Experimental study of the liquid jet-induced loads following a wave impact on MarkIII corrugations

by

Olivier KIMMOUN, Guillaume DUPONT & Fabien REMY (Ecole Centrale Marseille/IRPHE)

In collaboration with

Laurent BROSSET (GTT)

Multiphase 2017 – ENS Cachan – 16-18 October 2017
1. **First Campaign (2014)**
   a) Experimental setup
   b) How to generate experimentally waves to obtain significant pressures on ceiling
   c) The most interesting case of this campaign

2. **Second Campaign (2017)**
   a) The modified setup
   b) Strong impact – First case
   c) Strong impact – Second case

3. **Conclusions**
What we wanted to study?

Wave Impact on an instrumented corrugated ceiling

Impact on the corner

Impact at some distance from the wall with gas pocket

Small gas pocket

Large gas pocket

Separation of the flow at the top of the corrugation – creation of a jet

Reattachment of the jet on the ceiling – propagation of the building jet
Experimental setup – 1\textsuperscript{st} campaign

Wave gauges

\begin{align*}
\text{h} &= 70 \text{ cm} \\
L &= 12.4 \text{ m}
\end{align*}
Experimental setup – 1\textsuperscript{st} campaign

corrugated ceiling

Design by Arnaud Landure – GTT
Experimental setup – 1st campaign. Corrugated ceiling

1. 99 Pressure sensors on the roof
   1. 19 PCB 112A21 (7 bars max)
   2. 80 PCB 113B24 (70 bars max)

1. 8 pressure sensors on the corrugations
   1. 8 ENTRAN surface mount pressure sensors
How to generate representative impact on the ceiling?

The classical space-time focusing technique

Starting from a given spectrum (RICKER)

All the phases $\varphi_i$ are determined to obtain a single wave at a given distance.

Due to dispersion, the single wave transforms into multiple waves

By reversing the time, this wave group leads to the single wave at the distance $X_f=15m$
How to generate representative impact on the ceiling?

One focusing wave is not enough to obtain significant impact pressures

Superposition of 2 Ricker spectra

\[ T_p = 2.55 \text{s, } A = 0.32 \text{m} \]

\[ T_p = 1.80 \text{s, } A = 0.18 \text{m} \]

\[ X_{\text{wall}} = 12.55 \text{m} \]

Behind the wall
The focusing wave is reflected

\[ + \]

In front of the wall

\[ = \]

The two crests meet together at the same location

\[ X_f = 13.3 \text{m} \]

\[ X_f = 12.5 \text{m} \]
The most interesting case of this campaign
The most interesting case of this campaign

Space-time representation of the pressure on the ceiling for one row of pressure sensors

This case corresponds to the maximum pressure measured on the ceiling and on the corrugations for the case with a gas pocket
The most interesting case of this campaign

2 Rickers

$x=9.85\text{cm}$
The most interesting case of this campaign

2 Rickers

$x=14.85\text{cm}$
The most interesting case of this campaign
Experimental setup – 2\textsuperscript{nd} campaign

\begin{itemize}
\item wavemaker
\item One wave gauge
\item \( h = 70 \text{ cm} \)
\item \( L = 12.55 \text{ m} \)
\item 2000 frames/s
\end{itemize}
Corrugated Ceiling. 2\textsuperscript{nd} campaign

1. 56 Pressure sensors on the ceiling
   1. 15 PCB 112A21 (7 bars max)
   2. 42 PCB 113B24 (70 bars max)

1. 9 pressure sensors on the corrugations
   1. 9 ENTRAN surface mount pressure sensors
A test to calibrate the ENTRAN pressure sensors

Test n°24, $T_1 = 2.617s$, $H_1 = 0.285m$, $x_1 = x_{wall} + 0.85m$, $T_2 = 1.825s$, $H_2 = 0.16m$, $x_2 = x_{wall} - 0.1m$
Compression of the gas pocket

Impact on the left side of the first corrugation
Superposition of one sensor on the ceiling and the sensor on the right side of the first corrugation.
High pressures on the first part of the ceiling

Tests n°17 & 18, $T_1=2.65s$, $H_1=0.300m$, $x_1=x_{wall}+0.75m$, $T_2=1.8s$, $H_2=0.115m$, $x_2=x_{wall}-0.05m$
1 image = 0.5ms after
Impact on the corrugation

And repeatability
Repeatability

Test 17

Test 18
Line from the first campaign

SECOND CORRUGATION

Very low pressures

Building jet

BUILDING JET

WALL

FIRST CORRUGATION

FIRST CORRUGATION

WALL
Comparisons with the previous campaign

Evolution of the free surfaces before impact

Velocity of the crest close to the wall
Impact close to the right side of the corrugation

Tests n°21 & 25, $T_1 = 2.617s$, $H_1 = 0.300m$, $x_1 = x_{wall} + 0.75m$, $T_2 = 1.825s$, $H_2 = 0.11m$, $x_2 = x_{wall} - 0.05m$
Small pressures on the second part of the ceiling.
Compression of the gas pocket

First impact
2 images = 1ms
3 images = 1.5ms
High pressures between the two corrugations

Tests n°20 & 26, $T_1=2.617\text{s}$, $H_1=0.300\text{m}$, $x_1=x_{\text{wall}}+0.75\text{m}$, $T_2=1.825\text{s}$, $H_2=0.115\text{m}$, $x_2=x_{\text{wall}}-0.05\text{m}$
Compression of the gas pocket
Maximum pressure in the gas pocket
Conclusions

• During the first campaign (2014)
  ➢ High pressures were measured on the ceiling (12 bars) but at the corner between the ceiling and the vertical wall.
  ➢ For a case (repeat once), the jet-induced flow led to noteworthy pressures on the right side of the second corrugations (3.5 bars).
  ➢ Only one pressure sensor on the height of the corrugation. Limitation to capture the measurement of the maximum pressure.

• During the second Campaign (2017)
  ➢ Three pressure sensors were installed on the height of corrugations. Unfortunately only one sensor worked during the campaign. Probably due to the reuse of the sensors of the 2014 campaign. The wires that connect the sensors are very tiny and are maybe cut.
  ➢ New interesting cases with high pressures on ceiling far from the wall and on the first corrugation (8 bars).
  ➢ Relatively high pressures measure on the ceiling between the two corrugations (2.5 bars). This impact doesn’t lead to high pressure on the second corrugation. The jet-induced flow doesn’t propagate to the direction of the second corrugation.
Thank you for your attention