Development and Verification of IMPACT35

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Fifth Annual ONR Mine Burial Prediction Workshop
Kailua-Kona, Island of Hawaii, January 31 – February 2, 2005
References


• Chu, P.C., A. Gilles, and C.W. Fan, 2005: Experiment of falling cylinder through the water column. Experimental and Thermal Fluid Sciences, in press.


Comparison Between IMPACT28 and IMPACT35 Using Carderock Data
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Major Features of IMPACT35

(1) Three-Dimensional, Full Physics

(2) Triple Coordinate Systems
   - E-Coordinate: Momentum Equations
   - M-Coordinate: Moment of Momentum Equations
   - F-Coordinate: Hydrodynamic (drag/lift) Forces and Torques

(3) Drag/Lift Coefficients Depends on Reynolds Number and L/D ratio

(4) Cavitation

(5) Sediment Resistant Force (Bearing Strength and Pore-Water Pressure)
Mine Parameters
Triple Coordinate Transform

- Earth-fixed coordinate (E-coordinate)

- Cylinder’s main-axis following coordinate (M-coordinate)

- Hydrodynamic force following coordinate (F-coordinate).
$\mathbf{j}_M = \mathbf{k} \times \mathbf{i}_M$,  \hspace{1cm} \mathbf{k}_M = \mathbf{i}_M \times \mathbf{j}_M$
F-Coordinate System
Transform Between E- and M-Coordinate Systems

\[ E_M R(\psi_2, \psi_3) \equiv \begin{bmatrix} r_{11} & r_{12} & r_{13} \\ r_{21} & r_{22} & r_{23} \\ r_{31} & r_{32} & r_{33} \end{bmatrix} = \begin{bmatrix} \cos \psi_3 & -\sin \psi_3 & 0 \\ \sin \psi_3 & \cos \psi_3 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos \psi_2 & 0 & \sin \psi_2 \\ 0 & 1 & 0 \\ -\sin \psi_2 & 0 & \cos \psi_2 \end{bmatrix}, \]
E- and F-Coordinate Transform

\[ i_F = i_M = \begin{bmatrix} r_{11} \\ r_{21} \\ r_{31} \end{bmatrix}, \quad j_F = \mathbf{V}_2/|\mathbf{V}_2|, \quad k_F = i_F \times j_F. \]

\[ ^E_F R(\psi_2, \psi_3, \phi_{MF}) = \begin{bmatrix} r_{11} & r_{12} & r_{13} \\ r_{21} & r_{22} & r_{23} \\ r_{31} & r_{32} & r_{33} \end{bmatrix}, \]
Momentum Equation in E-Coordinate System

\[
\frac{d}{dt} \begin{bmatrix} u \\ v \\ w \end{bmatrix} = - \begin{bmatrix} 0 \\ 0 \\ (1 - \rho_w / \bar{\rho}) g \end{bmatrix} + \frac{1}{\rho \Pi} \begin{bmatrix} F_x \\ F_y \\ F_z \end{bmatrix},
\]
Moment of Momentum Equation in M-
Coordinate System

\[ J \cdot \frac{d\omega}{dt} = -2J \cdot (\Omega \times \omega) + M_{nh} + M_h \]
M-Coordinate

The moment of gyration tensor for the axially Symmetric cylinder is a diagonal matrix

\[
\mathbf{J} = \begin{bmatrix}
J_1 & 0 & 0 \\
0 & J_2 & 0 \\
0 & 0 & J_3
\end{bmatrix},
\]
Moment of Momentum Equations

\[ \frac{d \omega_1}{dt} = -a_1 \omega_1 , \]

\[ \frac{d}{dt} \begin{bmatrix} \omega_2 \\ \omega_3 \end{bmatrix} = -B \cdot \begin{bmatrix} \omega_2 \\ \omega_3 \end{bmatrix} + a_2 , \]
Sediment Resistant Forces
(Bearing Strength and Pore-Water Pressure)

IMPACT28

Bearing Strength
= 10 X Shear Strength

IMPACT35

More Realistic
Model Verification Using Carderock Data

COM at $t = 0.4$ s

IMPACT35 $(x, y, z)$

IMPACT28 $(x, z)$
Model Verification Using Carderock Data

COM at $t = 0.8$ s

IMPACT35 $(x, y, z)$

IMPACT28 $(x, z)$
Model Verification Using Carderock Data

COM at $t = 1.4$ s

IMPACT35 ($x, y, z$)

IMPACT28 ($x, z$)

Experiment X($m$)

Model X($m$)

Time = 1.4(s)

Total number: 34

Experiment X($m$)

Model X($m$)

Experiment Y($m$)

Model Y($m$)

Experiment Z($m$)

Model Z($m$)

Time = 1.6(s)

Total number: 30

Experiment X($m$)

Model X($m$)

Experiment Y($m$)

Model Y($m$)

Experiment Z($m$)

Model Z($m$)
Model Verification Using Carderock Data

COM at $t = 1.8 \text{ s}$

IMPACT35 ($x, y, z$)

IMPACT28 ($x, z$)
Model Verification Using Carderock Data
Orientation t = 0.4 s

IMPACT35 (psi2, psi3)

IMPACT28 (psi2)

Experiment
Model

Time = 0.4(s)
Total number: 42

Experiment $\psi_2$ ($^\circ$)
Model $\psi_2$ ($^\circ$)
Number

Experiment $\psi_3$ ($^\circ$)
Model $\psi_3$ ($^\circ$)
Number
Model Verification Using Carderock Data
Orientation $t = 0.8$ s

IMPACT35 ($\psi_2, \psi_3$)

IMPACT28 ($\psi_2$)
Model Verification Using Carderock Data
Orientation $t = 1.4$ s

IMPACT35 ($\psi_2, \psi_3$)

IMPACT28 ($\psi_2$)

Total number: 42
Model Verification Using Carderock Data
Orientation $t = 2 \text{ s}$

**IMPACT28 (psi2)**

**IMPACT35 (psi2, psi3)**
Temporally Varying RMSE
IMPACT28

- Observation Number
- $X$
- $Z$
- $\Psi_2$
Temporally Varying RMSE IMPACT35

- Observation Number
- X
- Y
- Z
- PSI$_2$
- PSI$_3$
Gravity Cores During MIBEX (5/21/2000)
Predicted Burial Depth Comparison Using MIBEX Data
Predicted Burial Depth Comparison Using MIBEX Data

![Graph showing predicted burial depth comparison using MIBEX data. The graph displays penetration depth (m) against drop number. The data is compared to experiment and Impact35, Impact28 models.](image-url)
Conclusions

- IMPACT35 has capability to predict the COM position and mine orientation in the water column.

- The sediment part of IMPACT35 needs improvement
Future Work

• (1) Extensive Model Verification
  • NRL (Drs. Phil Valent, Paul Elmore, Andre Abelev)
  • JHU-APL (Drs. Alan Brandt, Sarah Rennie)
  • FWG (Dr. Thomas Wever)

• (2) Extension the IMPACT35 for Cylindrical Mines to Non-Cylindrical Mines for Naval Operational Mines
  • Manta, Rockan
  • Korean Mines, Bowen Mines, Psi Mines
  • KW36, KW52, KWDST, KWGE, KWIT
  • Mark36N, Mark52 …