Modelling gear seabed interaction during demersal trawling – design study

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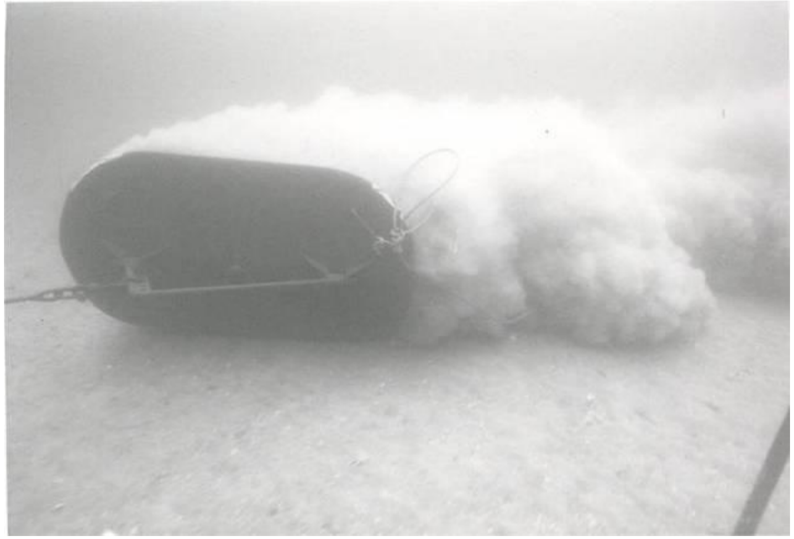

- to investigate
  - (i) the engineering performance and
  - (ii) the environmental impact of towed fishing gears.

- assess gears that
  - (i) are more fuel efficient,
  - (ii) have a reduced environmental impact

- inform policy makers, fisheries managers and fishing industry

- a better understanding of the interaction of the trawl gear components and the seabed
    - Small scale models and laboratory trials
    - Full scale trials
    - Numerical modelling

Paschen et al (2000) – Trapese

Enerhaug (2011)

O'Neill and Summerbell (2011)

Ivanovic et al (2010)

Outline

- focus on the numerical approach
  - CEL method
  - Frame of reference
  - Non dimensionalisation
- carry out a design study
- Description of recent sea trials

Numerical model

- ABAQUS and a Coupled Eulerian-Lagrangian (CEL) method
  - Form of the model
  - Numerical approach
- ABAQUS has been used in a number of dynamic geotechnical studies
- Lagrangian framework has been used – small deformations
- For large deformations the computational grid can become misshapen – leading to stability and accuracy issues
- Coupled Eulerian-Lagrangian (CEL) method

Coupled Eulerian-Lagrangian (CEL) method

- is based upon a fixed mesh where the material is free to cross element boundaries
- accuracy is no longer affected by large material deformations as the computational grid is not fixed to a material point
- Qiu et al. (2010) showed accuracy is equivalent or better than the conventional method
- Here we extend this approach and instead of the seabed being fixed with respect to the interacting object we fix the object and move the seabed

Punch and die problem

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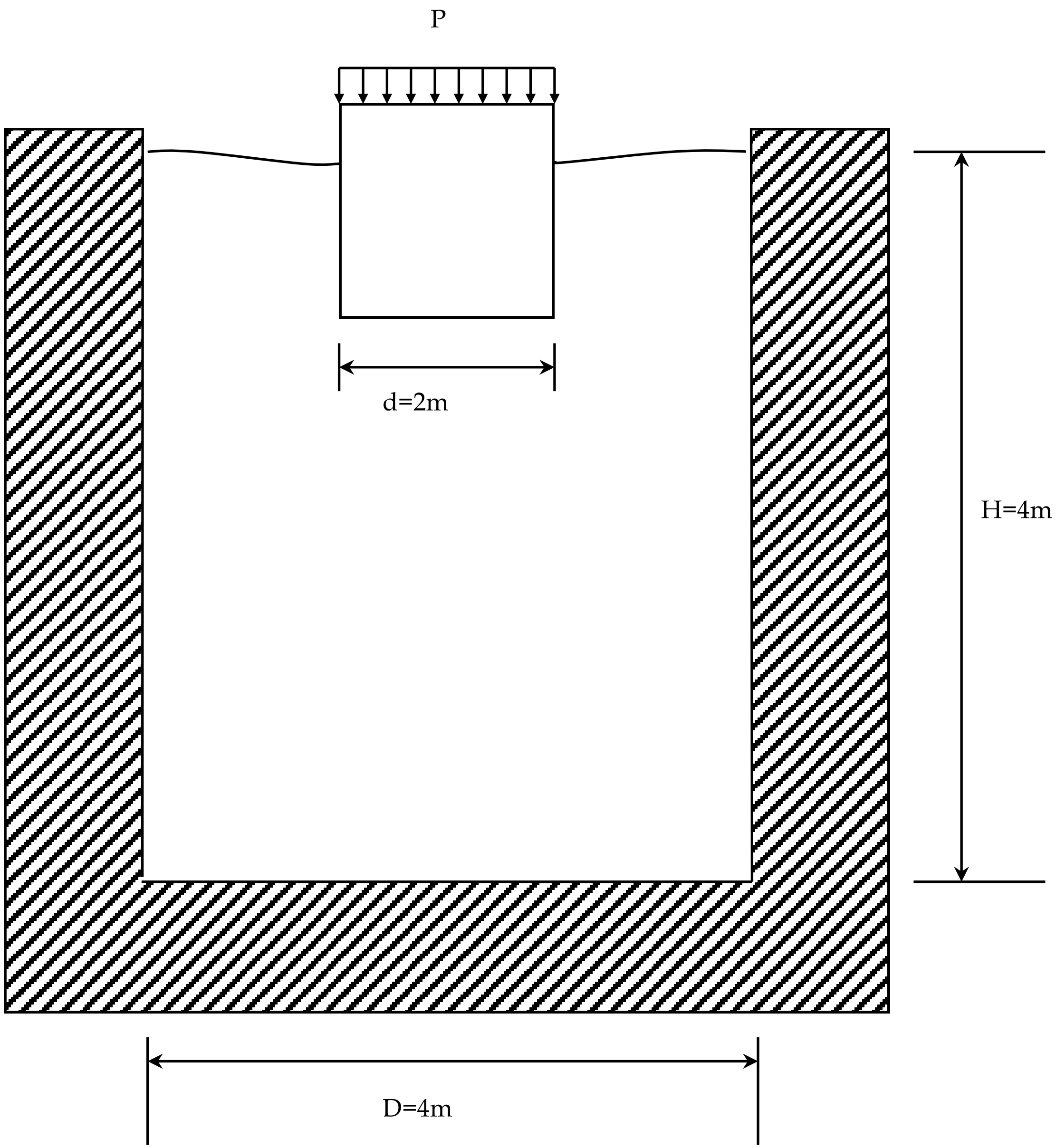

