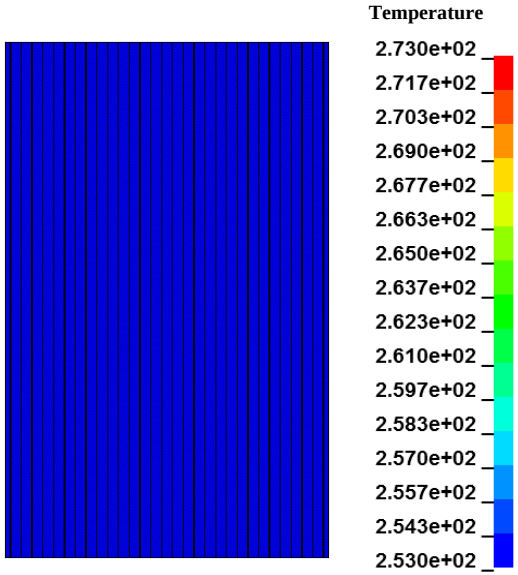
Full model (1000mm x 600mm x 4mm)



Heating line model





Boundary Conditions

- Heating modeled with ***BOUNDARY_FLUX_SET**
- Environmental temperature: -20°C/~253K
- Estimated assumption for emissivity and convective coefficient

2. FE-Modeling and Simulation

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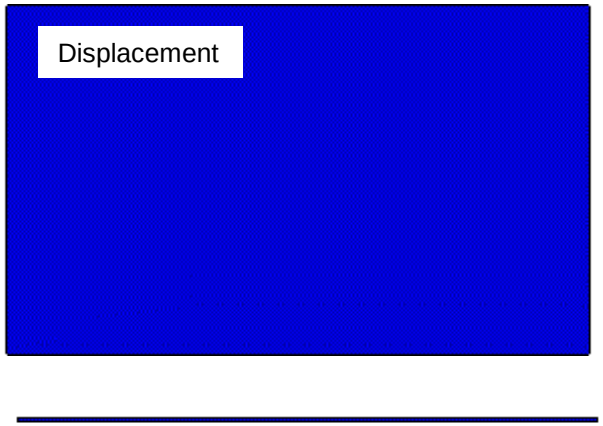
- Implicit thermal simulation (SOLN=1)
- Full Newton nonlinear solution (ILIMIT=1)
- Solid-Elements for both PMMA and heating lines
- Heat capacity and thermal conductivity for PMMA tabulated in **`*MAT_THERMAL_ISOTROPIC`**

- **`*MAT_ADD_THERMAL_EXPANSION`** was used in thermomechanical coupled analysis, but not primary in the focus; furthermore leading to excessive solution time



