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Heat Generation in MRE under dynamic loading.

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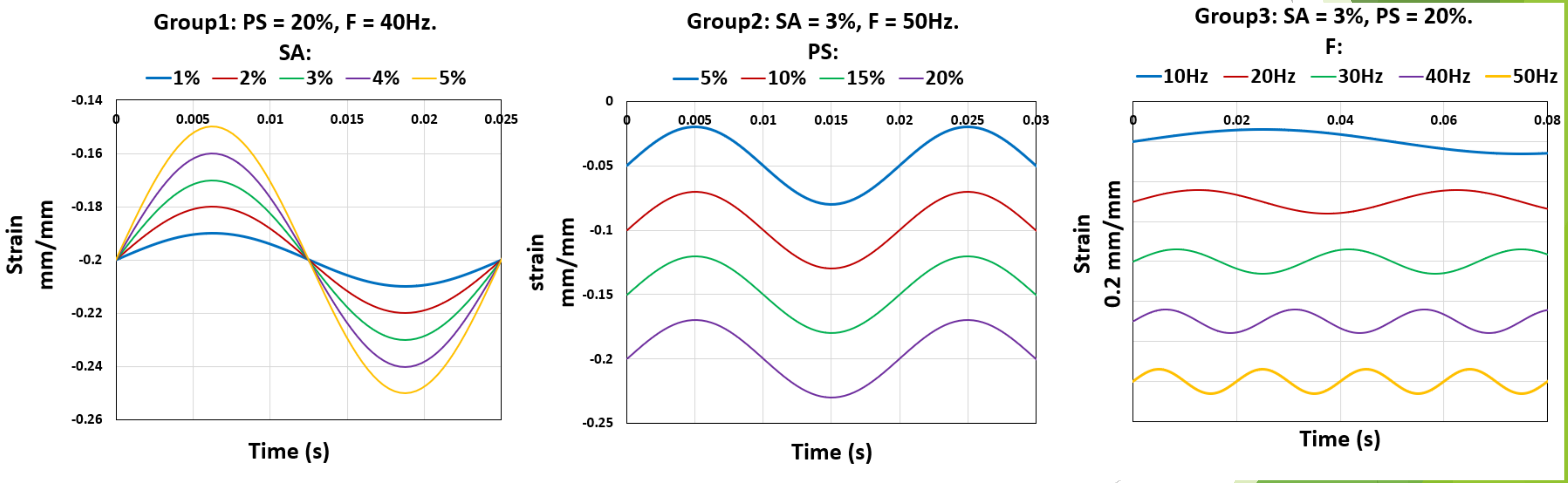
Experimental part: Dynamic Load.

- Dynamic tests were performed at different strain amplitudes (SA), pre-strains (PS) and frequencies (F) according to the shown groups for two hours.



Experimental part: Results.

- ***Dissipated energy*** is measured from stress strain hysteresis loops (J/m^3).

