Numerical 3D-FEM-Simulation made by COMSOL Multiphysics of a Microwave Assisted Cleaning System for a Diesel Sooty Particle Filter and its Experimental Validation

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Content

Concept for the DPF-System

Methods of Regeneration

- **Active System**

- **Regeneration by Heating the Soot to the Ignition Temperature by Microwave Radiation**

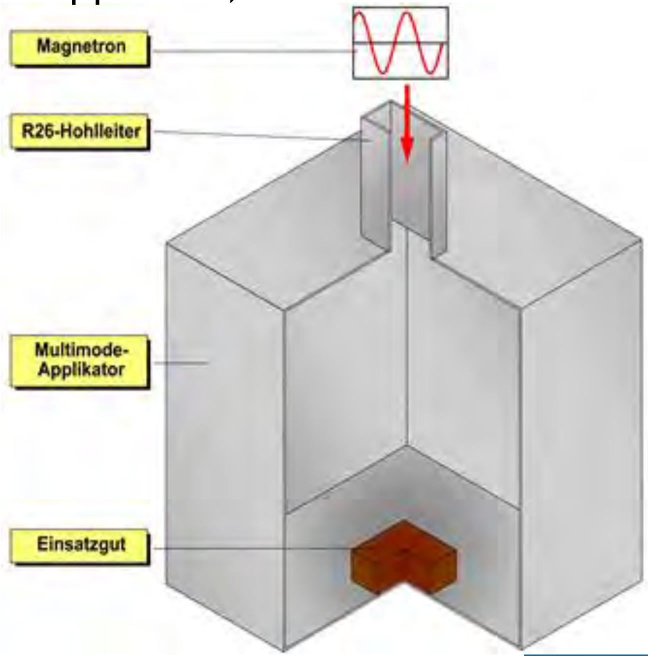
- **Engine Management System**

- **Specifications for Vehicle Construction**

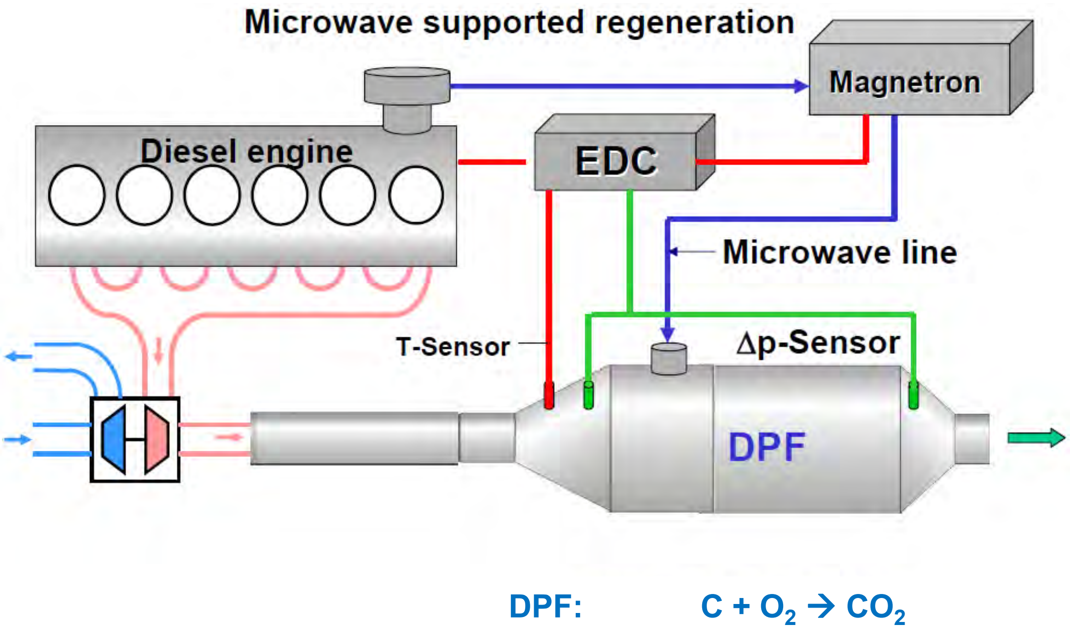
Concept for the DPF-System

Relevant parameters for an ideal design of the plant to the heated goods

1. Energy Source: Generator (e.g. Magnetron) characterized by Frequency and Output
2. Microwave Transfer Element (Geometric Design of the Wave Guide)
3. Microwave Applicator (Geometric Design of the MW-Applicator)
4. Measurement and Control Devices:
   Output and Temperature Measurement
5. Further:
   - Geometry of the Raw Material
   - Material Properties of the Raw Material
   - Material Properties of the Applicator Walls



