Implementation of an Active Fluid Cooling Design in a 48 V High-Power Battery Module

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Motivation

This study is carried out to analyze the thermal behavior of a 48 V high-power battery module while implementing a passive cooling design and an active cooling design. The ultimate goals are suppression of overall temperature and achievement of a homogenous temperature distribution across the battery module. Regarding modeling skills, minimization of the required computing duration and improvement of the model quality shall be achieved by employing suitable simplifications and modified meshes.

Concept

(1) - GM - A 48 V battery module containing 30 18650 cells, the Ground Model (GM), is designed using software COMSOL Multiphysics® (Fig. 1).

- Principle: Stationary FEM
- Scope: 3D, transient simulation
- Coupling of Non-Isothermal Flow:

Fluid Flow

Navier Stokes Equation:

$$\rho(T)(\mathbf{u}\cdot\nabla\mathbf{u}) = -\nabla p + \mu(T)\Delta\mathbf{u} + F$$

Temperature Field

Heat Transfer

Heat Transport Equation:

$$\rho C_p \mathbf{u}\cdot\nabla T + \nabla\cdot(-k\nabla T) = Q$$

Velocity Field

(2) - GM & ICF – A specific passive cooling design - Internal Cooling Fin (ICF) - is added to GM as an extension of the cover (Fig. 2).

(3) - GM & ICF & AFC - Active Fluid Cooling (AFC) system (Fig. 3) is embedded in the cover of the battery module. In this study water serves as cooling fluid. Its temperature and velocity are variable parameters (283.15 K and 0.1 m/s are applied in the analyzed cases).

Modeling Feature

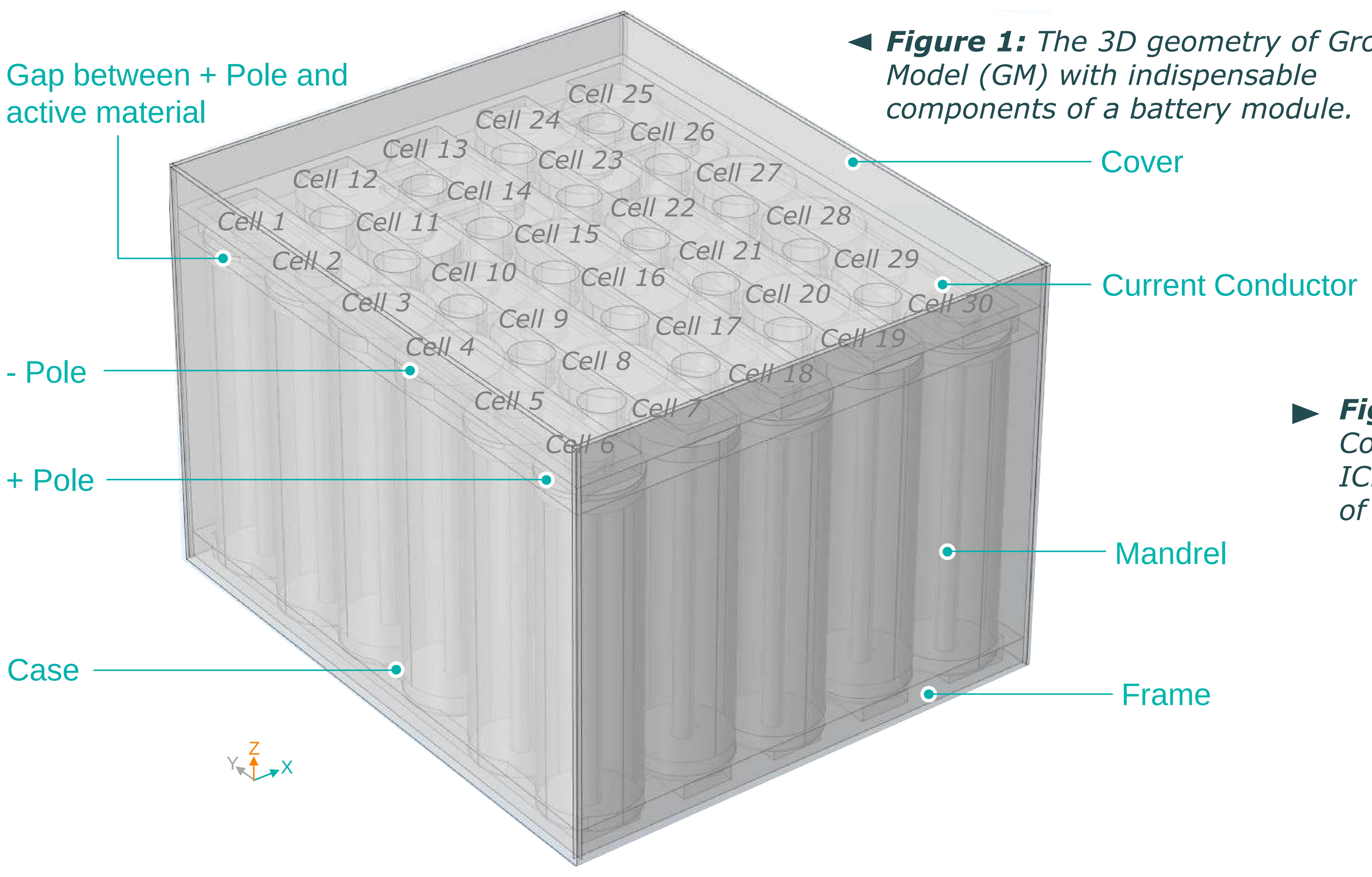
(1) - Temperature Probe – *Domain Point Probes* are located at specified coordinates (x,y,z) to define the fluid temperatures (Fig.3). Water is warmed up by battery generated heat (Fig. 4).