Punch and die problem

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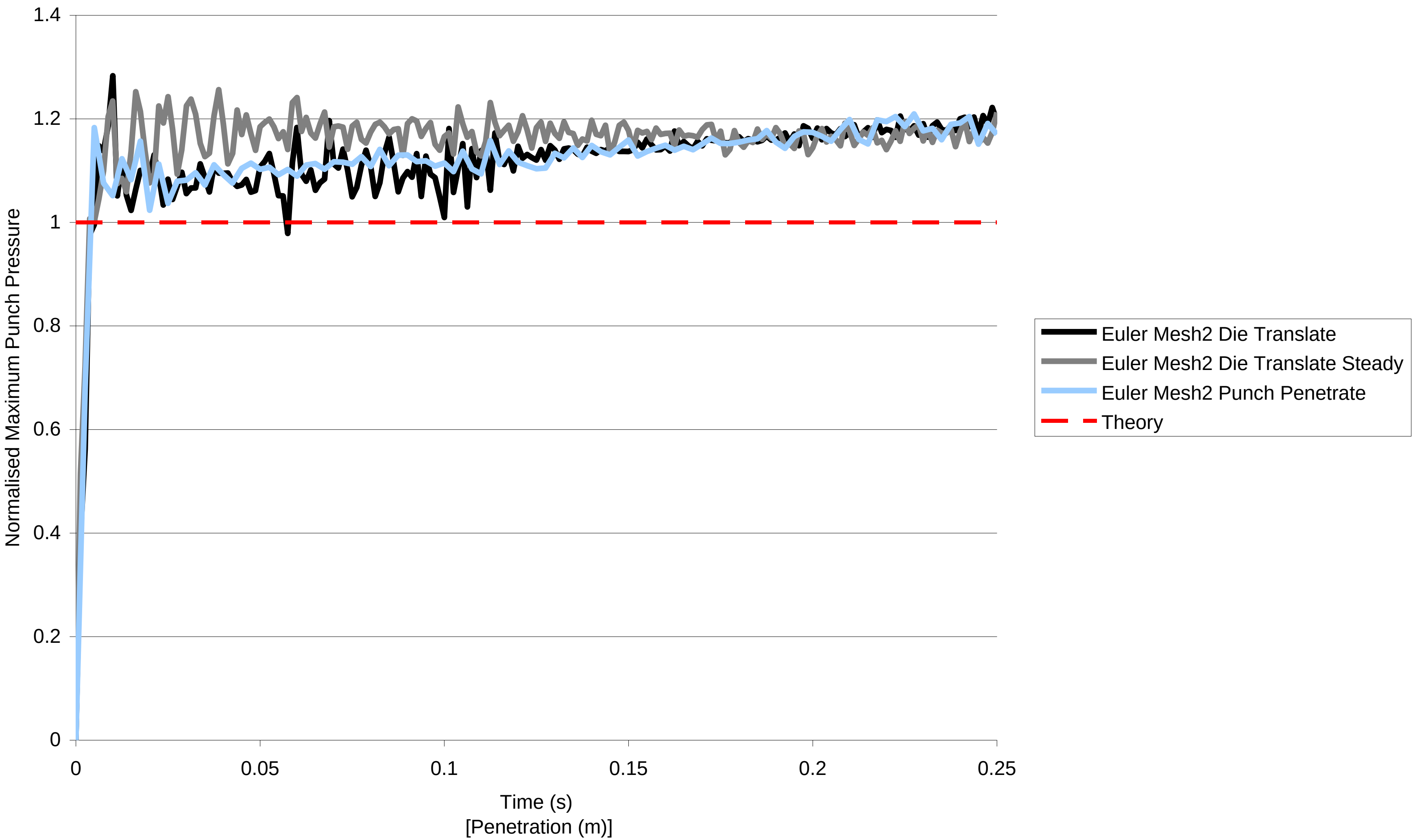

Soil/sediment model

- Many different possible models describing the constitutive relations
  - elastic perfectly plastic – saturated cohesive materials
  - Drucker – Prager model - granular materials

Conservation of linear momentum

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$$\nabla \cdot T + \rho g = \rho \left(v \cdot \nabla v \right)$$

$$T = \begin{bmatrix} \sigma_{xx} & \tau_{xy} \\ \tau_{yx} & \sigma_{yy} \end{bmatrix}$$

