Modeling Lightweight Charging Systems in the High Temperature Application

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INTRODUCTION: The advantages of carbon based materials in high temperature applications are their high-temperature stability, light weight, chemical resistance combined with good thermally and electrically conducting properties. In such applications, typically materials like graphite and carbon fiber reinforced carbon (CFRC) are used. One of the high temperature applications is in charging systems used in the heat treatment of the metals, or in the powder metallurgy in the process of sintering.

	Standard graphite system	Carbon composite system (CFRC)
Number of shelves	19	25
Mass of charging system, kg	23.25	6.4
mass of loading (steel rings), kg	76.4	100.5

Table 1. Configuration of the standard graphite (HLM grade) and CFRC charging systems

COMPUTATIONAL METHODS: For the simulation purpose, two different charging systems namely standard graphite (HLM type) and CFRC are used. The configuration of both systems is given in Tab. 1.

The Heat Transfer Module COMSOL Multiphysics® is used for the calculation of the temperature homogeneity using heating cycle [1] given in fig. 1a, whereas the structural analysis and optimization of the rack thickness is done with Nonlinear Structural Mechanics Module.

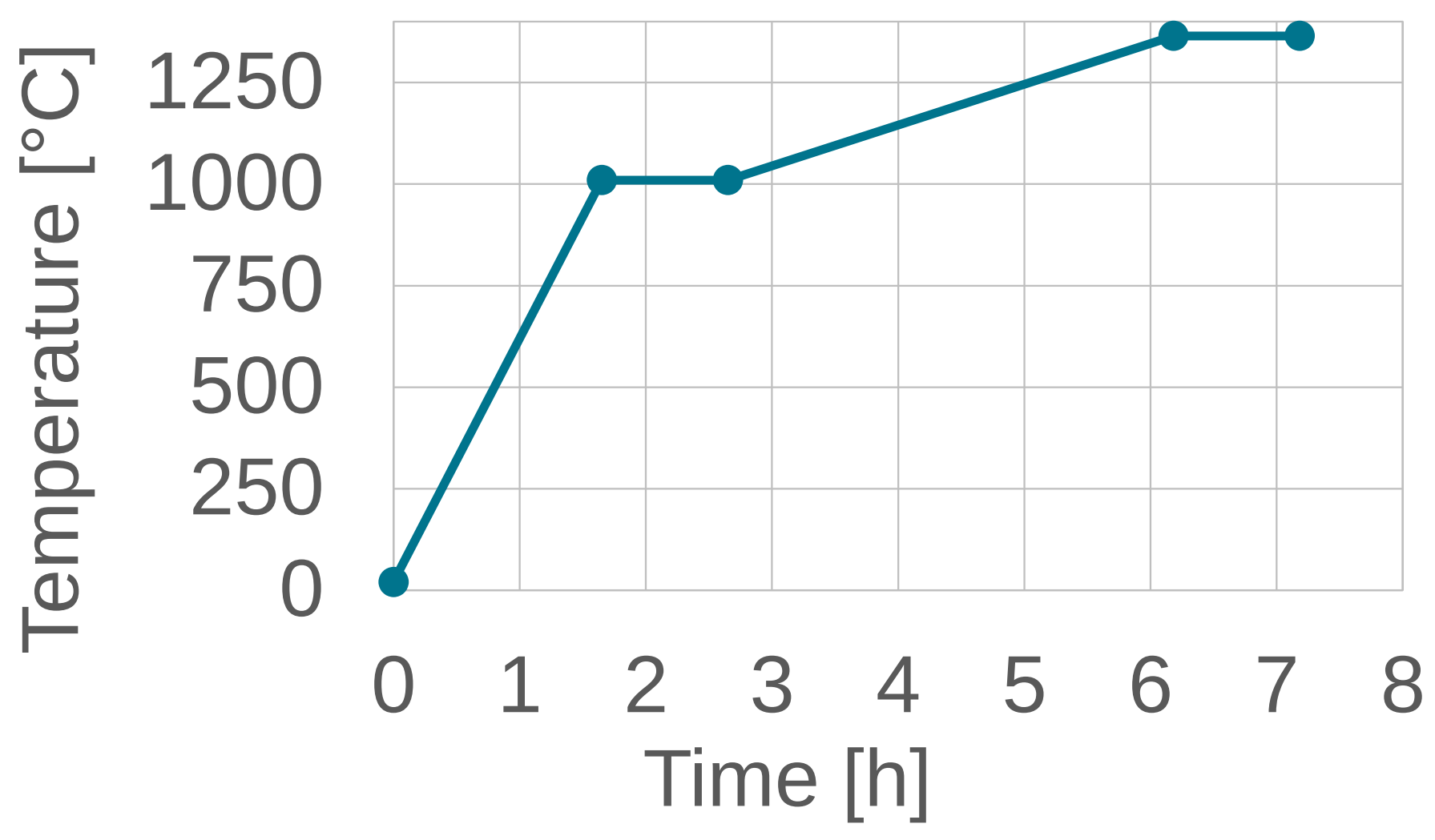


Figure 1a. Sintering temperature of stainless steel

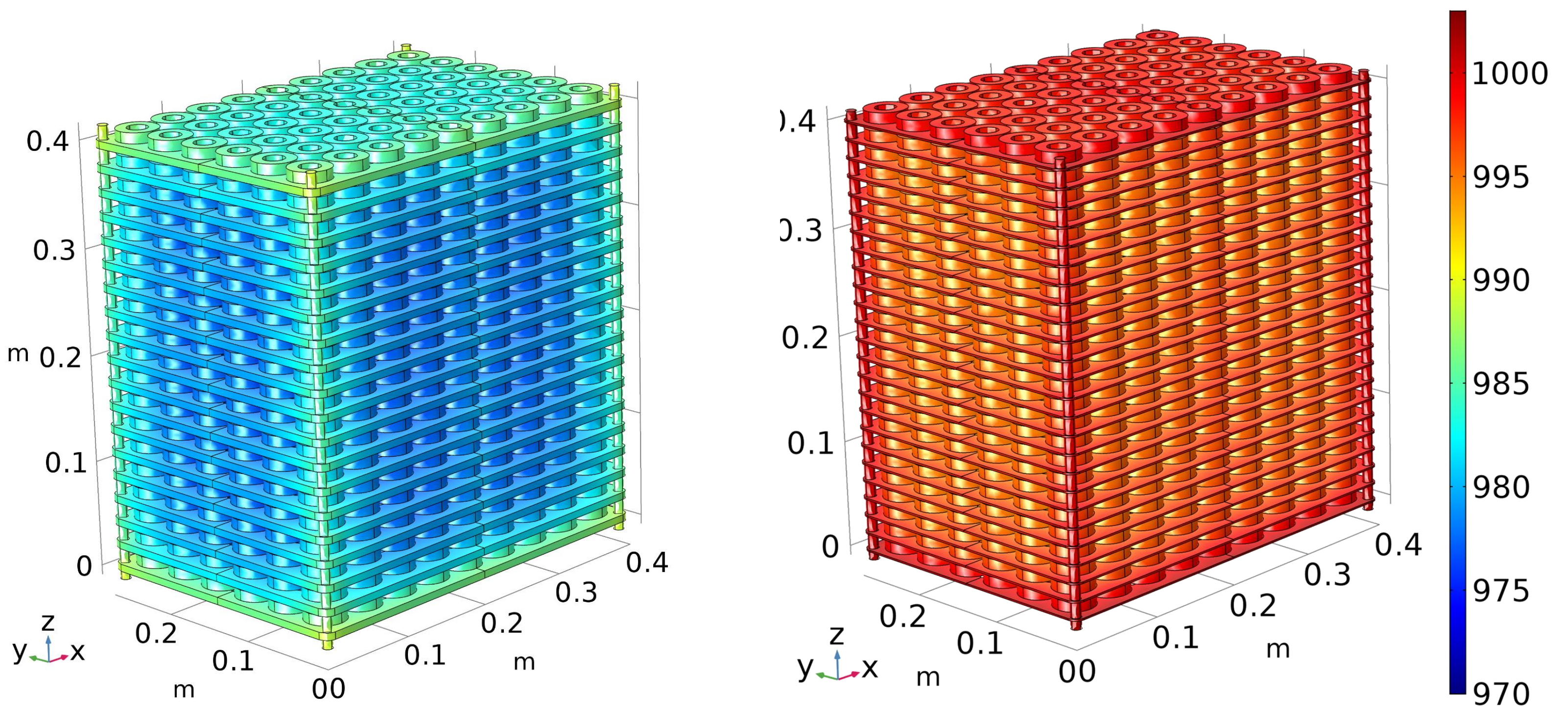
$$\frac{\partial \varepsilon_{cr}}{\partial t} = A\left(\frac{\sigma_{eff}}{\sigma_{ref}}\right)^{n} e^{\frac{-Q}{RT}} \boldsymbol{n}^{D}$$

$$\boldsymbol{n}^{D} = \frac{3}{2}\frac{dev(\sigma)}{\sigma_{ref}}$$

Figure 1b. Norton creep law implementation in Comsol Multiphysics®

The calculated domain represents a quarter of the total system with symmetry boundary conditions. For creep modeling, only a single rack is used. The creep has been simulated using Norton model (fig. 1b). Due to the high activation energy of 720-1130 kJ/mol [2] only a ramp at the maximum temperature, 1365 °C has been considered.