2. FE-Modeling and Simulation

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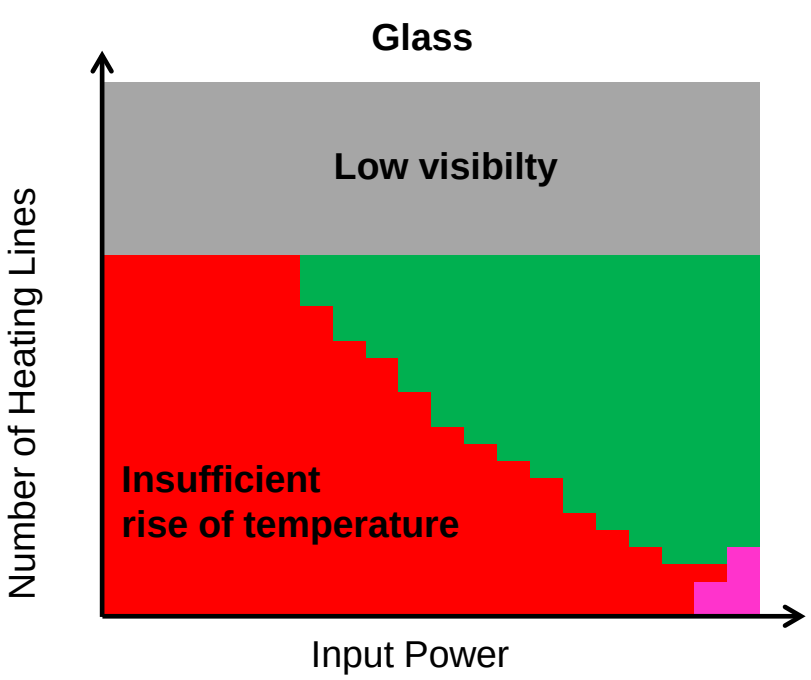
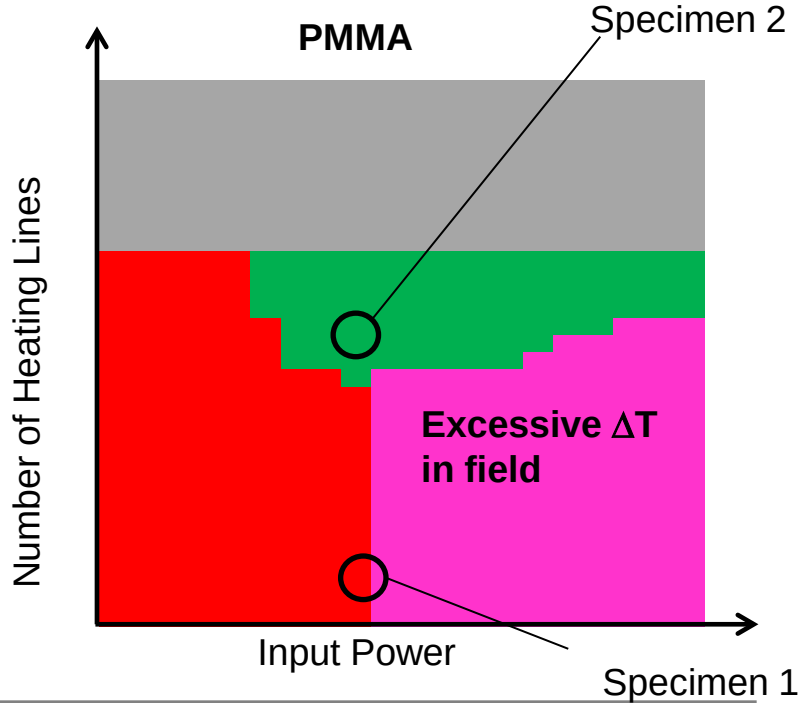
- Requirements to heated rear windows:
  - Restricted amount of heating lines due to visibilty
  - Minimum rise of temperature in whole heating field
  - Maximum temperature difference in whole heating field
- Results of simulation:

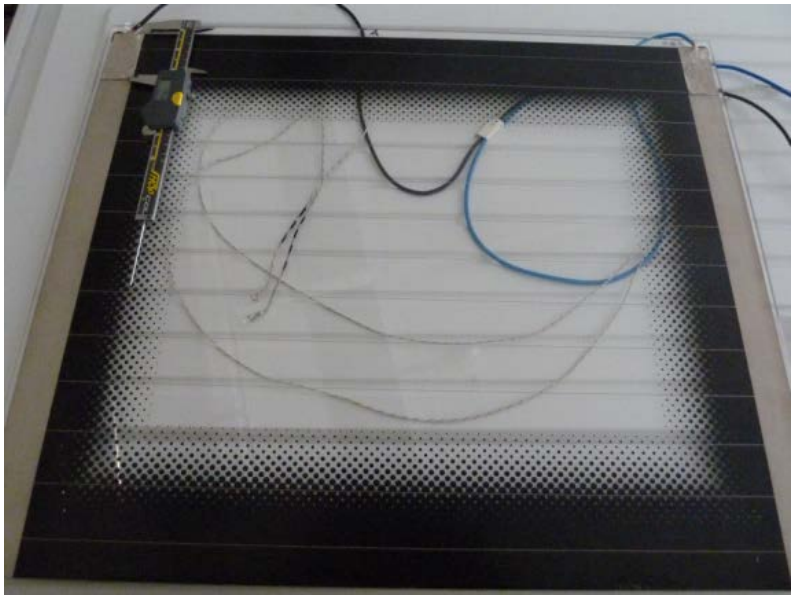




3. Experiments and Validation

3. Experiments

- Rear window made of PMMA (PLEXIGLAS)
- Input power via regulation of voltage and current
- Placed in a freezer at approximately -20°C
- Two different heating line distances were tested