(2) - Mesh – Customized mesh with a maximum element size of 0.01 m and a minimum element size of 0.001 m (Fig. 5). *Free Tetrahedral* and *Swept* meshes are applied. Computing of the mesh requires a physical memory of 12.9 GB. The full mesh consists of 3 124 337 domain elements, 552 777 boundary elements, and 44 487 edge elements. Boundary layers are applied for both air and cooling fluid areas.

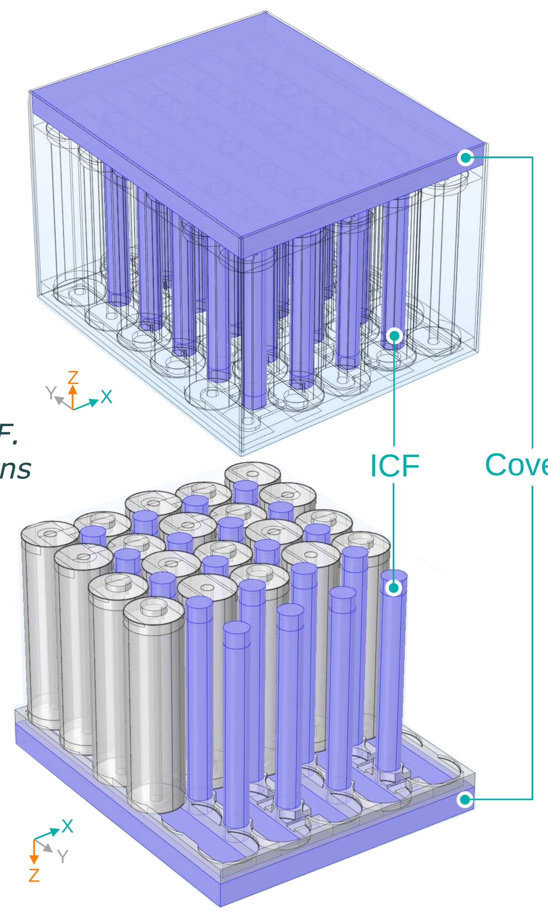
(3) - Auxiliary Sweep - By adding funktion *Auxiliary Sweep* for parameter *P_30cell* (user-defined total power of the battery module), the stationary calculation is carried out automatically for *range(10,5,30)* - 10 W, 15 W, 20 W, 25 W and 30 W. Fig. 7 illustrates the average temperatures of the cells in all analyzed cases.