Concept for the DPF-System



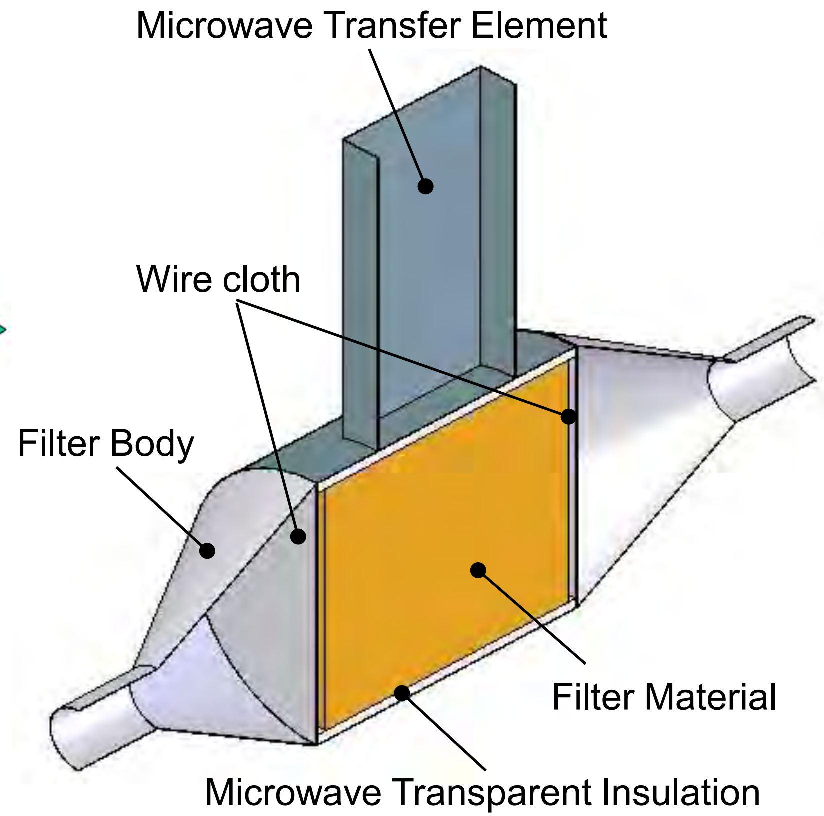
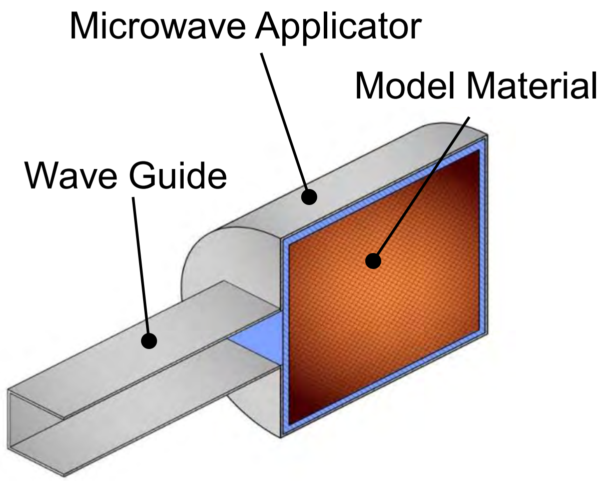