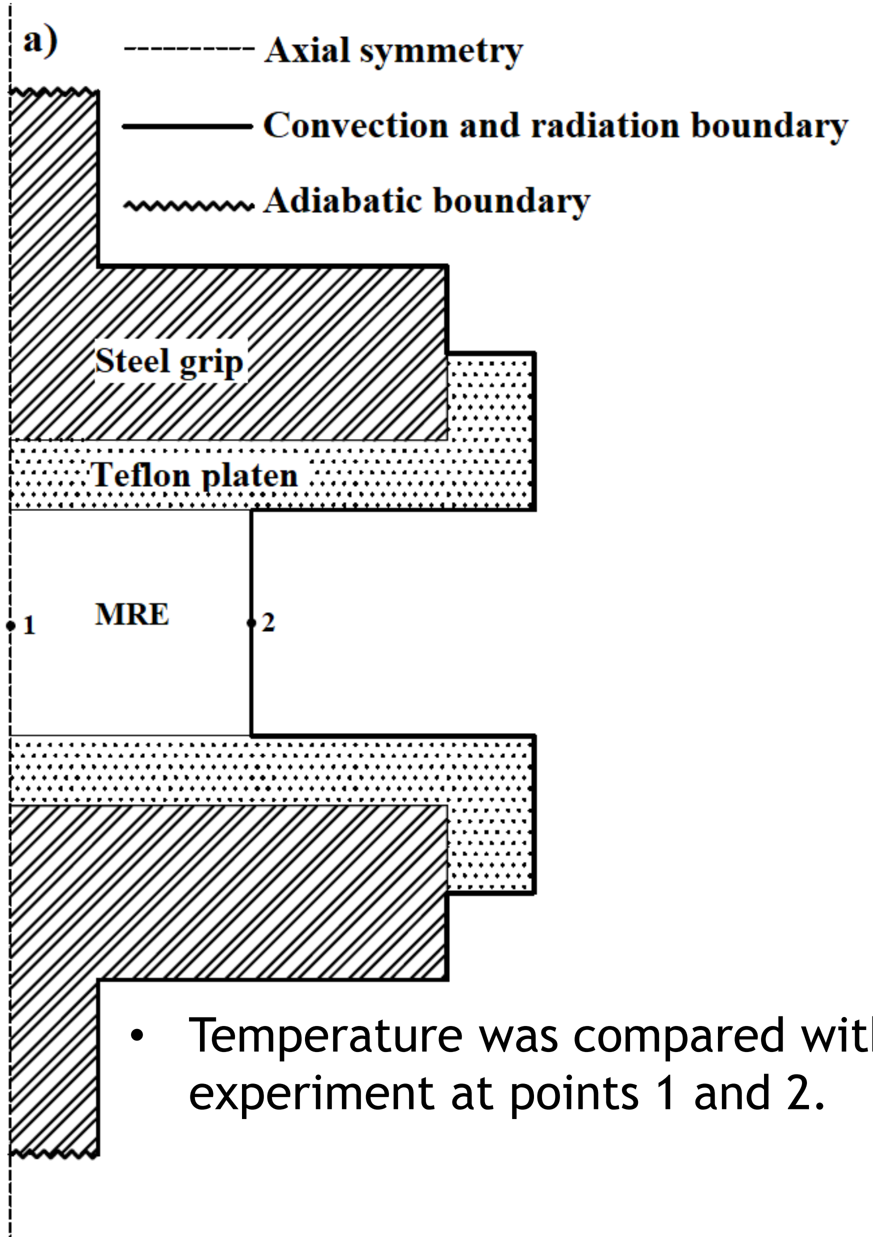
$$Q_{diss} = \int_{0}^{t1} \sigma(t)\dot{\varepsilon}(t)dt$$

- ***Sample Surface Temperature*** was measured by using of infrared Camera.
- ***Sample Internal Temperature*** was measured by thermocouple.
- ***Conversion ratios*** were calculated by using the measured temperature field, at each testing case. According to the following equation:

$$\eta\dot{q}_{diss} = \frac{\rho C_p V \Delta T}{t} + 2\frac{T_s - T_\infty}{R_t} + A\left(h_a(T_s - T_\infty) + \delta\gamma\left({T_s}^4 - {T_\infty}^4\right)\right)$$

Where, η is the conversion ratio and represents the part of dissipated power which transferred to heat. And $\dot{q}_{diss}$ is the total dissipated power in (W).

Simulation: Geometry, Boundary Conditions and parameters.

