



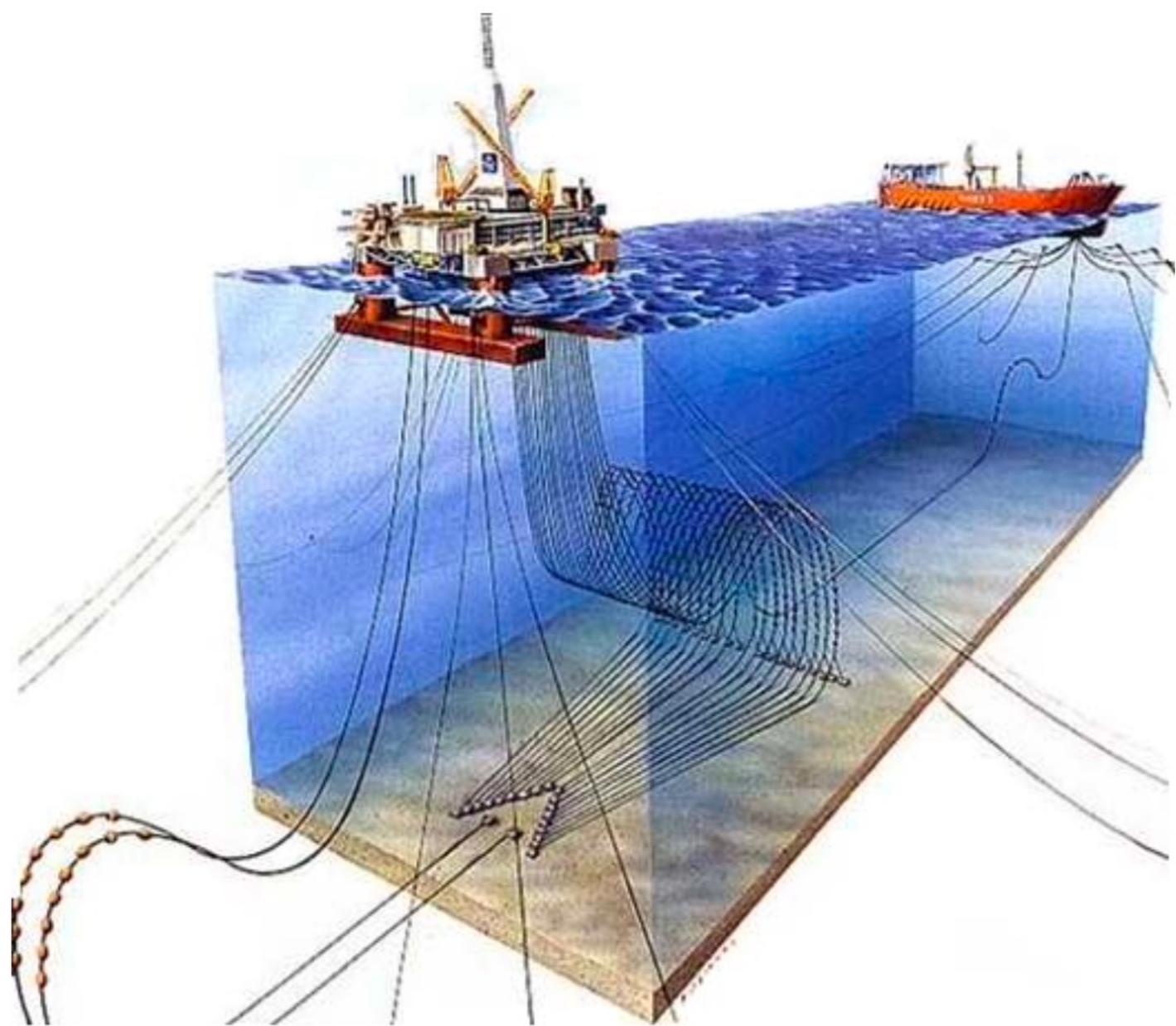
PNV5301

Supressão e amplificação de vibrações
induzidas pelo escoamento

PROF. DR. GUSTAVO ROQUE DA SILVA ASSI

DEPARTAMENTO DE ENGENHARIA NAVAL E OCEÂNICA
ESCOLA POLITÉCNICA DA UNIVERSIDADE DE SÃO PAULO