Non - dimensionalisation

$$T' = \frac{r}{W} T \qquad \left(x', y'\right) = \frac{1}{r}\left(x, y\right) \qquad v' = \frac{v}{V}$$

$$\nabla \cdot T' = \frac{\rho r V^2}{W}\left(v' \cdot \nabla v'\right)$$

Non - dimensionalisation

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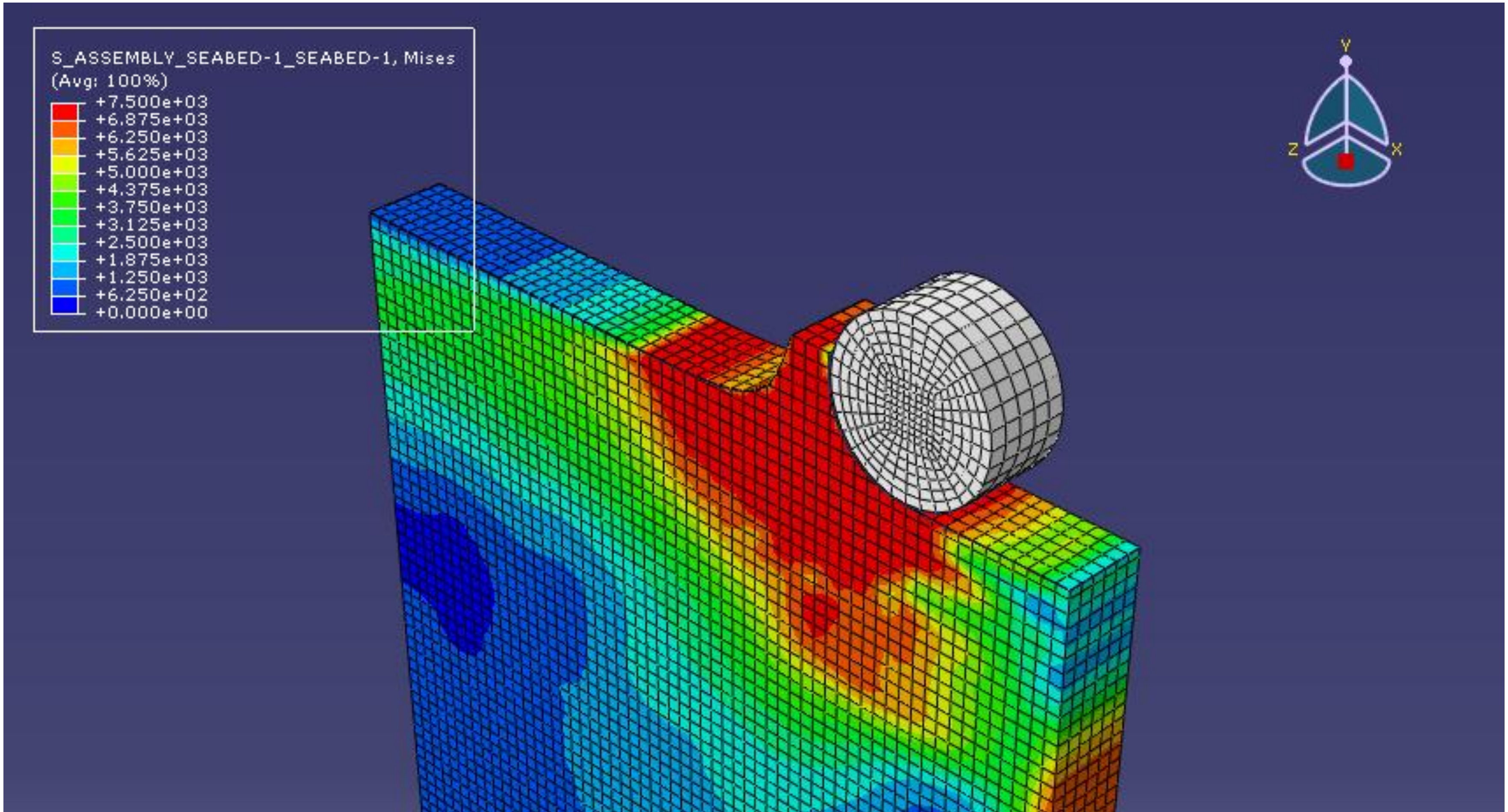
$$\frac{\rho r V^2}{W}$$



Dynamically similar solutions

σ_y (N/m²)	ρ (kg/m³)	v (m/s)	r (m)	F_V (N)	s (m)	$\frac{\rho V^2}{\sigma_y}$	s/r	F_H (N)
7500	1000	1	1	17500	0.21	**0.133**	0.21	12600
10000	1000	1	1	17500	0.05	**0.1**	0.05	3350
12500	1000	1	1	17500	0.02	**0.08**	0.02	1170
1875	62.5	2	2	17500	0.43	**0.133**	0.215	12576
2500	62.5	2	2	17500	0.09	**0.1**	0.045	3605
3125	62.5	2	2	17500	0.04	**0.08**	0.02	1315