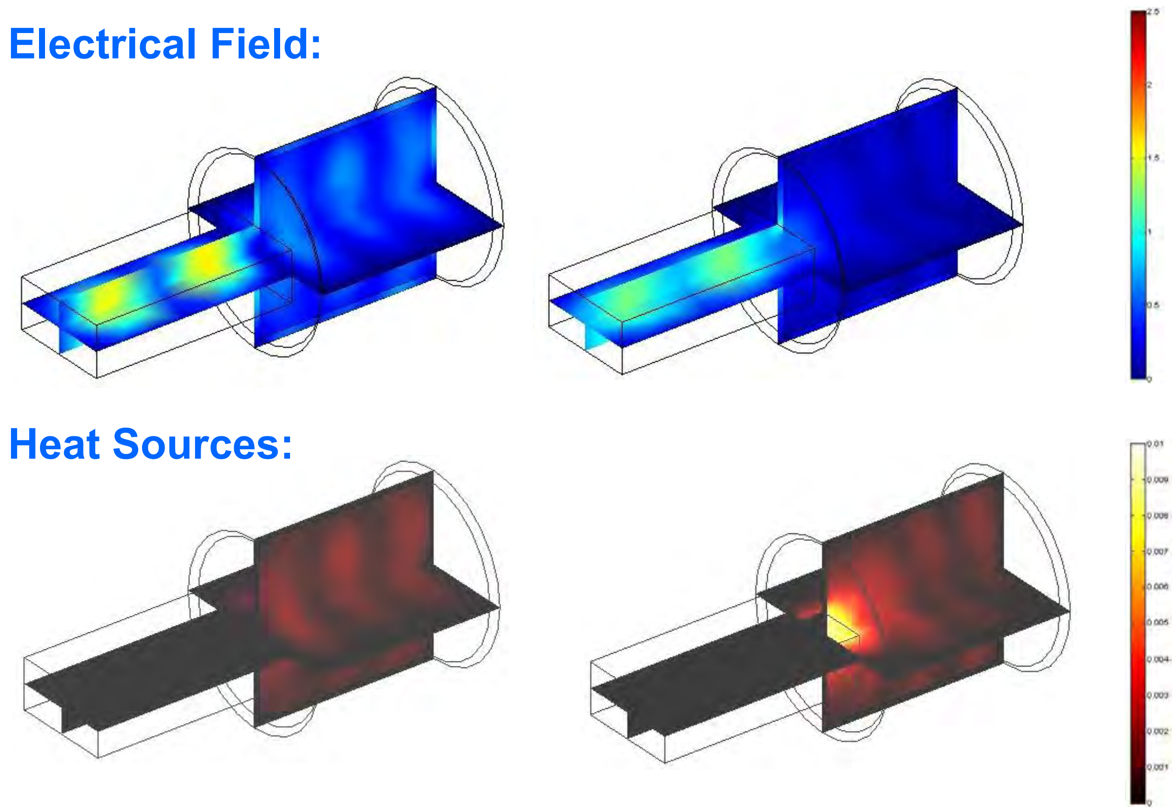
Figure 1: Design of a microwave assisted DPF Cleaning System