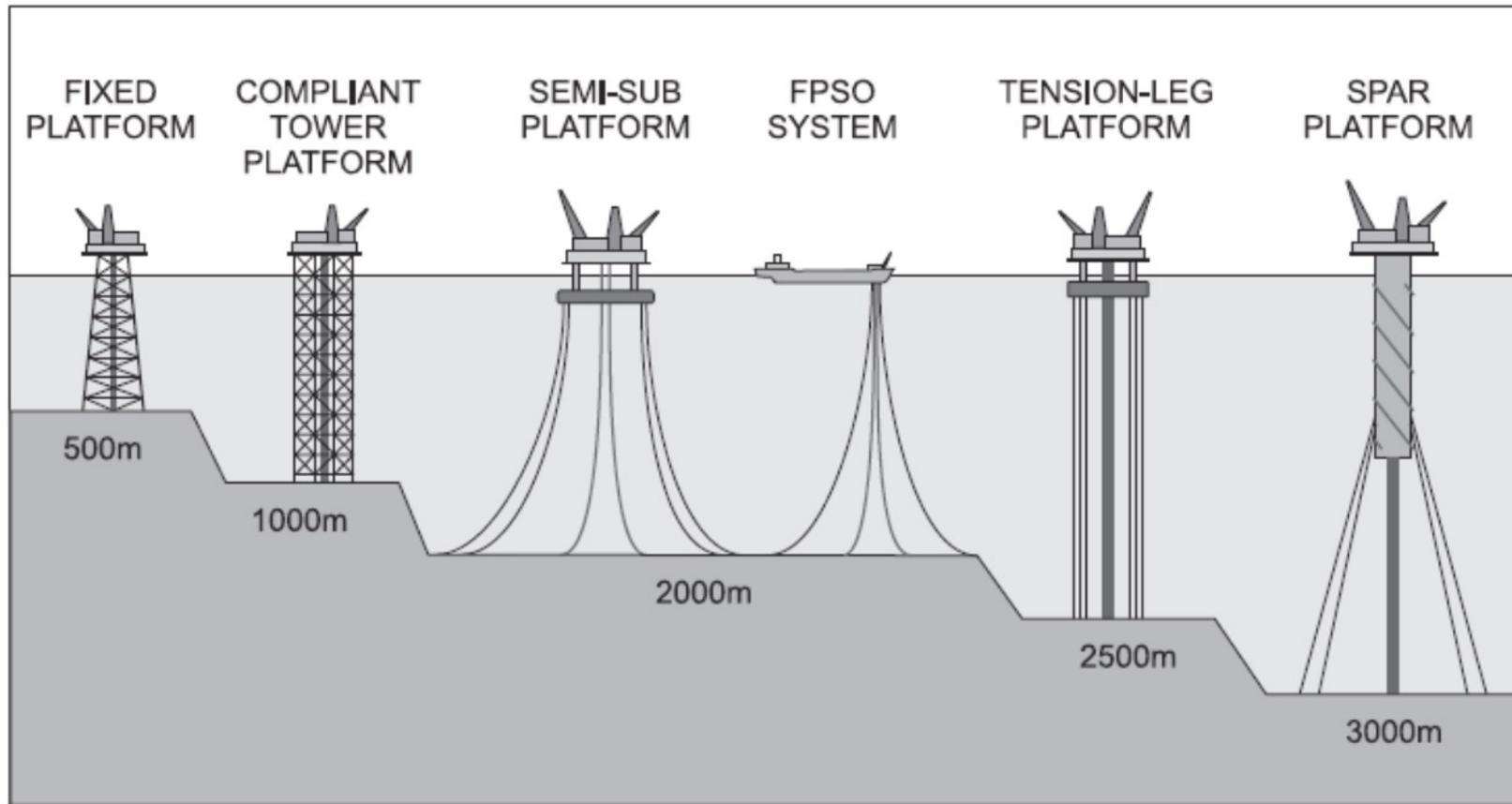


Figura 1: Tipos de plataformas de petróleo onde se verifica a presença de elementos cilíndricos, como cabos e dutos, sob a ação da corrente marítima (Assi, 2009).