Numerical approach

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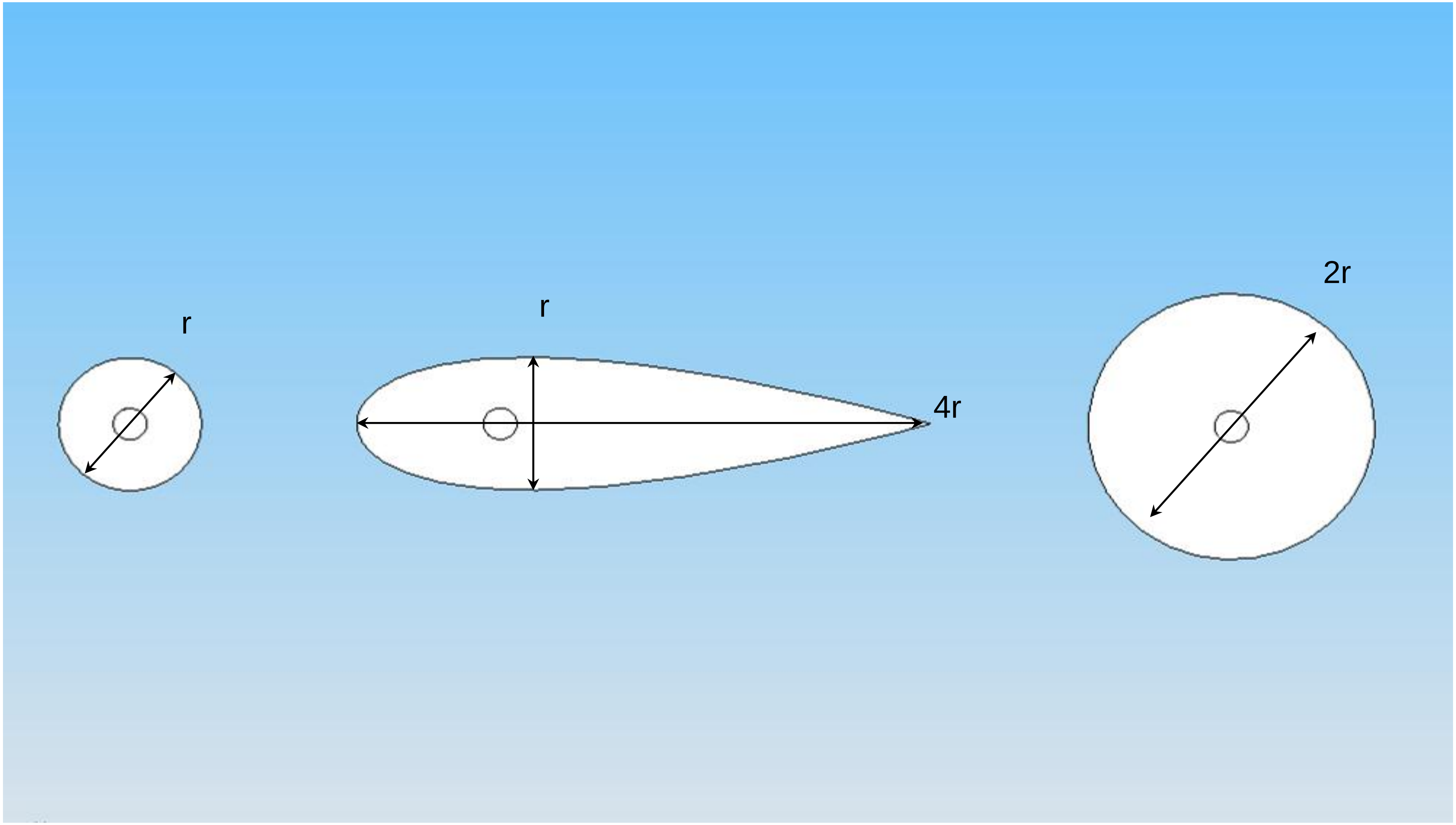
- CEL method

- Frame of reference

- Non dimensionalisation

Design study



Pelodynamic drag

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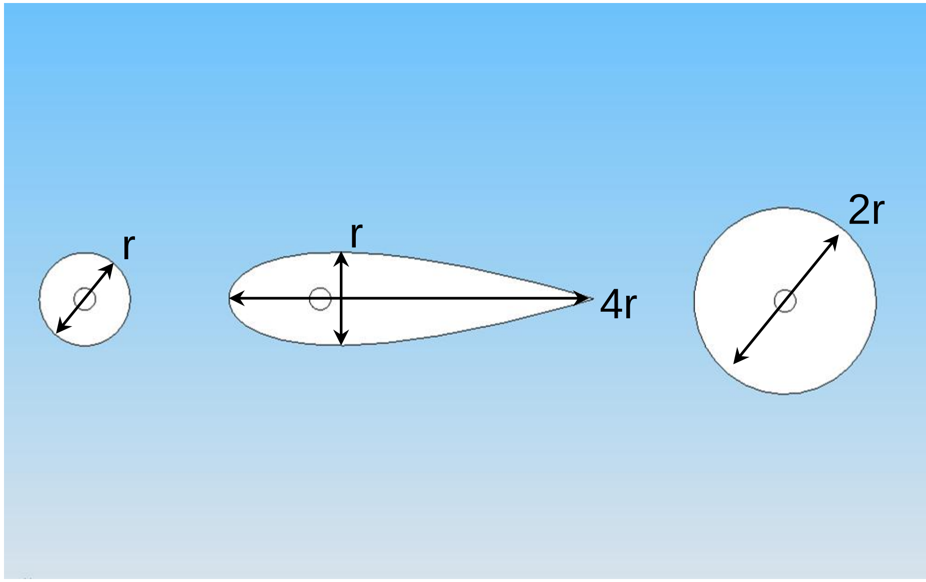
- The drag forces acting upon the fishing gear comes both from it passing through water and from it passing through the deforming seabed.
- To distinguish between the two process we adopt the term **pelodynamic** to describe the dynamic interaction of an object with the seabed. It comes from the Greek work for mud, earth or clay and also from the verb to push, beat or strike.
- **pelodynamic** will be used for the seabed induced forces and the usual term **hydrodynamic** will be used for water induced forces

Design study

- disc of diameter r
- disc of diameter 2r
- an aerofoil with length 4r and height r

- r = 1m
- vertical load of 17.5kN
- seabed has a yield stress of 7.5kPa
- density of 1000kg/m^3
- Young's modulus of 1GPa
- Poisson's ratio of 0.48