RESULTS: In fig. 2, temperature distribution in the charging system after 100 min is shown. Both systems show relatively small temperature inhomogeneity, though CFRC with its larger radiative surface at comparably similar mass, shows smaller time lag in following the furnace temperature change.



(a) Standard graphite (b) CFRC

Figure 2. Temperature in °C distribution after 100 minutes.

The elastic deformation under the equal load (fig. 3a) shows slightly lower values for the 1.7 mm thick CFRC compared to 7 mm thick std. graphite. Thus the number of racks can be significantly increased from 19 for the standard graphite to 25 racks for the CFRC. As expected, no creep could be observed at 1365 °C in any system. Actually for times below 1000 h, at max temperature, the creep in graphite could only be observed beyond 1700 °C (fig. 3b).

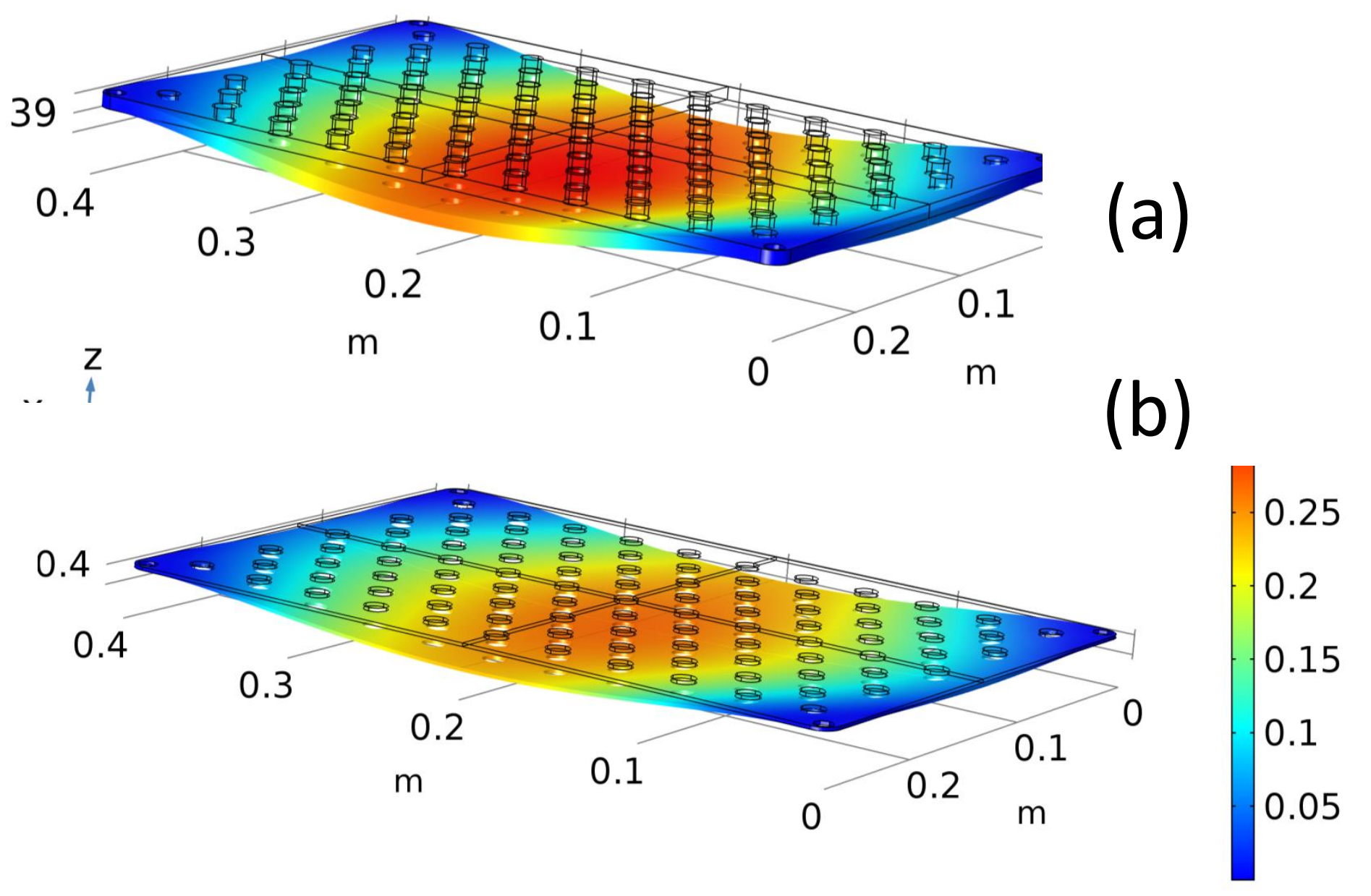


Figure 3a. Elastic deformation of std. graphite (a) and CFRC (b)