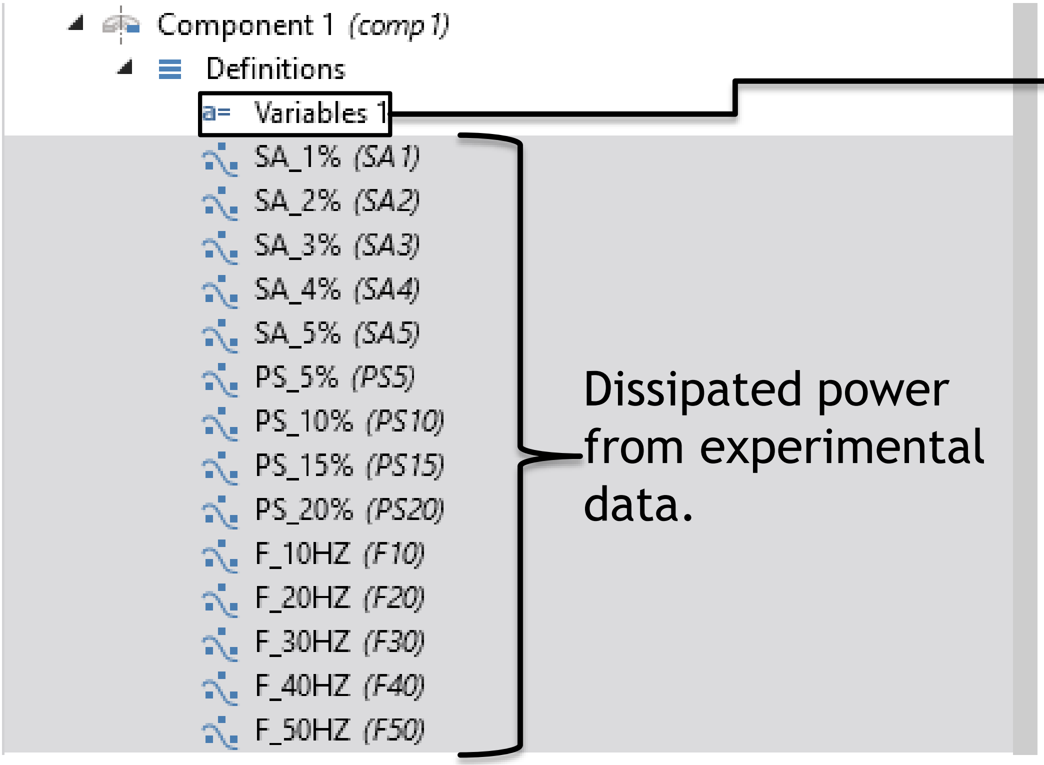


- Temperature was compared with experiment at points 1 and 2.

Material properties:

material	Emissivit (δ)	Conductivity (κ) $\left(\frac{W}{m.K}\right)$	Specific heat (C_p) $\left(\frac{J}{kg.K}\right)$
MRE	0.95	0.775	585
steel	0.22 [1]	22 [2]	475 [2]
Teflon	0.85 [1]	0.24 [2]	1050 [2]

Simulation: variables and functions.



Dissipated power from experimental data.

Variables

Name	Expression	Unit
h_cylinder1	if(T>T_inf,(0.025/0.01295)*(0.825+17.04*(0.0138^3*(T-T_inf)/T_inf)^(1/6))^(2),1) [W/(m^(2)*K)]	W/(m²·K)
h_cylinder2	if(T>T_inf,(0.025/0.048)*(0.825+17.04*(0.048^3*(T-T_inf)/T_inf)^(1/6))^(2),1) [W/(m^(2)*K)]	W/(m²·K)
h_lower1	if(T>T_inf,1.5*((T-T_inf)/((0.0146)^(2)*T_inf))^(1/5),1) [W/(m^(2)*K)]	W/(m²·K)
h_lower2	if(T>T_inf,1.5*((T-T_inf)/((0.0117)^(2)*T_inf))^(1/5),1) [W/(m^(2)*K)]	W/(m²·K)
h_upper1	if(T>T_inf,5.15*((T-T_inf)/(0.0146*T_inf))^(1/4),1) [W/(m^(2)*K)]	W/(m²·K)
h_upper2	if(T>T_inf,5.15*((T-T_inf)/(0.01173*T_inf))^(1/4),1) [W/(m^(2)*K)]	W/(m²·K)
Q_int	eta*SA1(t)*(0.91==eta)+eta*SA2(t)*(0.84==eta)+eta*SA3(t)*(0.82==eta)+eta*SA3(t)*(0.82==et...	

Convection coefficients were written according to the following equations [1]:

$$h_{cyl} = \frac{0.025}{0.01295}\left[0.825 + 17.04\left(L^3\frac{(T_s - T_\infty)}{T_\infty}\right)^{1/6}\right]^2$$