Design study

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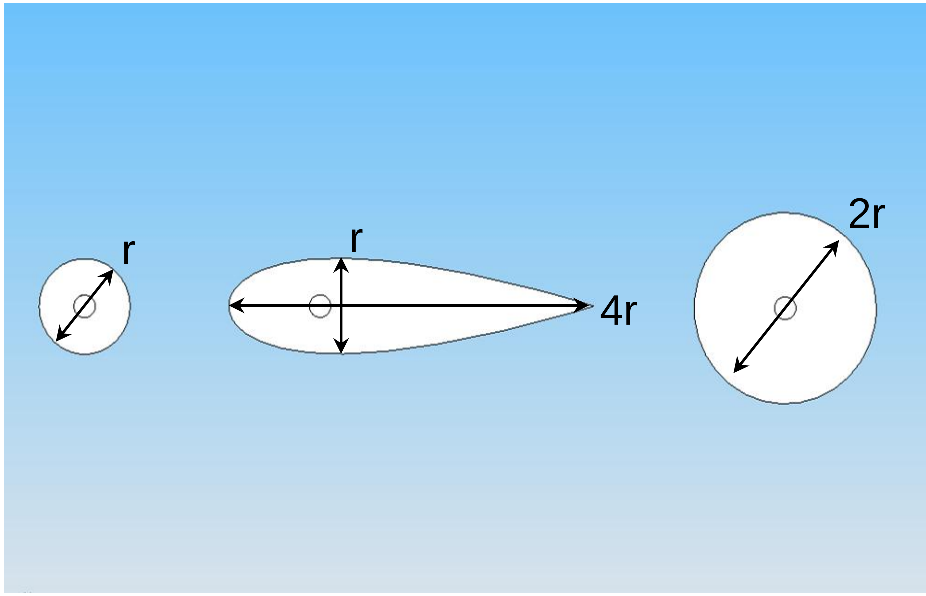
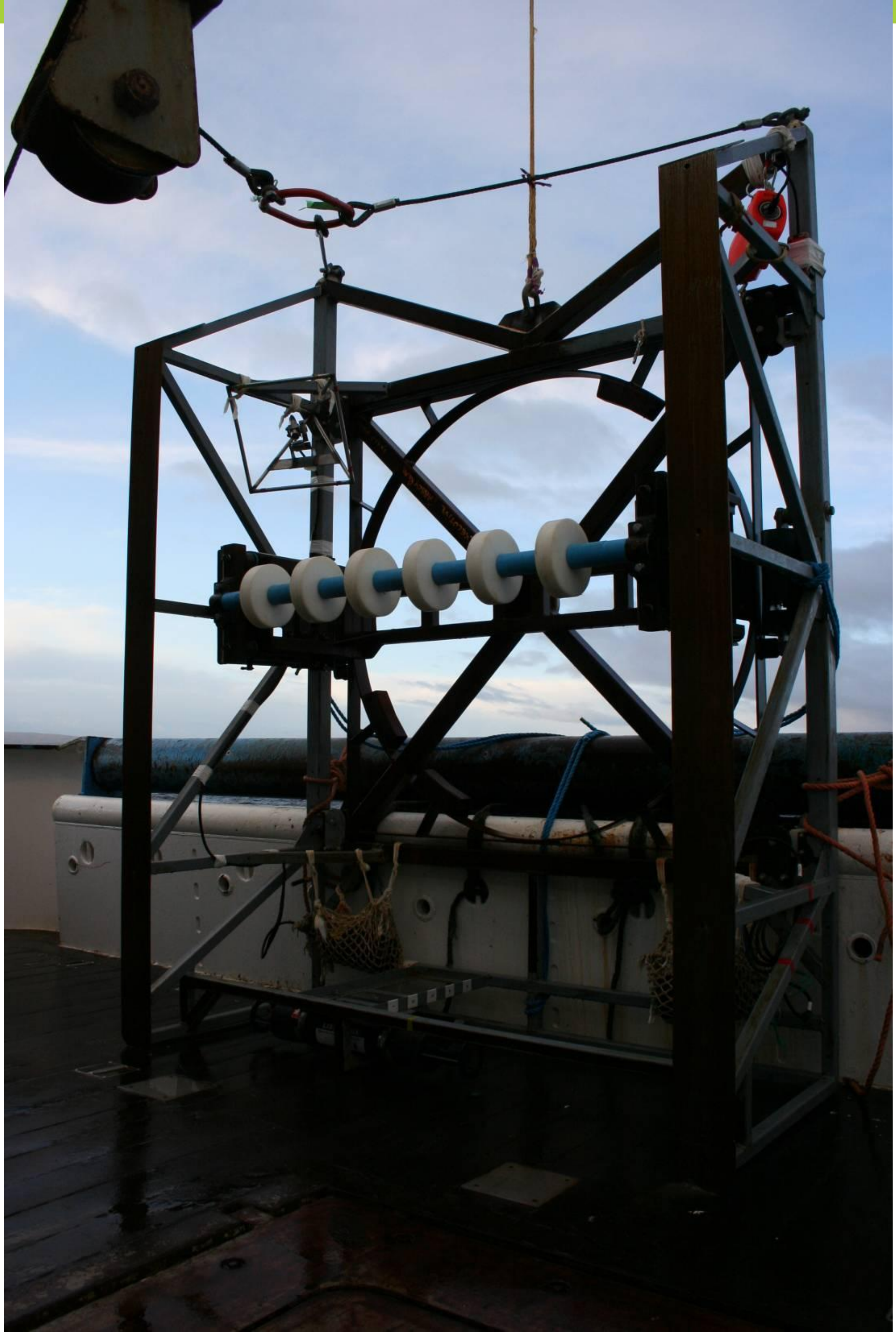
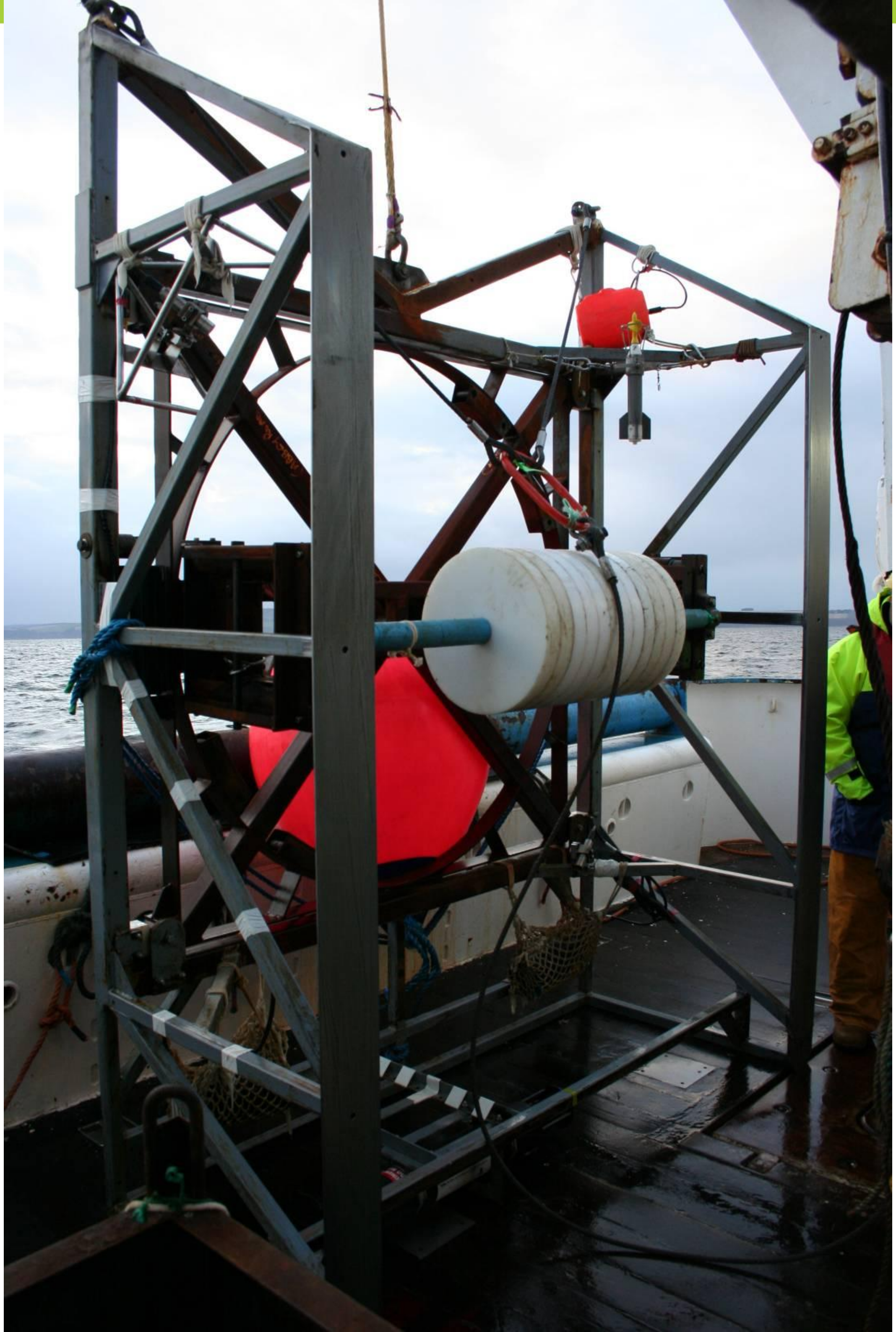
