A multiphysic approach to improve helmets comfort and reduce time and costs in design process

Longoni Matteo¹, Formaggia Luca², Ferrandi Paolo¹
¹Moxoff Srl, Via D’Ovidio 3, 20131 Milano, Italy
²MOX - Modeling and Scientific Computing
Dipartimento di Matematica “F. Brioschi”, Politecnico di Milano, Italy

Motivation
- Improve helmet comfort in every-day conditions
- Key issue: pleasure of driving and safety

Technology
- Starting point: very latest research works
- Handling of real and complex CAD geometries
- Model coupling: aerodynamics 3D, thermofluid 2D and vibroacoustics 3D
- Multiphase (water/vapour) flows in porous media (comfort tissue/human hair)
- Human head sweating model for heat generation
- Advanced numerical methods
- Improvement and development of robust simulation codes

Mathematical model
- ThermoFluid dynamic problem
  - Navier–Stokes coupled with Darcy–Forchheimer: Penalized NS
    \[
    (\rho \left( \nabla \cdot \vec{u} \right) - \mu \Delta \vec{u}) \chi_w + \nabla P = \left( \frac{\mu}{\kappa} \nabla \cdot \vec{u} \right) \chi_w, \quad \chi_w = 0
    \]
  - Temperature \( T \):
    \[
    \frac{\partial T}{\partial t} + C \nabla \cdot \vec{u} = \nabla \cdot \left( \lambda \nabla T \right) - \sigma \left( h, w, T \right)
    \]
  - Humidity \( h \):
    \[
    \frac{\partial h}{\partial t} + \nabla \cdot \vec{u} \cdot \nabla h = D_h \Delta h + s \left( h, T, w \right)
    \]
  - Sweat content \( w \):
    \[
    \frac{\partial w}{\partial t} + \nabla \cdot \vec{u} \cdot \nabla w = D_h \Delta w - s \left( h, T, w \right)
    \]
  - Evaporation rate \( s \):
    \[
    s \left( h, T, w \right) = E \left( \frac{M_f}{2 \pi R T} \left( \rho_u(T) - \rho_h(T) \right) \right) \chi_w
    \]
- Vibroacoustic model - WIP!
  - Elastodynamics equations:
    \[
    \begin{align*}
    \left\{ \begin{array}{l}
    \rho \ddot{u} - \nabla \cdot \sigma = f, & \text{in } \Omega \times [0, T] \\
    u = 0 & \text{on } \Gamma_{\text{dir}} \times [0, T] \\
    \sigma \cdot \mathbf{n} = \mathbf{t}, & \text{on } \Gamma_{\text{b.c.}} \times [0, T] \\
    \dot{u}(0) = u_0, & \text{in } \Omega \times [0] \\
    u = u_T & \text{in } \Omega \times [0] \\
    \end{array} \right.
    \end{align*}
    \]
  - Discontinuous Galerkin formulation
  - Multi-domain formulation

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  \]
- Discontinuous Galerkin formulation
- Multi-domain formulation
- 3D hexa mesh

Results
- Accurate and efficient simulations of the physics involved
- Evaluation tool for engineers to explore different design solutions
- Time and costs of the overall design process drastically improved
- Optimized process satisfying comfort requirements for a successful product.

References