Conclusion

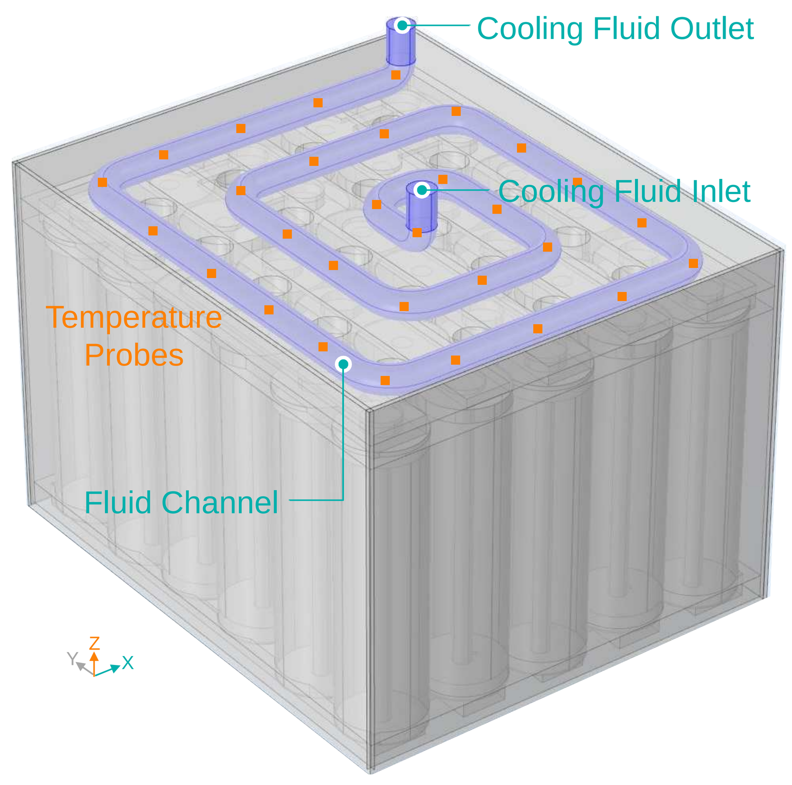
The employed passive cooling design contributes significantly to achieving homogeneous temperature distribution across the battery module. Suppression of the average module temperature has been enhanced by involving active water cooling since generated heat is transported away efficiently by the water flow. However, the homogeneous temperature distribution worsened, which underlines the next task – maintaining the homogeneous temperature distribution while suppressing the overall module temperature.