Numerical Simulation: Results

Example: Multimode Applicator with an Axial Microwave Discharge



Cross section of an axial arrangement



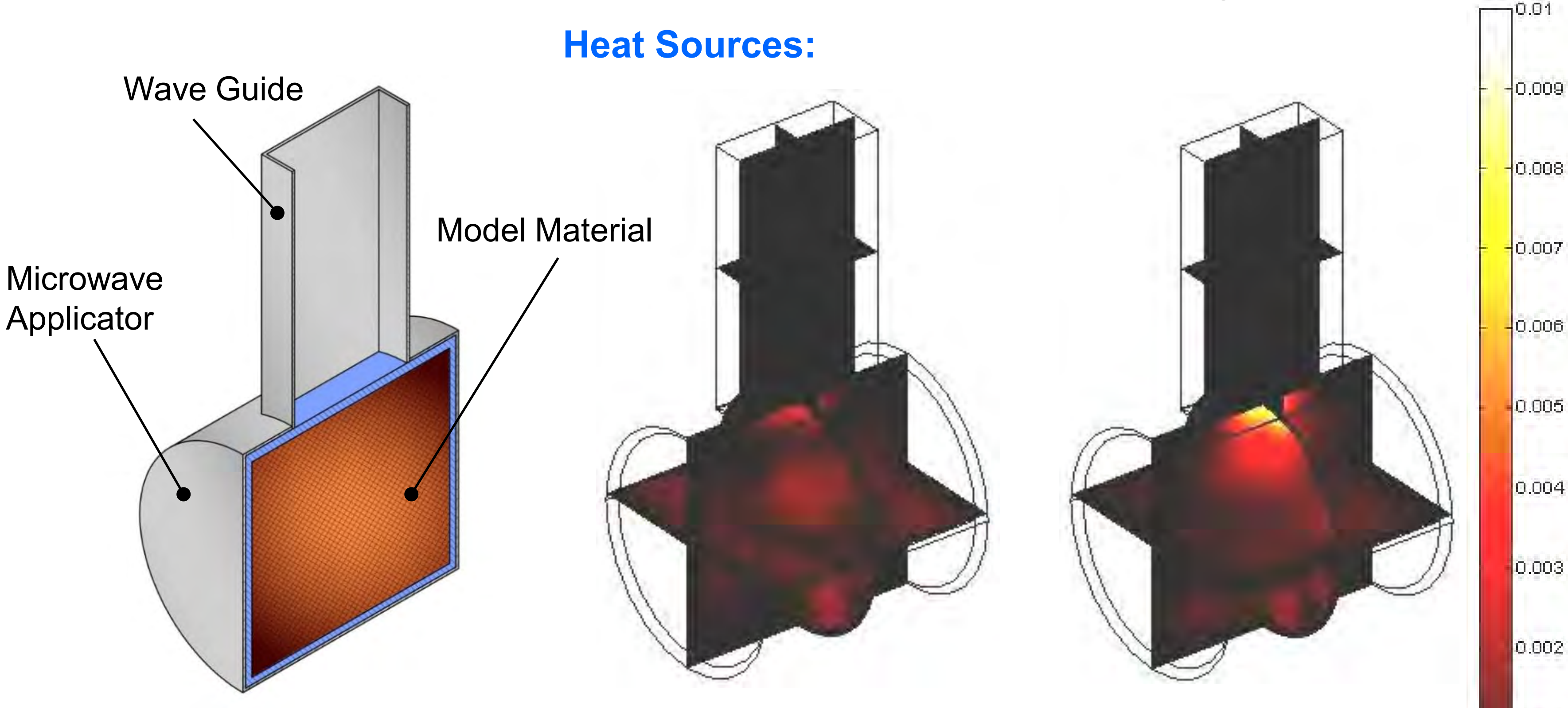
Low absorbing material

High absorbing material

Figure 2: ***Numerical 3D-Simulation: E-Field and Heat Source Density Distribution***