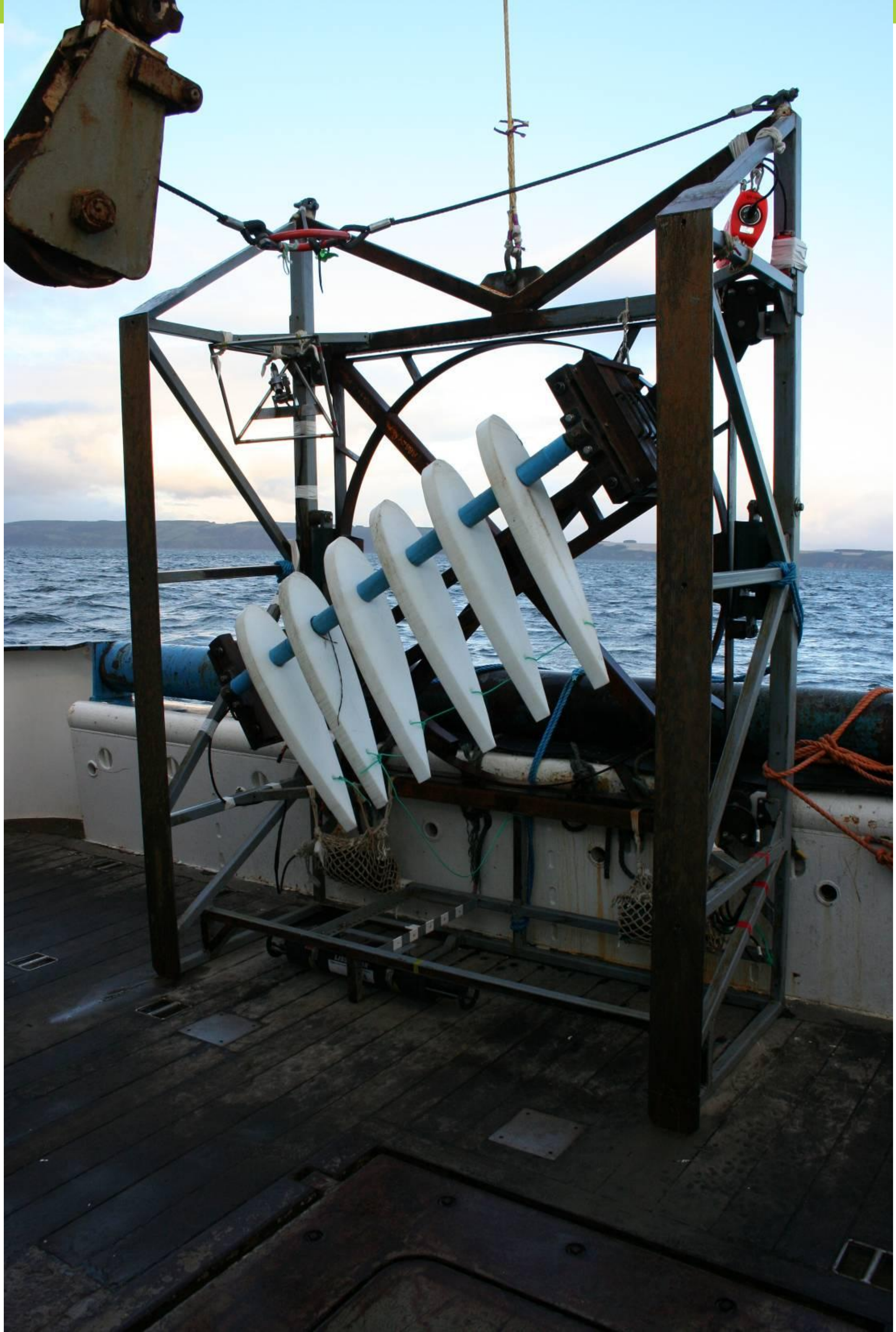
Shape	Maximum sinkage (m)		F_H (N)		Hydrodynamic drag
r	0.21		12878		
2r	0.13	~ 40%	5941	~ 50%	~ 100%
aerofoil	0.08	~ 60%	1906	~ 85%	~ 90%