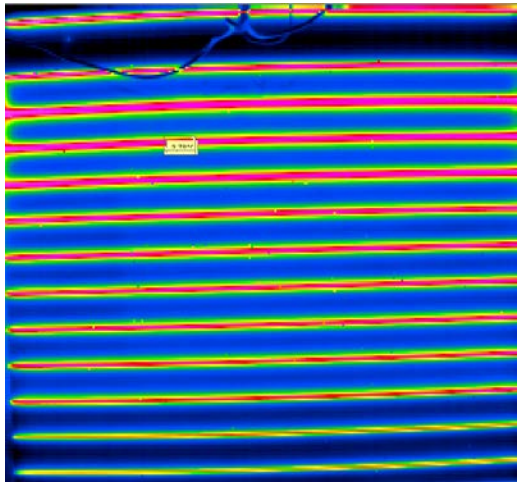


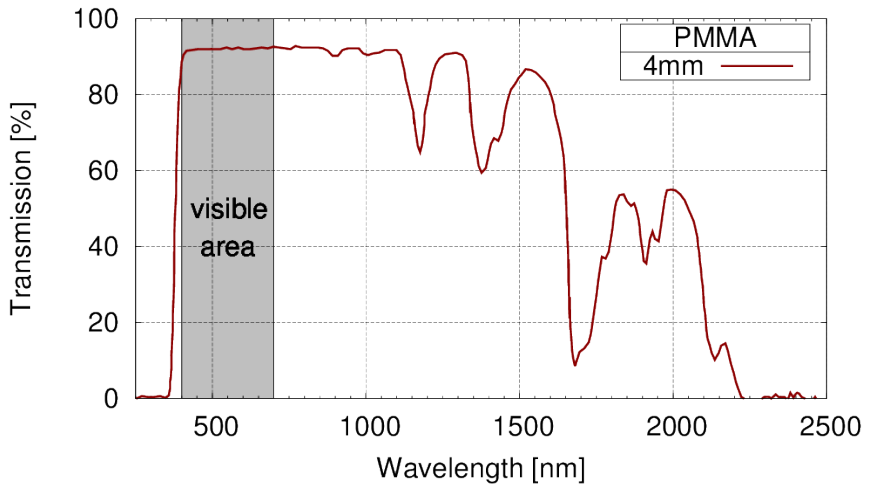
Rear window with heating lines.

Experimental Setup.

3. Experiments

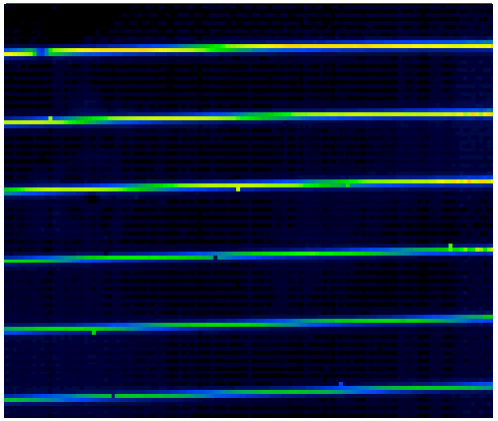
- Spectral range: 3,7 to 4,8 μm (MWIR)
- 320 x 256 IR-pixel
- Temperature range: -30°C to 300°C
- Detector type: MCT
- Accuracy: +/- 1°C or +/- 1%