$$h_u = 5.15\left(\frac{T_s - T_\infty}{L\,T_\infty}\right)^{1/4}$$

$$h_l = 1.5\left(\frac{T_s - T_\infty}{L^2 T_\infty}\right)^{1/5}$$

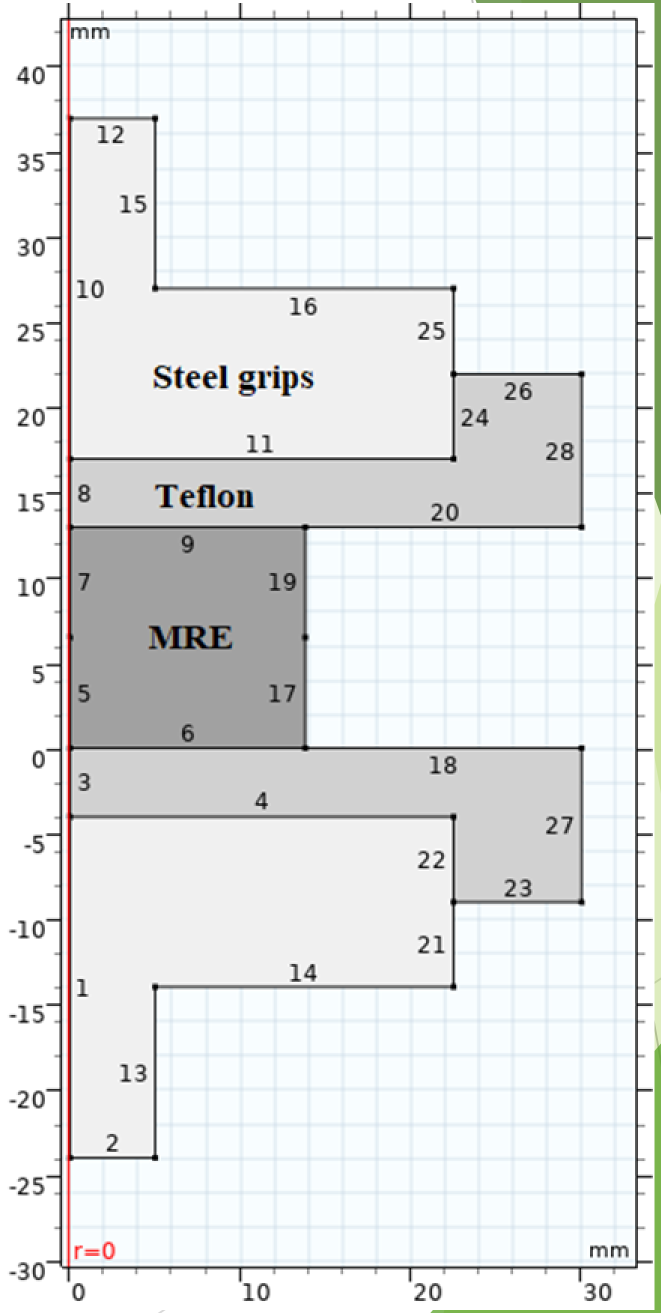
Where L is the characteristic length

$$\frac{Volume}{Area} \text{ or } \frac{Area}{Perimeter}$$

Simulation: Heat transfer in solids.

- Heat Transfer in Solids *(ht)*
  - Solid (Sample)
  - Initial Values 1
  - Axial Symmetry 1
  - Thermal Insulation 1
  - Solid (Teflon)
  - Solid (Steel)
  - Heat Source (Q_int)
  - Heat Flux (h_cylinder1)
  - Heat Flux (h_cylinder2)
  - Heat Flux (h_lower1)
  - Heat Flux (h_lower2)
  - Heat Flux (h_upper1)
  - Heat Flux (h_upper2)

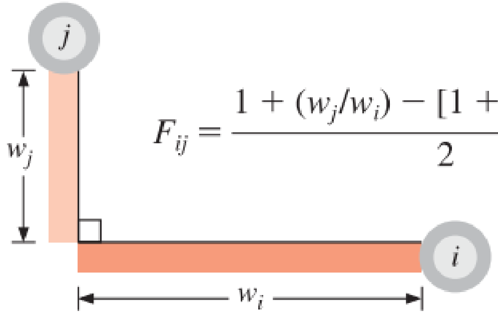
Coefficient:	Boundary No.
h_cylinder1	17, 19
h_cylinder2	27, 28
h_lower1	14,23
h_lower2	20
h_upper1	16, 26
h_upper2	18



- ***Thermal contact resistance*** is ignored as the Teflon surface is soft and in pressure contact with steel and MRE [1].

Simulation: Surface to surface radiation.

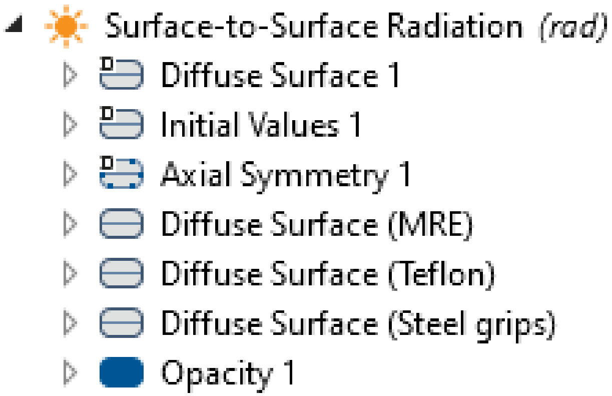
Radiation between MRE sample and Teflon platens was proved to be significant by using the following equation to calculate the view factor between them:



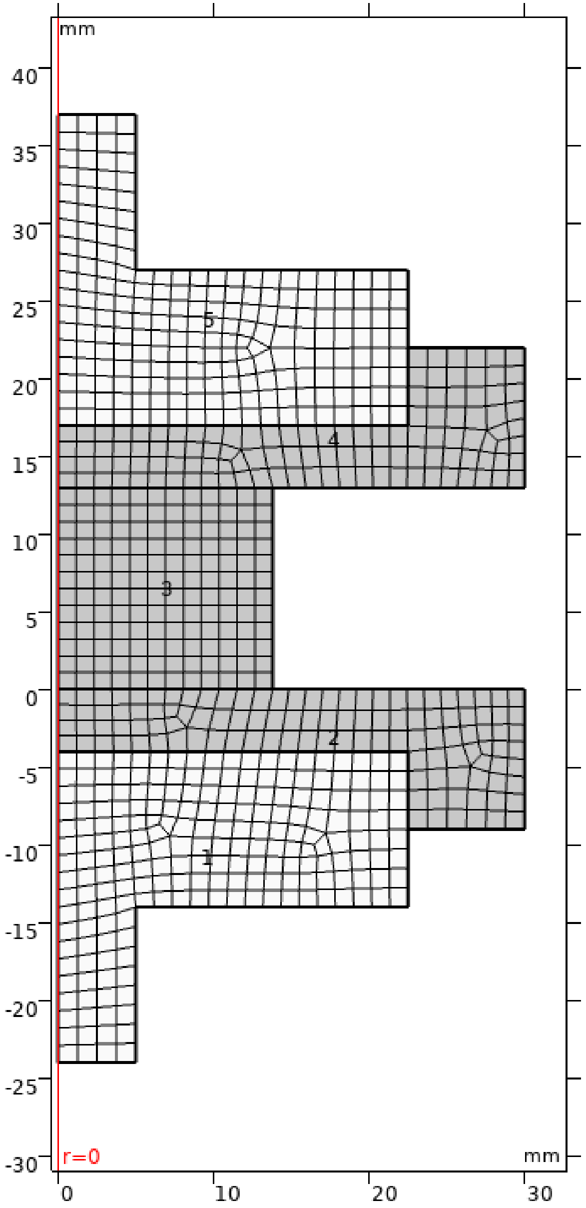
$$F_{ij} = \frac{1 + (w_j/w_i) - [1 + (w_j/w_i)^2]^{1/2}}{2}$$

Therefore, a Surface to surface Radiation physics was used to calculate both radiations:

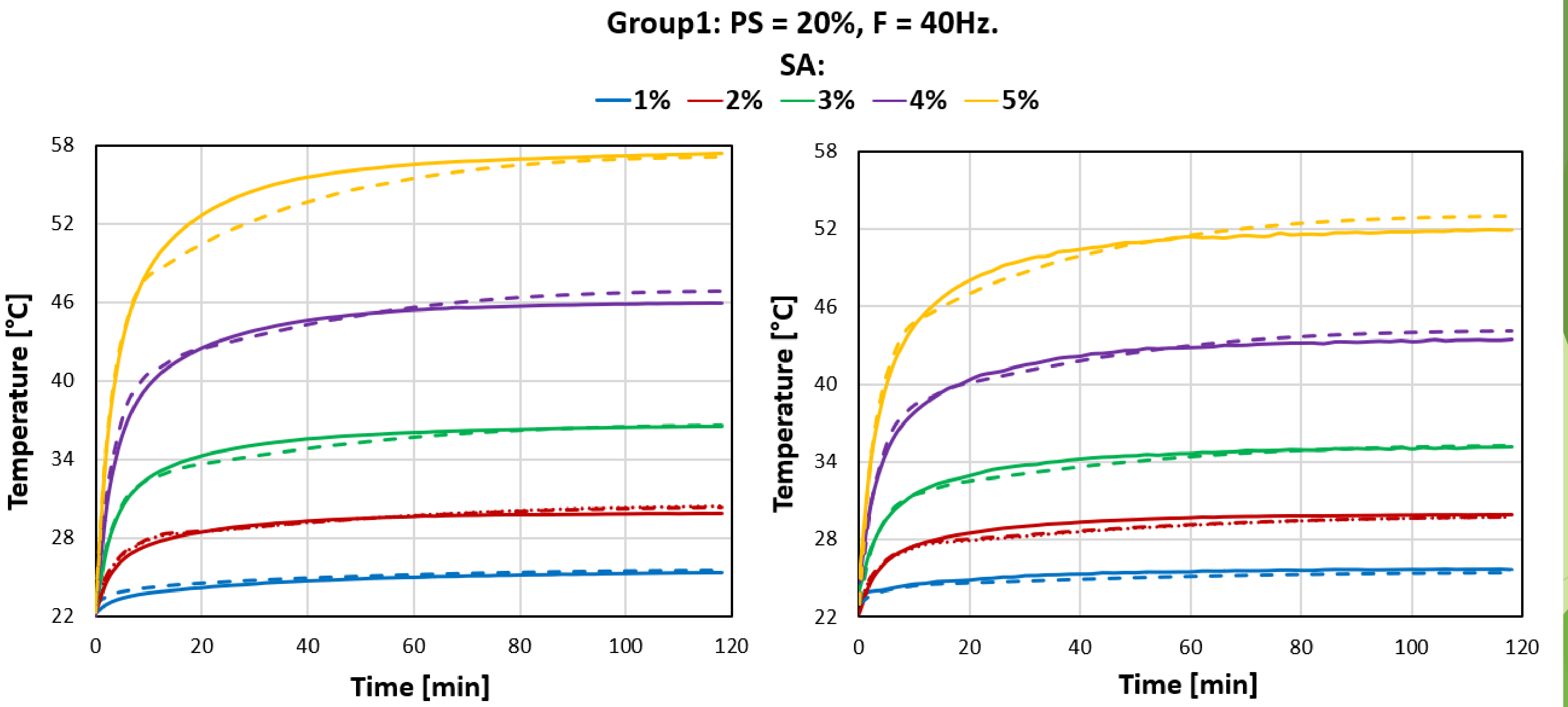
1. To ambient.
2. Between surfaces.