Numerical Simulation: Results

Example: Multimode Applicator with a Radial Microwave Discharge



Cross section of a radial arrangement

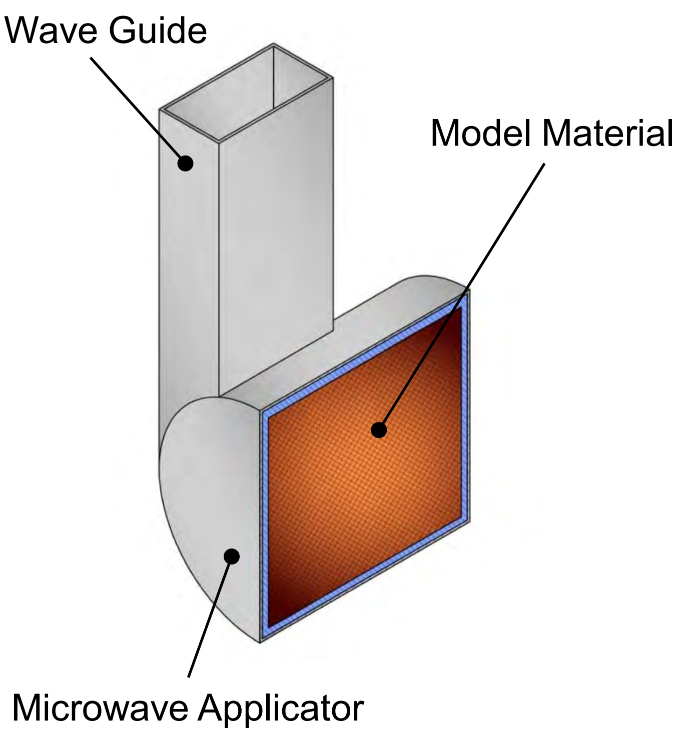
Low absorbing material

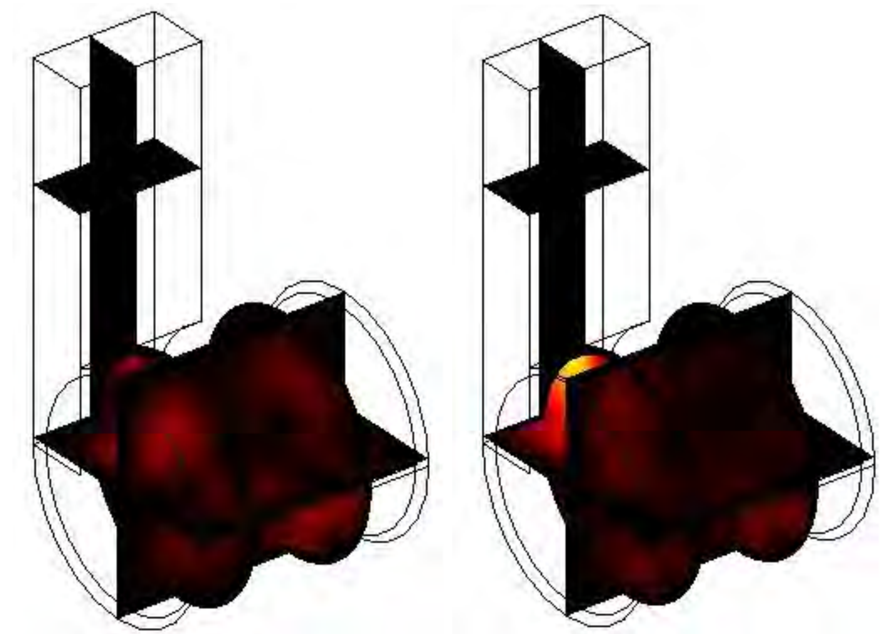
High absorbing material

Figure 3: ***Numerical 3D-Simulation: Heat Source Density Distribution***

Numerical Simulation: Results

Example: Multimode Applicator with a Tangential Microwave Discharge





Cross section of a tangential arrangement

Low absorbing material

High absorbing material

Figure 4: ***Numerical 3D-Simulation: Heat Source Density Distribution***

Numerical Simulation: Results

The simulation leads to a couple of possibilities:

- Simulation of different heating mechanism according to the geometry and general conditions of the plant
- Comparison with experimental pre-heating trials
- Optimized plant design according to the good to be heated
- Reduction in production time
  - Reduction in heating-up, processing and cooling time
  - Only heating of the good (no heating of the air volume and walls of the reactor)

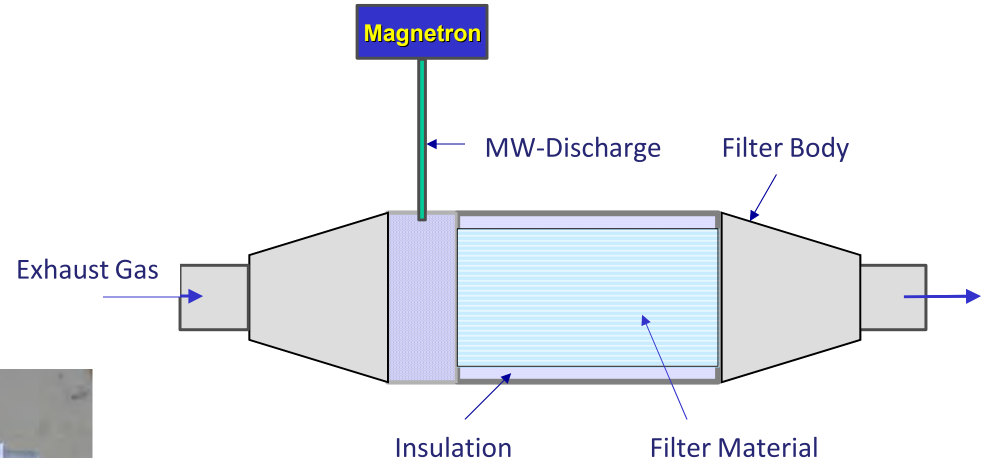
A mathematical optimization of the design of a microwave assisted diesel sooty particle filter cleaning system is possible, but an experimental validation is indispensable.