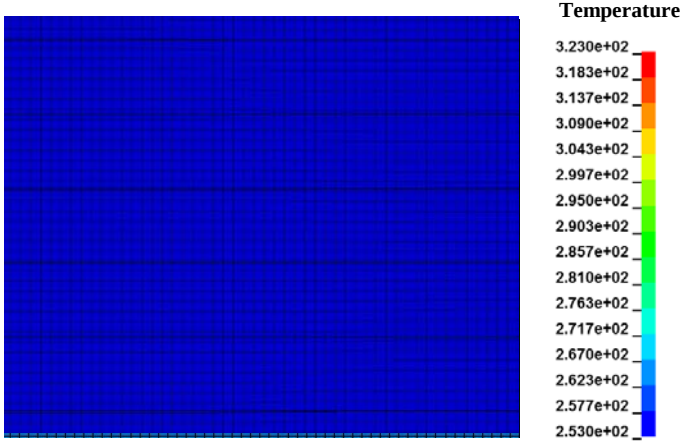


4. Experiments and Validation

photo

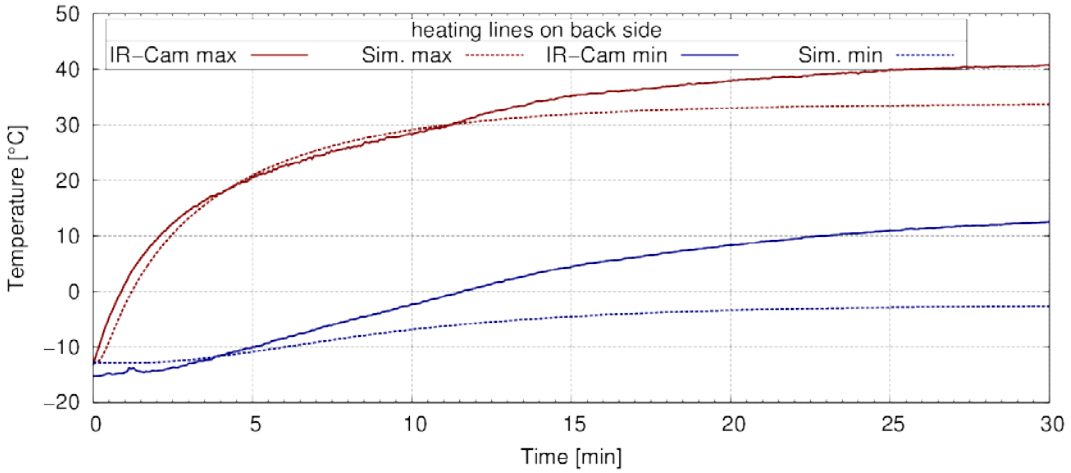


IR-picture



FE-simulation

- First model shows partially agreement with experiment
- Critical time of 10 minutes is reproduced well
- So far assumed values can now be adjusted