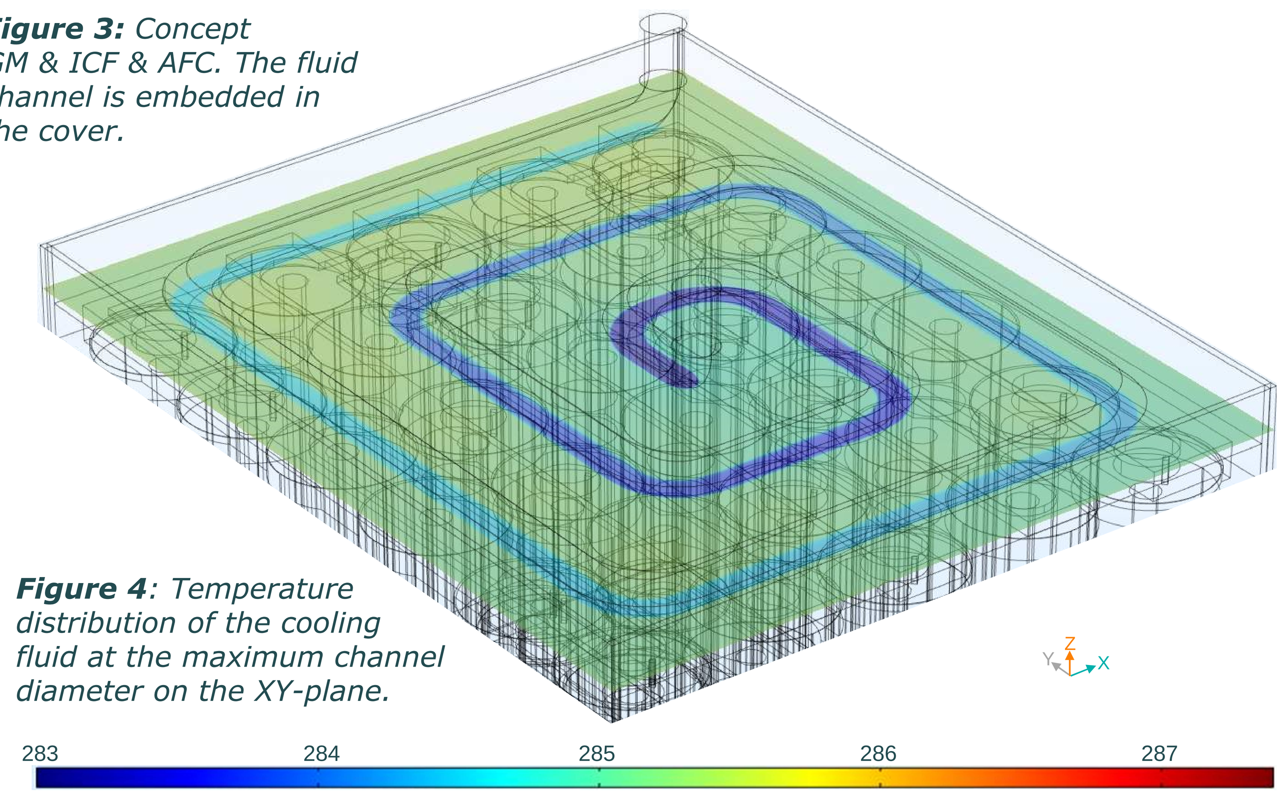
◄ ***Figure 1:*** *The 3D geometry of Ground Model (GM) with indispensable components of a battery module.*



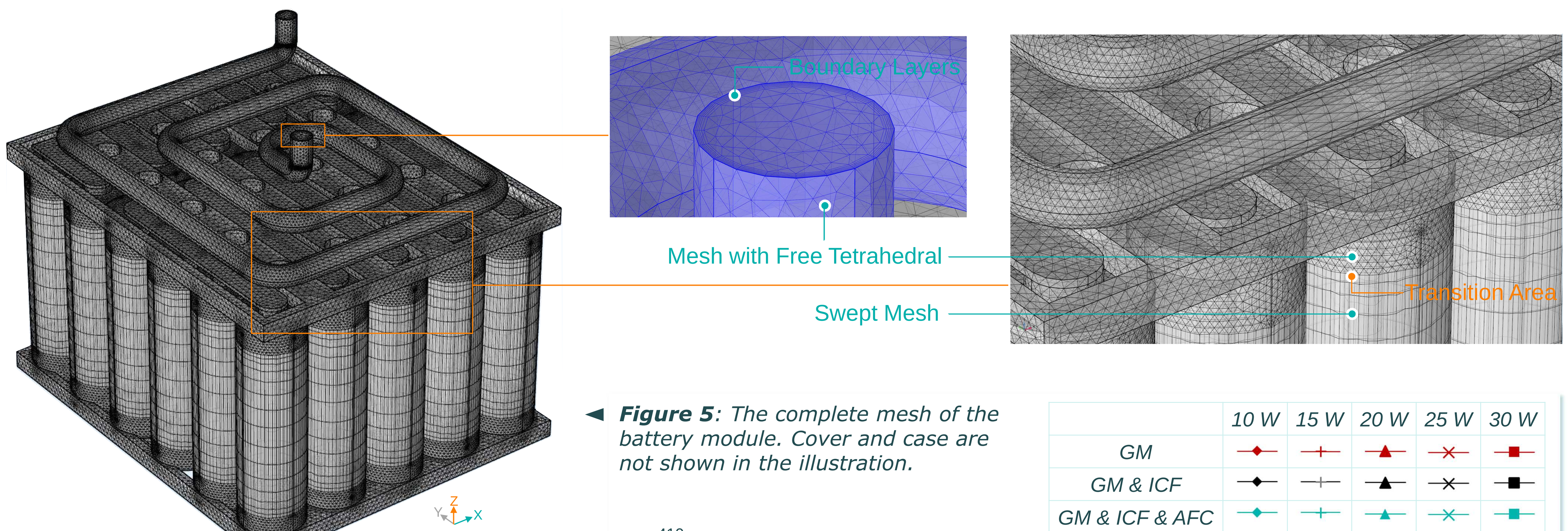
► ***Figure 2:*** *Concept GM & ICF. ICFs are extensions of the cover.*