Experimental Validation: Experimental Station

Cylindrical Multimode-Applicator
with tangential Microwave Discharge

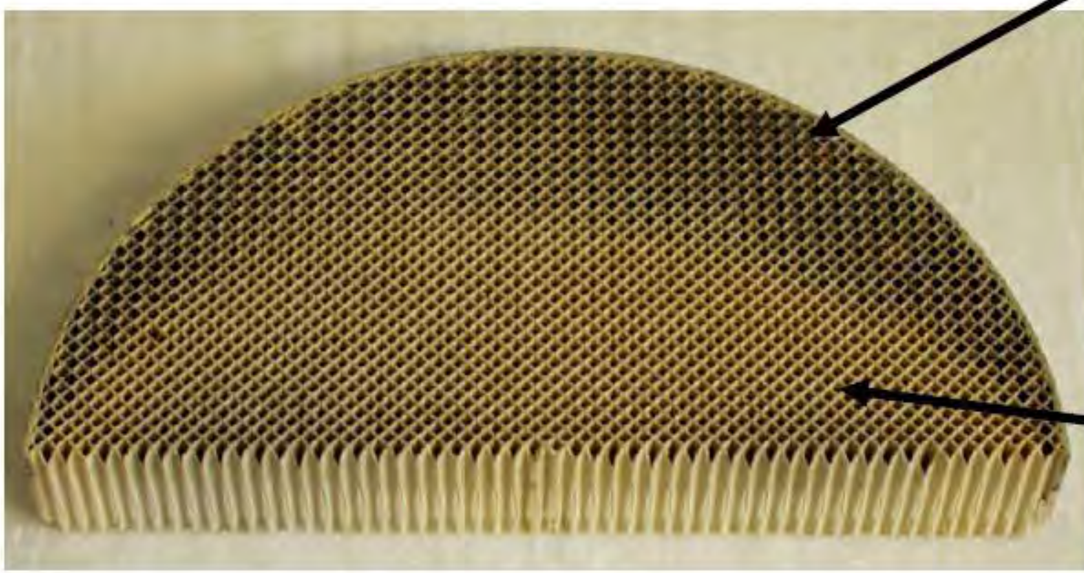
Experimental Station, Back Side

Measuring Zone

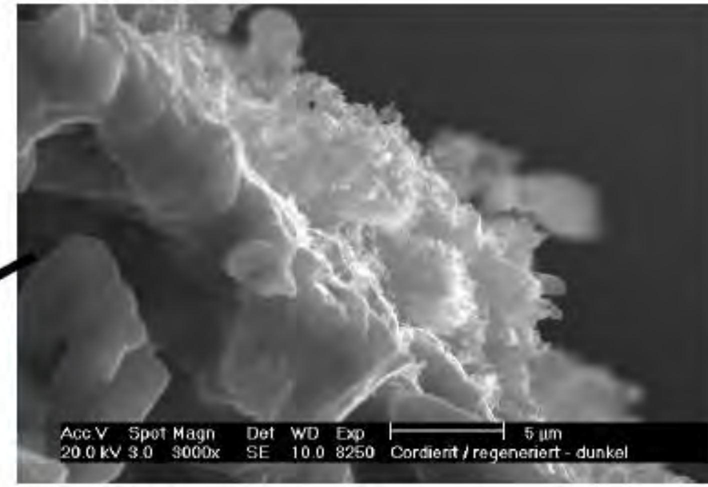


Parameter	*Multimode-Applicator*	*Cordierite-DPF*
Length, mm	**168**	**152,4**
Diameter, mm	**161**	**143,76**
Wall thickness, mm	**3**	**0,1**
Volume, l	**3,42**	**2,5**
Filling factor	**0,73**	