Validation of FE-model

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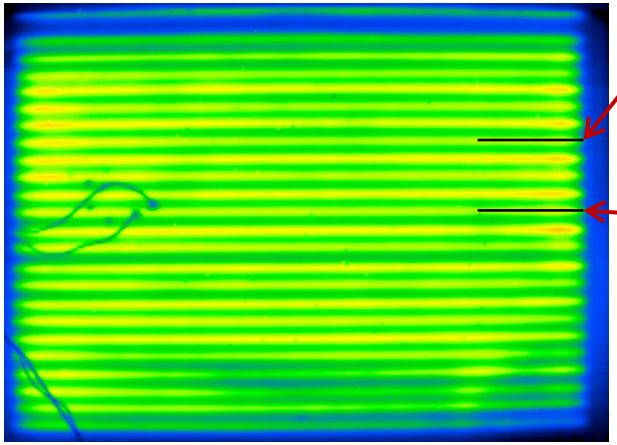
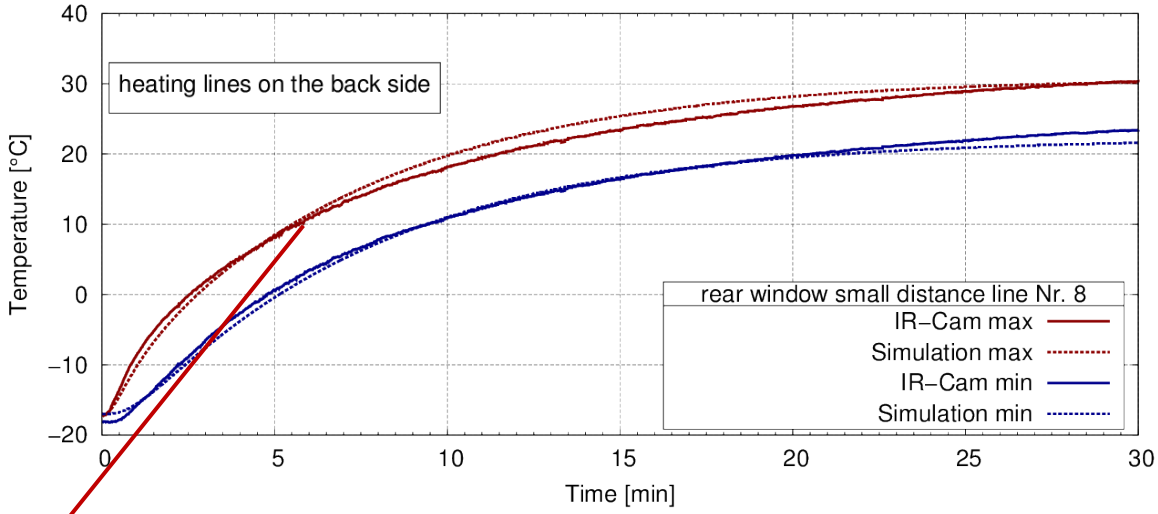
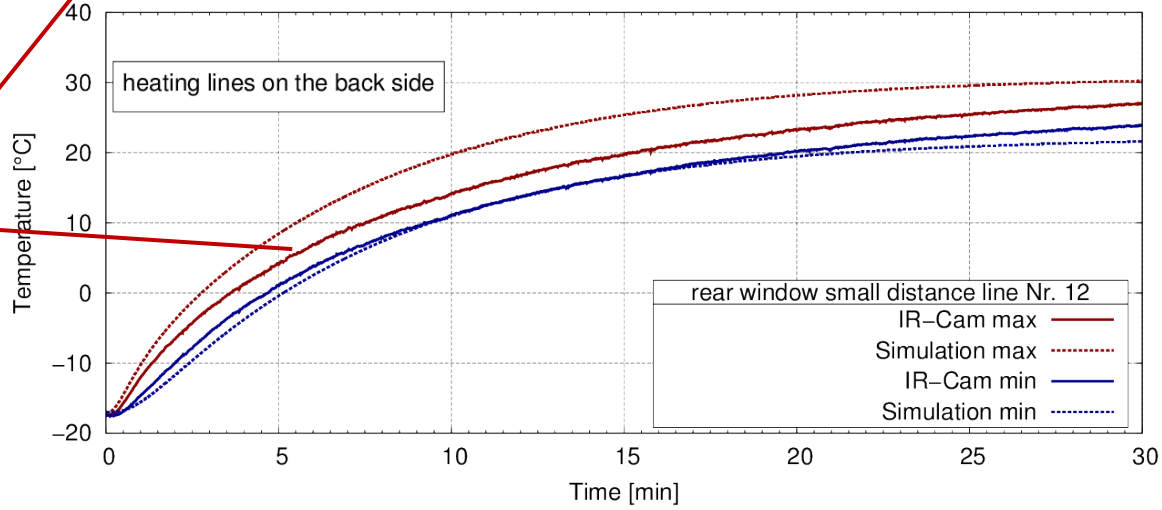
Final set of parameters leads to:

- Good reproduction of experimental results in minimum and maximum temperature
- In some areas visible discrepancies due to inhomogeneous input power distribution







5. Summary

Summary

- FE-Simulations of a heated rear window consisiting of PMMA were conducted without prior knowledge of test results.

- Later conducted experiments showed good approximation of the simulation, especially at critical time.

- Validation and adjustment of parameters through experiments lead to a well predicting model in terms of temperature distribution and quantitative predictions of hot- and cold-spots.

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Thank you for your attention!

We thank Evonik Industries AG for their support.

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