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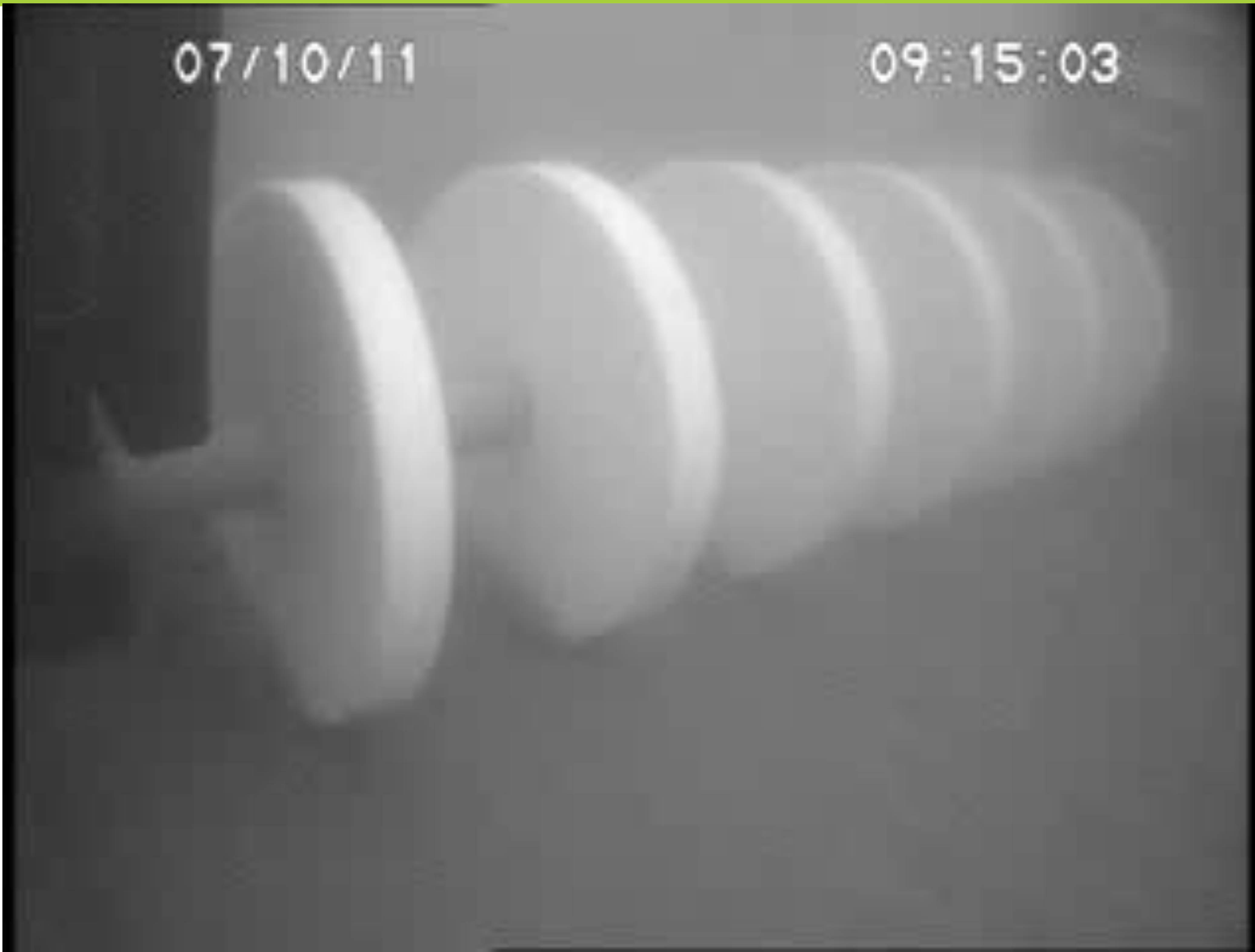
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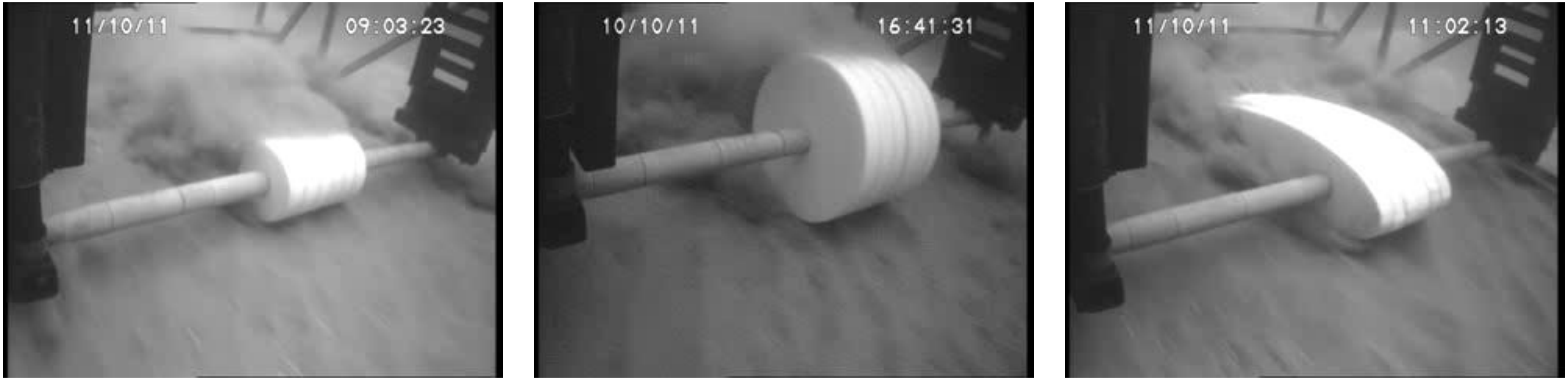
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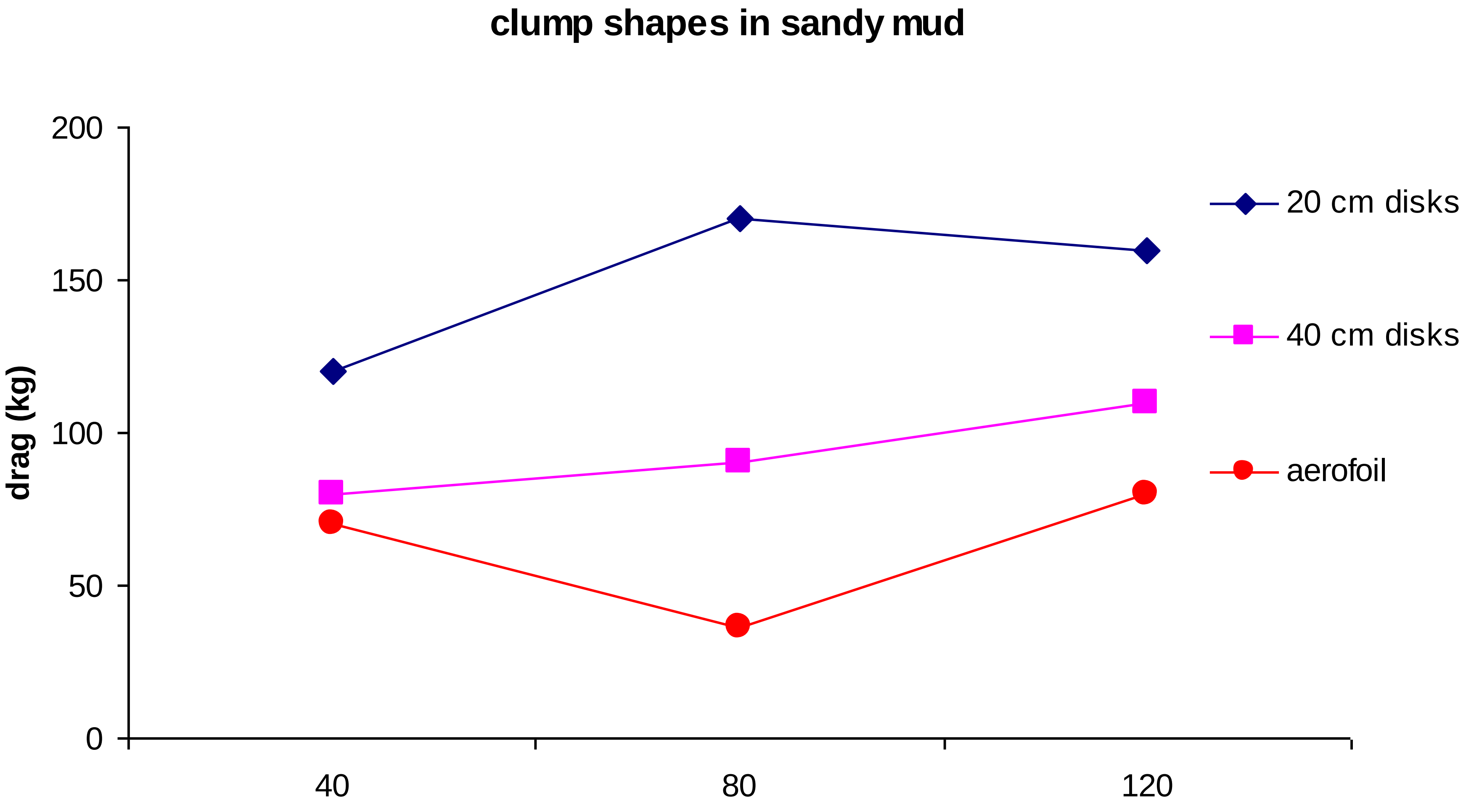
clump shapes in sandy mud
drag (kg)
200
150
100
50
0
40
80
120
20 cm disks
40 cm disks
aerofoil