Experimental Validation: Results



Partielly Regenerated Cordierite-honeycomb filter



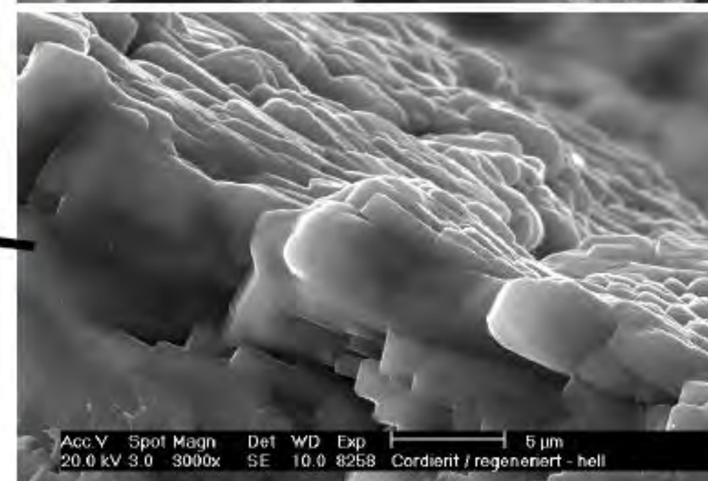
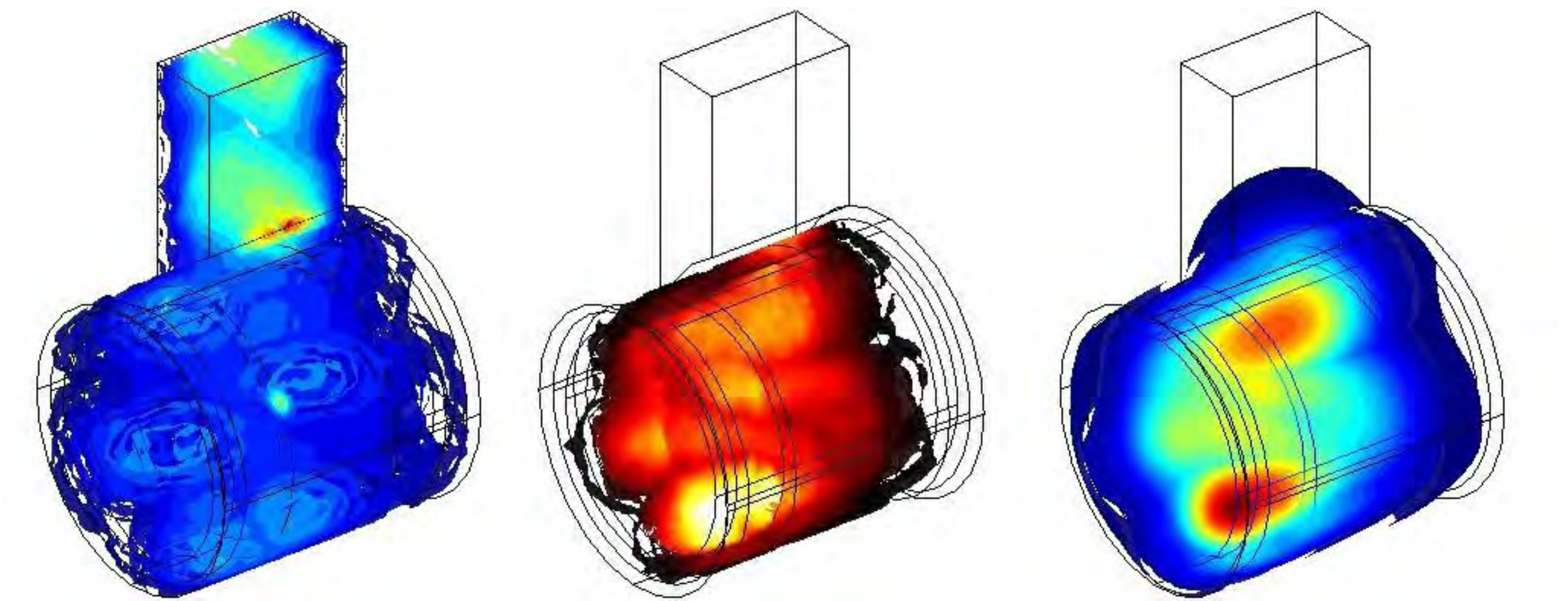