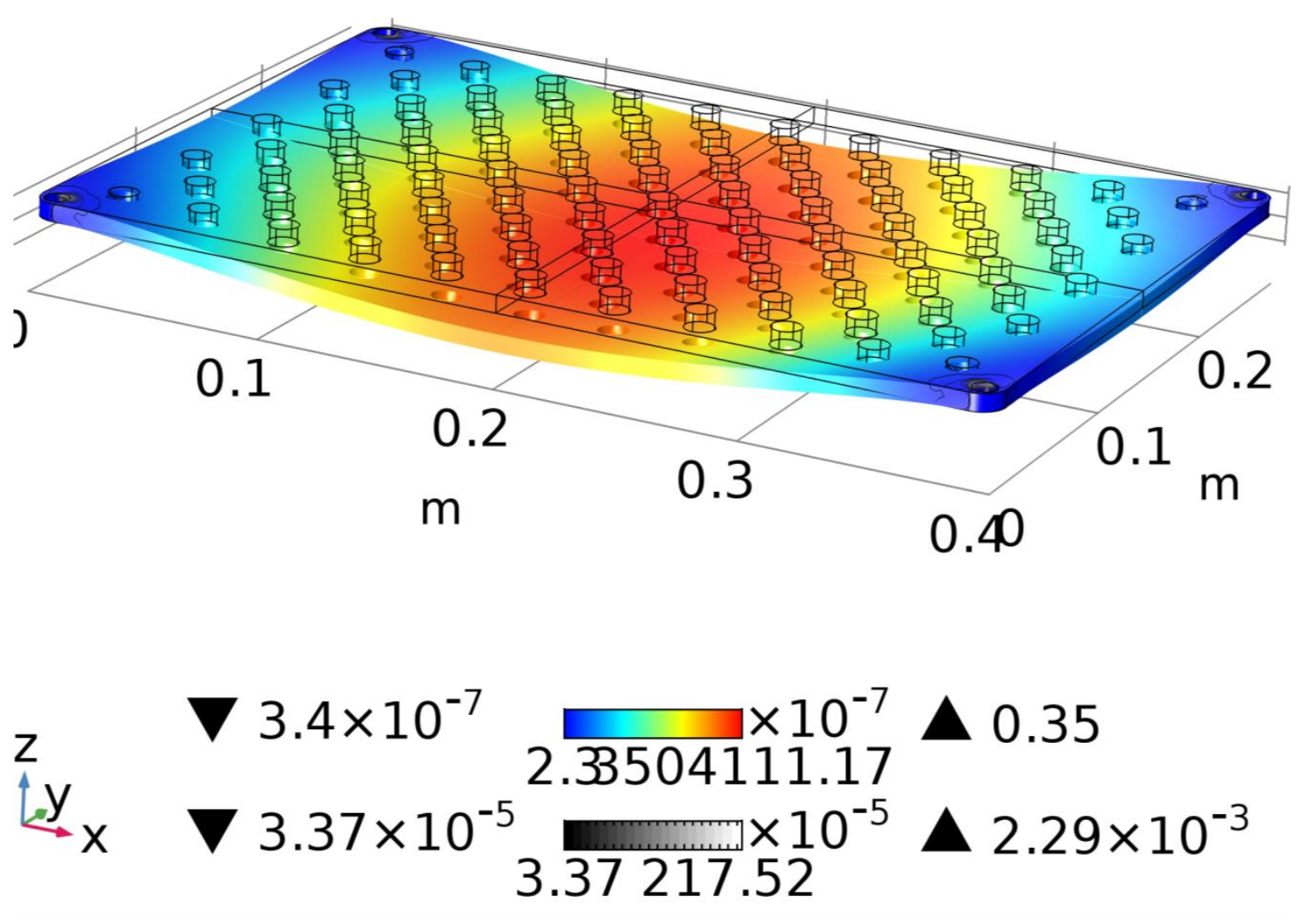


Figure 3b. Total deformation and eff. creep strain in graphite after 1000 h at 1700 °C

CONCLUSIONS: CFRC rings can improve the productivity in the process of steel sintering more than 30 %, due to their high strength. The temperature homogeneity is comparable or slightly better to the case with the graphite racks.

The thickness of the CFRC racks could be optimized using COMSOL Multiphysics®. The creep was predicted using the Norton creep model and it does not show a significant influence at the operating temperatures.

REFERENCES:

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