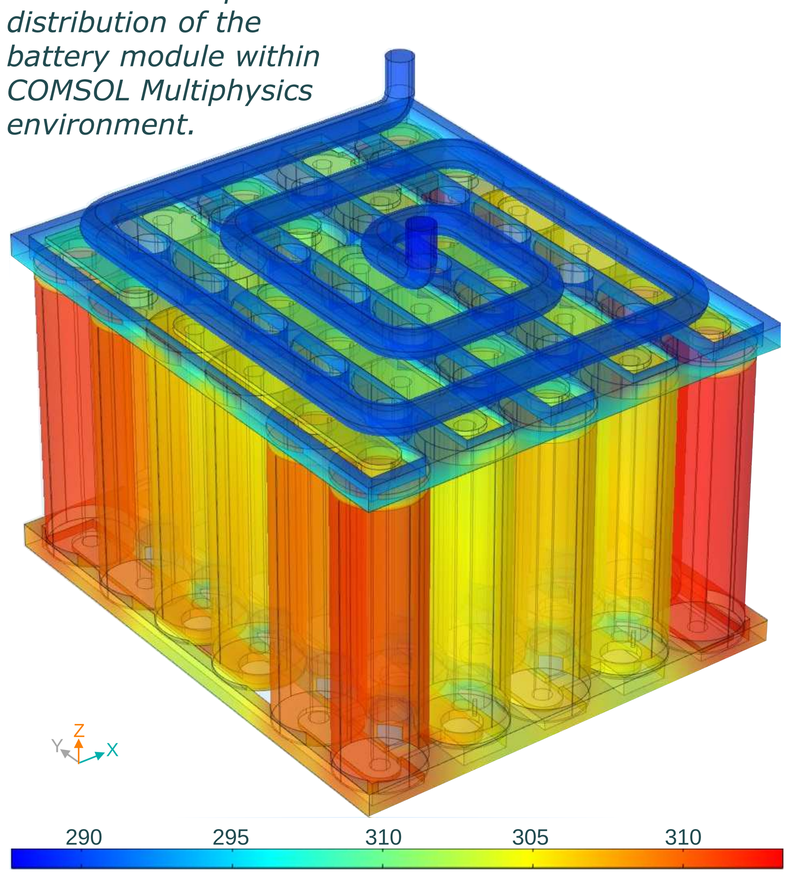
◄ ***Figure 3:*** *Concept GM & ICF & AFC. The fluid channel is embedded in the cover.*



