Heat flow tuning during a material densification process with variable electromagnetic properties

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In this work we are interested in the power-regulation of an induction heating system with strongly variable electromagnetic properties during time. We want to maintain the induced heat flux constant and consider the whole system charge+inductor+power supply from an experimenter's point of view. The system is represented in figure 1: An inductor and the initially porous charge are placed in a system filled with gas. Then the charge is heated up in volume (penetration depth is of the charge's size). When a certain temperature is reached, the gas cracks and deposes inside the porous medium. The so densified zone has a much lower resistivity than the porous medium and catches from now on most of the induced current. During time, inductance and resistivity of the charge seen by the induction system vary with ongoing densification. Those changes lead to an evolution of the resonance frequency as shown in figure 2 for different assumed variations of resistance and inductance. We can see that many cases are possible: A linear increase, a linear decrease or evolutions with maximum points in time. So, the electromagnetic coupling and the relation between the imposed power supply and induced power and heat flux also vary in time. For acceptable results, the heat flux inside the preform has to be maintained at a certain level during the whole process. This means that the experimenter has to adapt the power supply on the corresponding interface continuously. The aim of this work is to give a rule of "regulated power during time" for each of the scenarios presented in figure 2 such that the induced heat flux stays inside a certain fixed range. We will present i) Simulations with Comsol to obtain the relation "current in the inductor" versus "induced power" and "inductance and resistance of the induction system" for different densification states, ii) semi-analytic calculations of the heat equation to relate the "induced power" to the "heat flux", iii) analytical calculations to obtain the power which has to be regulated on the supply to have the desired current inside the inductive system for its different values of resistance and inductance and iv) measurements on the system with a Rogowski coil and validation of the model.

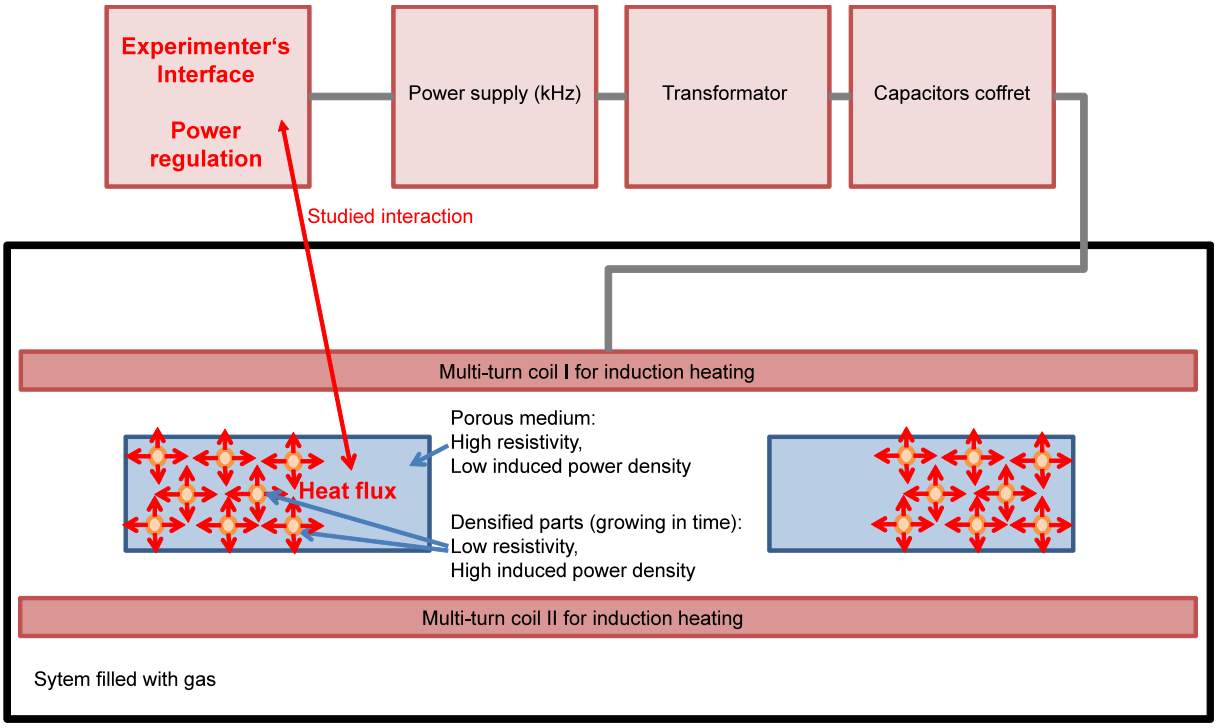

Fig 1: Geometry: Initially porous preform is heated up by induction. The gaseos precursor inside the disc cracks, the disc densifies and changes electromagnetic properties with time. The regulation of the generator has to be adapted to obtain a constant heat flow.

Fig 2: Resonance frequency [Hz] for different variations of resistance *R* and inductance *L* during normalized densification time *x*