Simulation: Mesh.



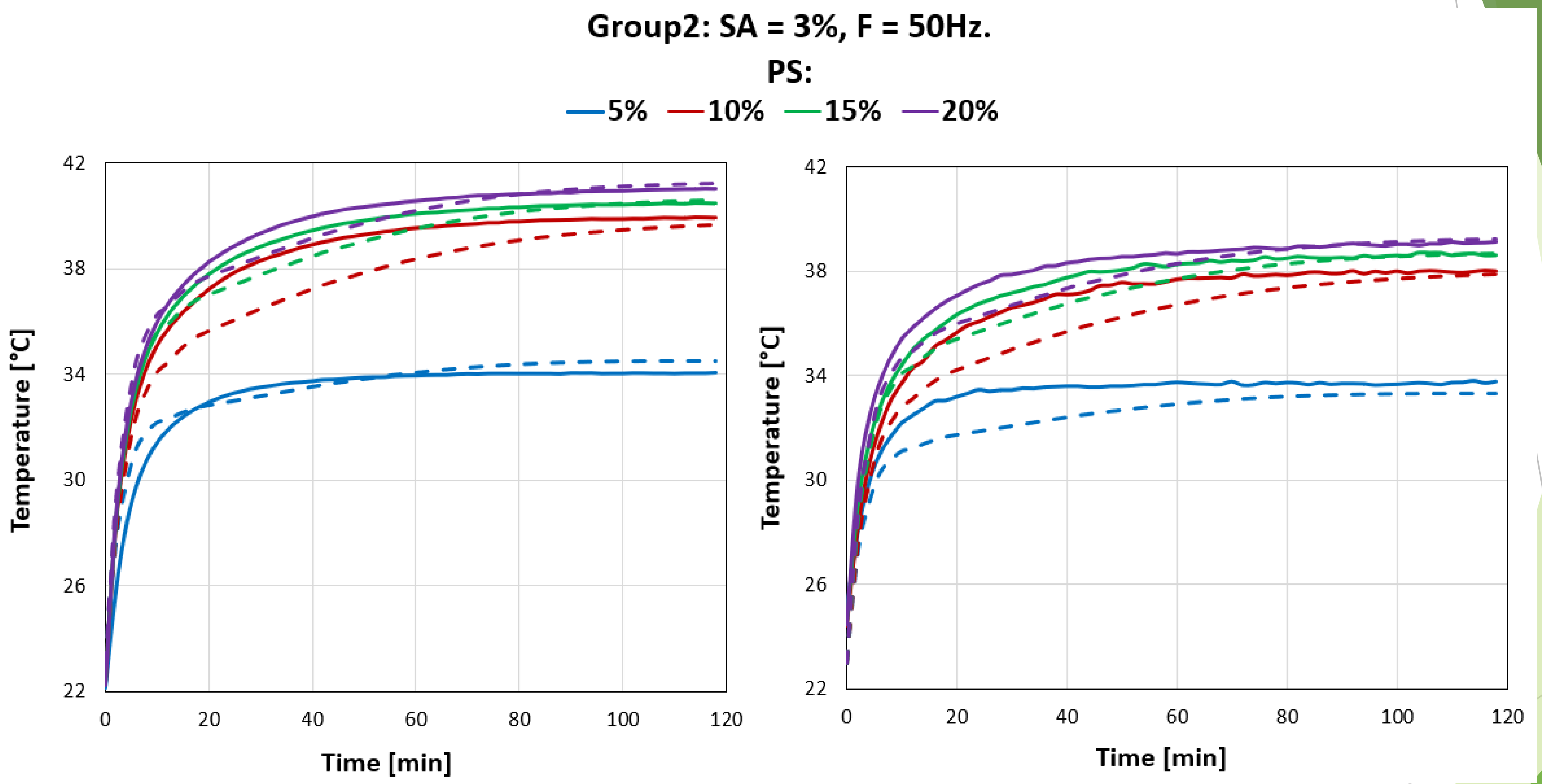
Results: At variable Strain Amplitudes (Group1):



