Optimization of an Explosive Mixture Cooling Process Including a Phase Change

J.-D. Wheeler\textsuperscript{1}, C. Coulouarn\textsuperscript{2}, E. Benade\textsuperscript{2}, P. NAMY\textsuperscript{1}

1. SIMTEC, 8 rue Duployé, Grenoble, 38100, France, +33 9 53 51 45 60
   jean-david.wheeler@simtecsolution.fr
2. Thales TDA, Thales, La Ferté-Saint-Aubin, 45240, France
   christophe.coulouarn@thalesgroup.com

COMSOL CONFERENCE
2017 ROTTERDAM

- French company, founded in 2006, 4 Ph. D. Engineers

- Experts in Modeling, COMSOL Certified Consultants:
  - CFD
  - Structural mechanics
  - Electromagnetism
  - Heat transfer
  - Chemical engineering

- Services:
  - Numerical modeling
  - Custom-made training sessions
  - Modeling assistance

- Main Clients:
1. Model description
   a) Challenge

Production of the **new** ammunition bodies with melt casting:
- Good solidification quality
- Minimum amount of experimental tests
- Exploring more cooling methods

→ **COMSOL numerical model**
and **application**!

- Cast iron ammunition body
- Aluminium part
- Plastic accessories
1. Model description
   a) Challenge

Circulation of a cooling fluid

- Plastic skin
- Explosive mixture
- Cast iron ammunition body
- Aluminium part
- Plastic accessories

Ammunition body with the production accessories
1. Model description
   b) Geometry

The geometry is fully parametrised.
1. Model description  
c) Physics: the equation

**Axisymmetric model**
Heat equation solved:

\[ \rho C_p \frac{\partial T}{\partial t} - \nabla \cdot (k \nabla T) = 0 \]
Boundary condition: heat flux

\[ q = h \cdot (T_{\text{ext}} - T) \]

With \( h \), the HT coefficient which depends on:
- The area of the body
- The time
- The cooling fluid nature
- The cooling fluid velocity
- The cooling fluid temperature
- The convection conditions
- The presence of the plastic skin or not

With \( T_{\text{ext}} \), the cooling fluid temperature
1. Model description
   e) Physics: the phase change

Heat capacity $[\text{J/(kg \cdot K)}]$

Legend:
- Blue line: Heat capacity

$C_p \text{ solid}$

$C_p \text{ liquid}$

Graph of the explosive mixture $C_p$ values which includes the modified $C_p$ method
1. Model description

f) ONLINE HTTPS SECURED APPLICATION!!

Application screenshot: the environmental condition parameters
2. Computation / Validation

- COMSOL Server™
- On a SIMTEC https server
- 2.8 GHz processor, 2 cores used for the resolution
- 4h computation time

- Experimentally validated: comparison with in-situ temperature measurements
3. Results
   a) A wide range of possibilities!
3. Results

b) Air cooling: velocity influence on cooling time

→Threshold effect identified between \(x\) and \(y\) \(m/s\)

\[ u = 0 \text{ m/s} \quad u = x \text{ m/s} \quad u = y \text{ m/s} \]
3. Results

c) Water cooling conditions: quality analysis

\[ t_1 \rightarrow t_2 \rightarrow t_3 \]

Cavity formation risks

Explosive mixture (solid phase)

Influence of the water cooling process on the solidification quality

→ Cavity formation risk identified for water filling times \( t_1 \) and \( t_2 \)
Conclusion

Achievements: SIMTEC
- Solidification front evolution predictions
- For many cooling conditions
- Remote and secured computations

Resulting in: TDA
- Faster process optimisation
- Development of new processes