Vaporization at high reduced pressure induced by very rapid power input

*Dispersed two phase flow*

Jean Muller, Pierre Ruyer, Romuald Rullière, Marc Clausse

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**Context**

- High pressure transient (2MPa)
- Massive creation of vapour

*Atmospheric pressure and temperature*

**Main question**

How the test conditions influence the thermal shock consequences?

1. EDITE
   - Test section
   - Acquisition
   - Tests performed
EDITE (Etude d’un Dépôt Intense et Transitoire d’Énergie)

Discharge 9 condensers
Discharge: 1 kJ within 5 ms

Fluid: $CO_2$
\[
P \in [2.5 ; 6.2] \text{ MPa} \\
T \in [-15 ; 24] \text{ °C}
\]

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**EDITE** (Etude d’un Dépôt Intense et Transitoire d’Energie)

**Temperature and static pressure**
1 Hz

**Dynamic pressure** ($P_1, P_2, P_3$) – Voltage and Current
500 kHz

$$(U, I) \rightarrow R_W(T) \rightarrow T_W$$

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Tests performed

200 tests

\[ P \in [25 \text{ bar} ; 62 \text{ bar}] \]
\[ T \in [-15 ^\circ C ; 24 ^\circ C] \]
\[ E \in [75 J ; 340 J] \]
**Ensemble des essais**

200 tests

\[ P \in [25 \text{ bar} ; 62 \text{ bar}] \]
\[ T \in [-15 ^\circ \text{C} ; 24 ^\circ \text{C}] \]
\[ E \in [75 J ; 340 J] \]

Test chosen

\[ \begin{cases} P = 25.6 \text{ bar} \\ T = -12 ^\circ \text{C} \\ E = 240 J \end{cases} \]
Test chosen

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I. EDITE
   • Test section
   • Acquisition
   • Tests performed

II. Pressure peak
   • Phenomena
   • Influence of the test conditions
Phenomena

Electric power

\[ P \text{(W)} \]

\[ 0 \times 10^4 \]

\[ 10 \times 10^4 \]

\[ 2 \times 10^4 \]

\[ 4 \times 10^4 \]

\[ 0 \]

\[ 2 \times 10^5 \]

\[ 4 \times 10^5 \]

\[ 0 \times 10^5 \]

\[ 2 \times 10^5 \]

\[ 4 \times 10^5 \]

\[ 0 \]

\[ 2 \]

\[ 4 \]

\[ 0 \times 10^3 \]

\[ 1 \times 10^3 \]

\[ 2 \times 10^3 \]

\[ 3 \times 10^3 \]

\[ 4 \times 10^3 \]

\[ 5 \times 10^3 \]

\[ 6 \times 10^3 \]

\[ 0 \]

\[ 1 \]

\[ 2 \]

\[ 3 \]

\[ 4 \]

\[ 5 \]

\[ 6 \]

\[ \text{Temps (s)} \]

\[ \times 10^{-3} \]

\[ \times 10^5 \]

\[ \times 10^4 \]

\[ \times 10^3 \]

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Phénomena

Pressure increase \( p_{[Zhao \text{ et al.}]} \)
\[
\frac{d^2 V_{v}}{dt^2} > 0
\]

Pressure decrease \( P \)
\[
\frac{d^2 V_{v}}{dt^2} < 0
\]
+ acoustic rebounds


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Influence of test conditions on the thermal shock

- Reduced pressure
  $$P_r = \frac{P_i}{P_c}$$

- Theta
  $$\Theta = \frac{E}{\Delta H_{i\to v}} \frac{1}{m_f}$$

- Jakob
  $$Ja = \frac{\rho_l}{\rho_v} \frac{c_{p,l}(T-T_{sat(P)})}{L(P)}$$
\[ P_r = \frac{P}{P_c} \]

\[ \Theta = \frac{E}{\Delta H_{i-v} m_f} \]

Decrease of \( P_m \) for an increasing \( P_r \)

Increase of \( P_m \) with \( \Theta \) for low \( P_r \)

Saturation of \( P_m \) with \( \Theta \) for high \( P_r \)

Iincertitudes en annexe

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Dispersed two phase flows
I. EDITE
   • Test section
   • Acquisition
   • Tests performed

II. Pressure peak
   • Phenomena
   • Influence of the test conditions

III. Vapour created
   • Compression of the buffer layer
   • Influence of the test conditions
Buffer layer compression

The fluid is considered incompressible

1. $V_0$
2. $V_0 - V(t)$
3. CO$_2$ liquide

$V_\gamma(t)$
Buffer layer compression

The fluid is considered incompressible

Assumption:
Isentropic compression of the buffer layer composed of a non ideal gas
Buffer layer compression

Storage of thermal energy in the tungsten

Slower kinetic for $V_v(\text{real})$

Assumption: Isentropic compression of the buffer layer composed of a real gas
Test conditions influence on the volume created

Recondensation of the vapour with an increasing Jakob

$V_v$ decreases with an increasing $Ja$

Incertitudes en annexe
Test conditions influence on the volume created

Recondensation of the vapour with an increasing Jakob

$V_v$ decreases with an increasing $Ja$

Incertitudes en annexe

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Conclusion

- Experimental study of the consequences of a thermal shock
- Influence of the test conditions on the phenomena
- Theoretical study of the transient phase change

Perspectives

- Improvement of the thermal analysis
- Use of the theoretical model for all the tests