Internal temperature

Surface temperature

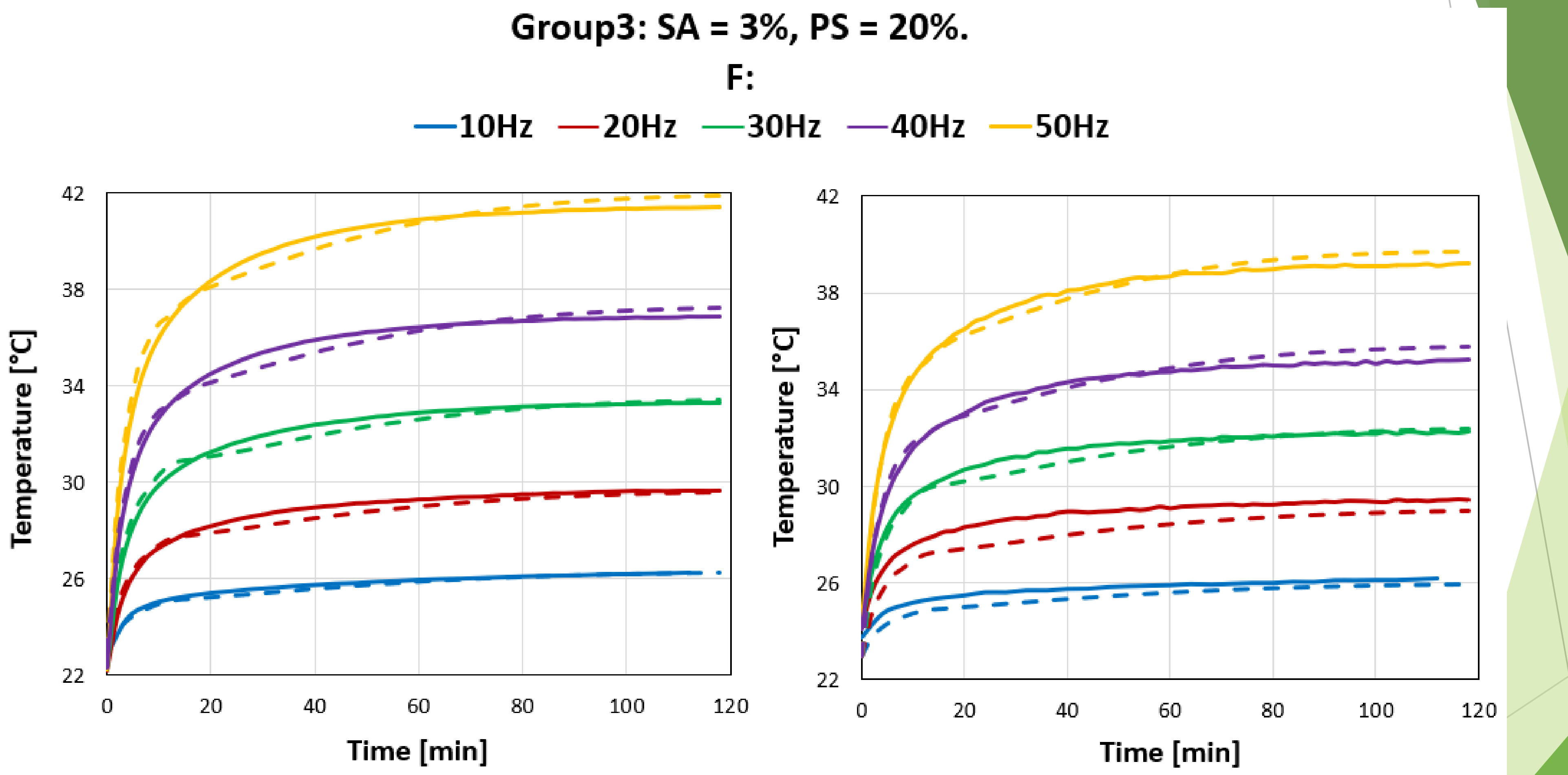
Results: At variable Pre-strains (Group2):