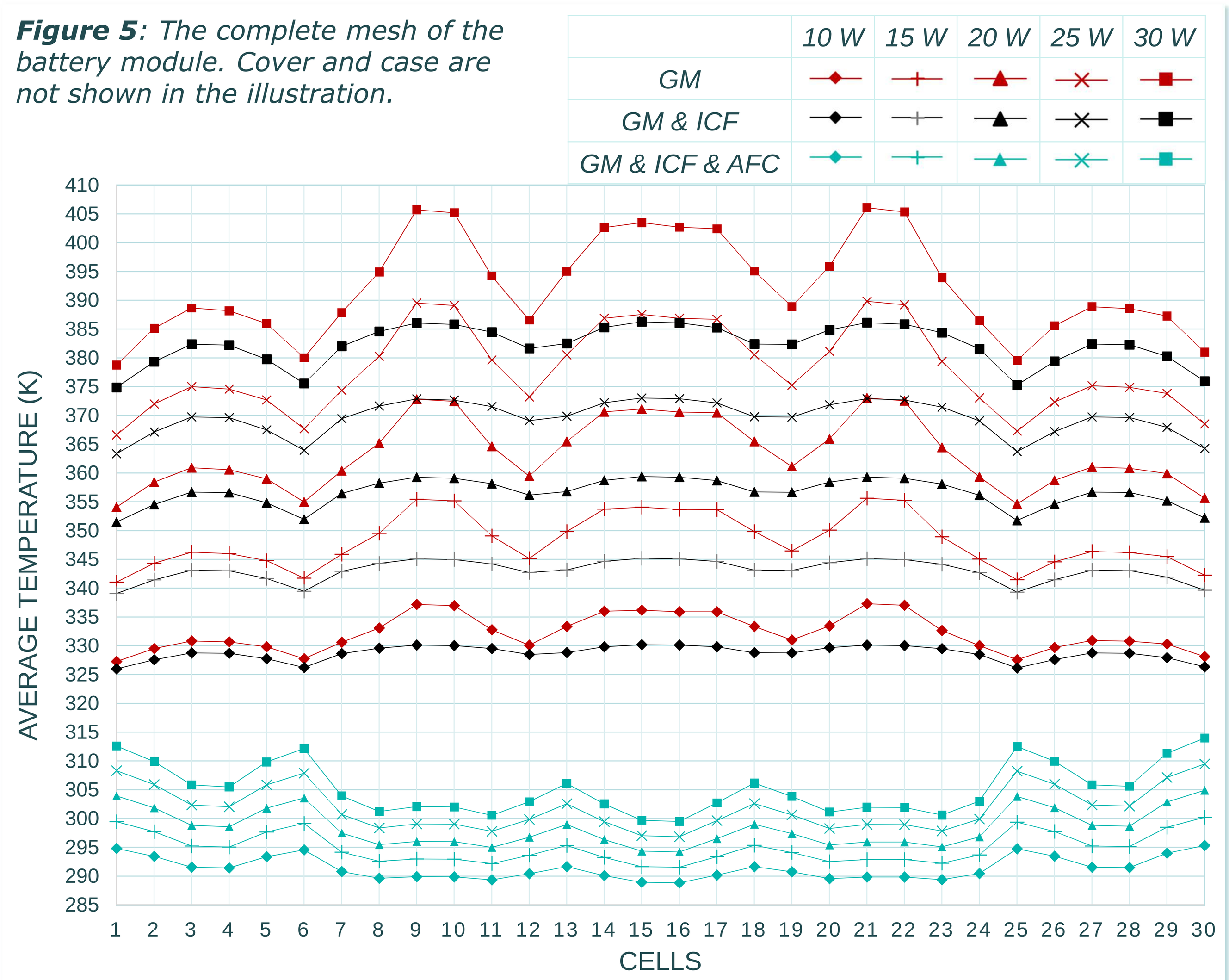
► ***Figure 4:*** *Temperature distribution of the cooling fluid at the maximum channel diameter on the XY-plane.*



◄ ***Figure 5:*** *The complete mesh of the battery module. Cover and case are not shown in the illustration.*



▼ ***Figure 6:*** *Volumetric temperature distribution of the battery module within COMSOL Multiphysics environment.*



▲ ***Figure 7:*** *Stationary average cell temperatures across the XY-plane. The numbers of cells are shown in Fig. 1.*

Acknowledgement

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References

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