In summary

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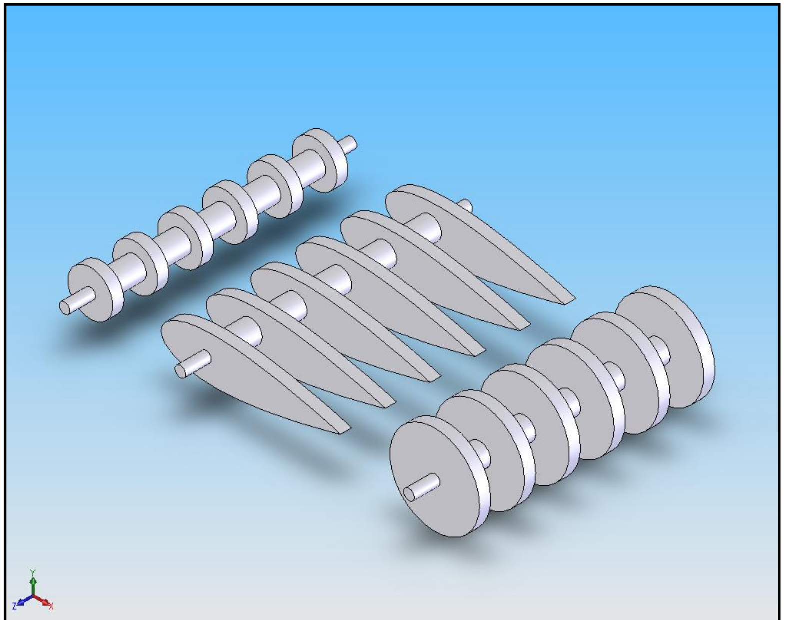
- Accuracy and stability of the numerical solutions can be improved by employing the CEL method and changing reference frame

- Can possibly make more of the solutions by non-dimensionalising

- Simple design modifications can lead to large reductions of both pelo- and hydrodynamic drag



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