Figure 5: ***Regeneration of the loaded filter by microwave radiation***

Experimental Validation: Results



E-Field Strength Distribution

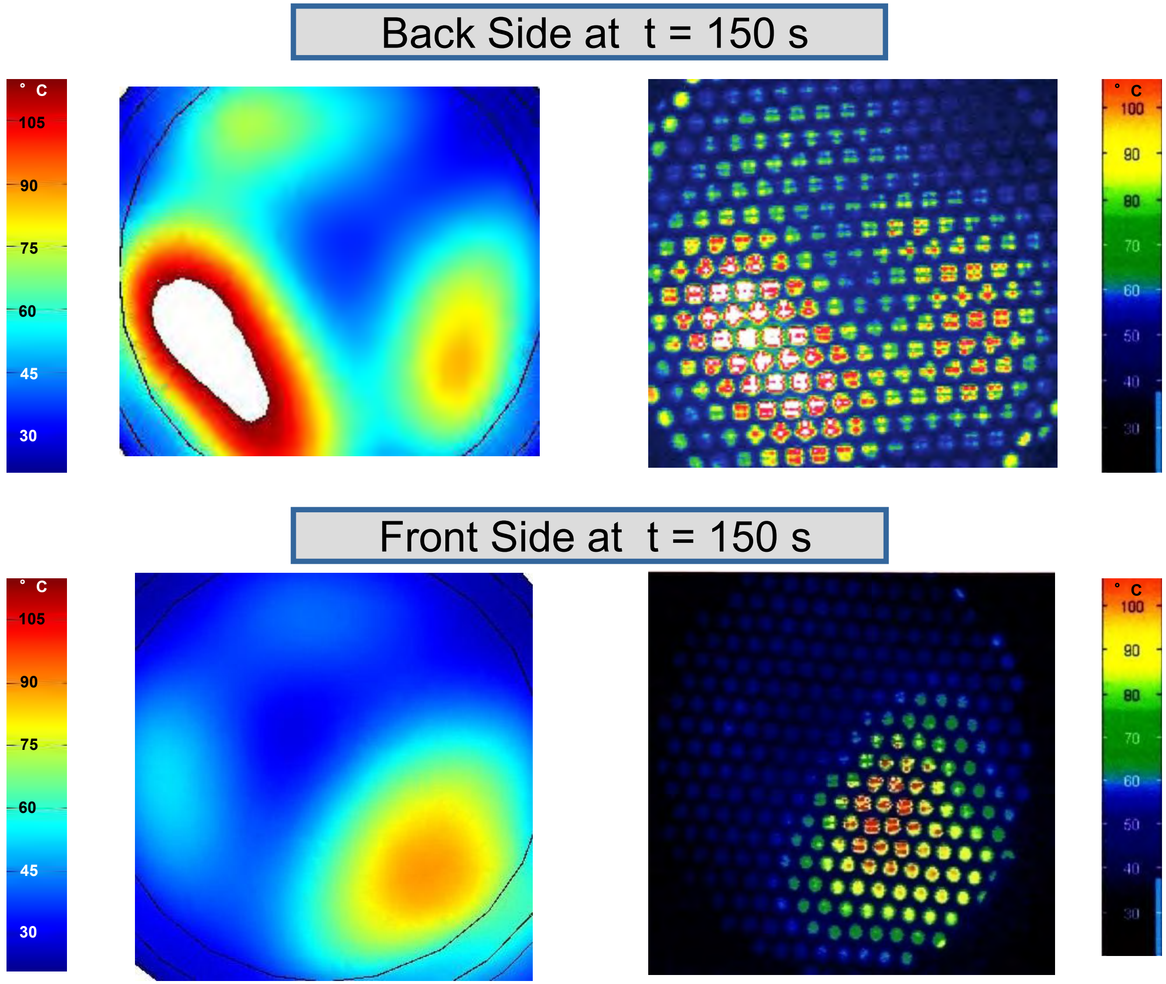
Heat Source Distrbution

Temperature Distribution at t = 200 s

Figure 6: ***Numerical 3D-Simulation: E-Field Strength, Heat Source Density- and Temperature Distribution***

Numerical 3D-Simulation of the Temperature Distribution

Infrared Camera – Temperature Measurement



Parameter	*Model*	*Experiment*
P_{in}, W	572	572
P_{abs}, W	532	545
P_{ref}, W	40	27
$P_{abs\ Wall}$, W	0,02	-
η, %	93	95,3
R_0	0,26	0,22
VSWR	1,72	1,56
T_0, °C	20	20
T_{max}, °C	165,6	~170

Figure 7: ***Results of the experimental validation [Reference: Imenokhoyev, 2007]***

Conclusion

1 The numerically and experimentally determined temperature field distributions match excellent in quality and quantity.

2 The 3D-FEM-models created with COMSOL Multiphysics provide practice-orientated results.

3 They can be used for a computer-assisted modeling and optimization of microwave heating.

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