Internal temperature

Surface temperature

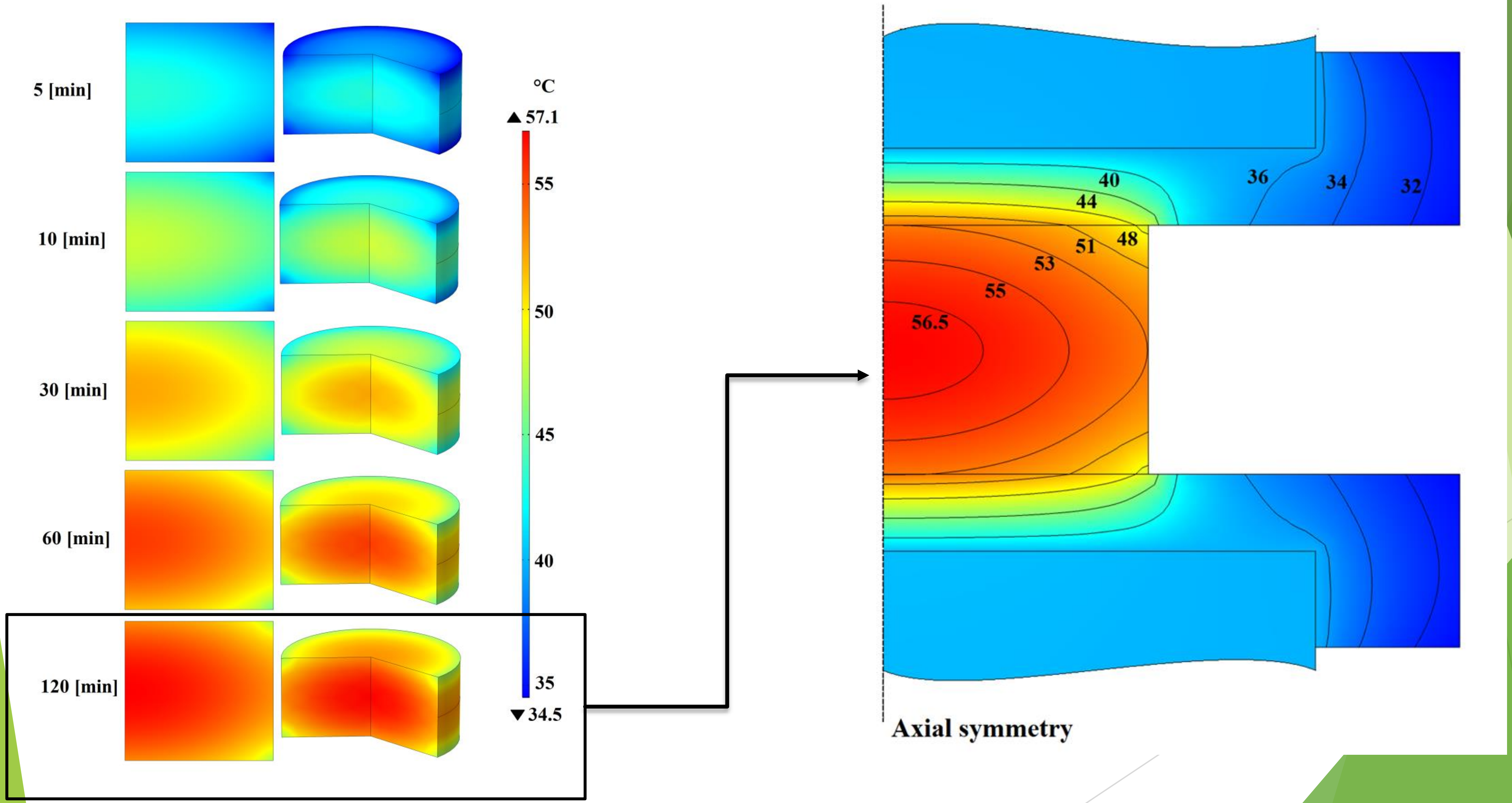
Results: At variable Frequencies (Group3):



Internal temperature

Surface temperature

Results: Temperature Distribution.
At F = 40Hz, PS = 20%, SA = 5% and time = (5 to 120)min.



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References:

[1]: Fundamentals of Heat and Mass Transfer, FRANK P. INCROPERA.

[2]: COMSOL Multiphysics 5.4 library.

Thanks for your attention.