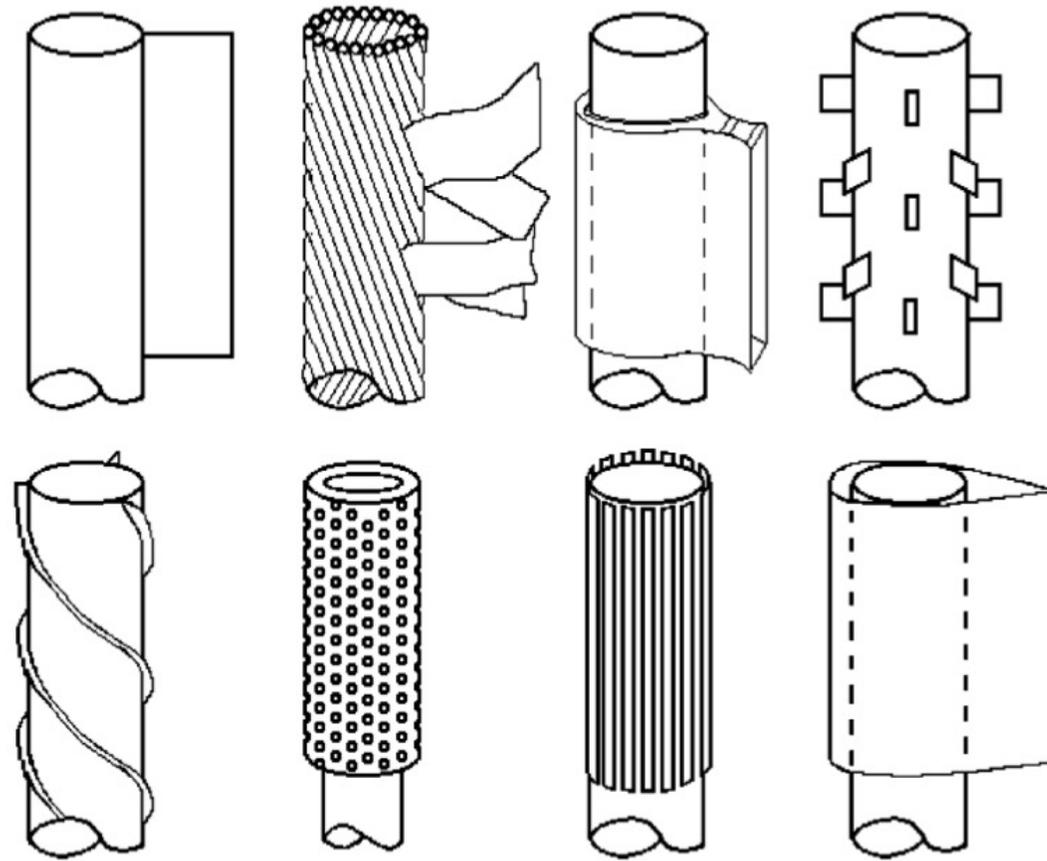
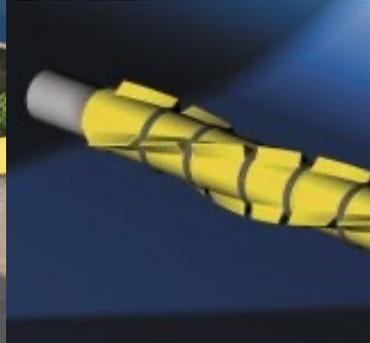
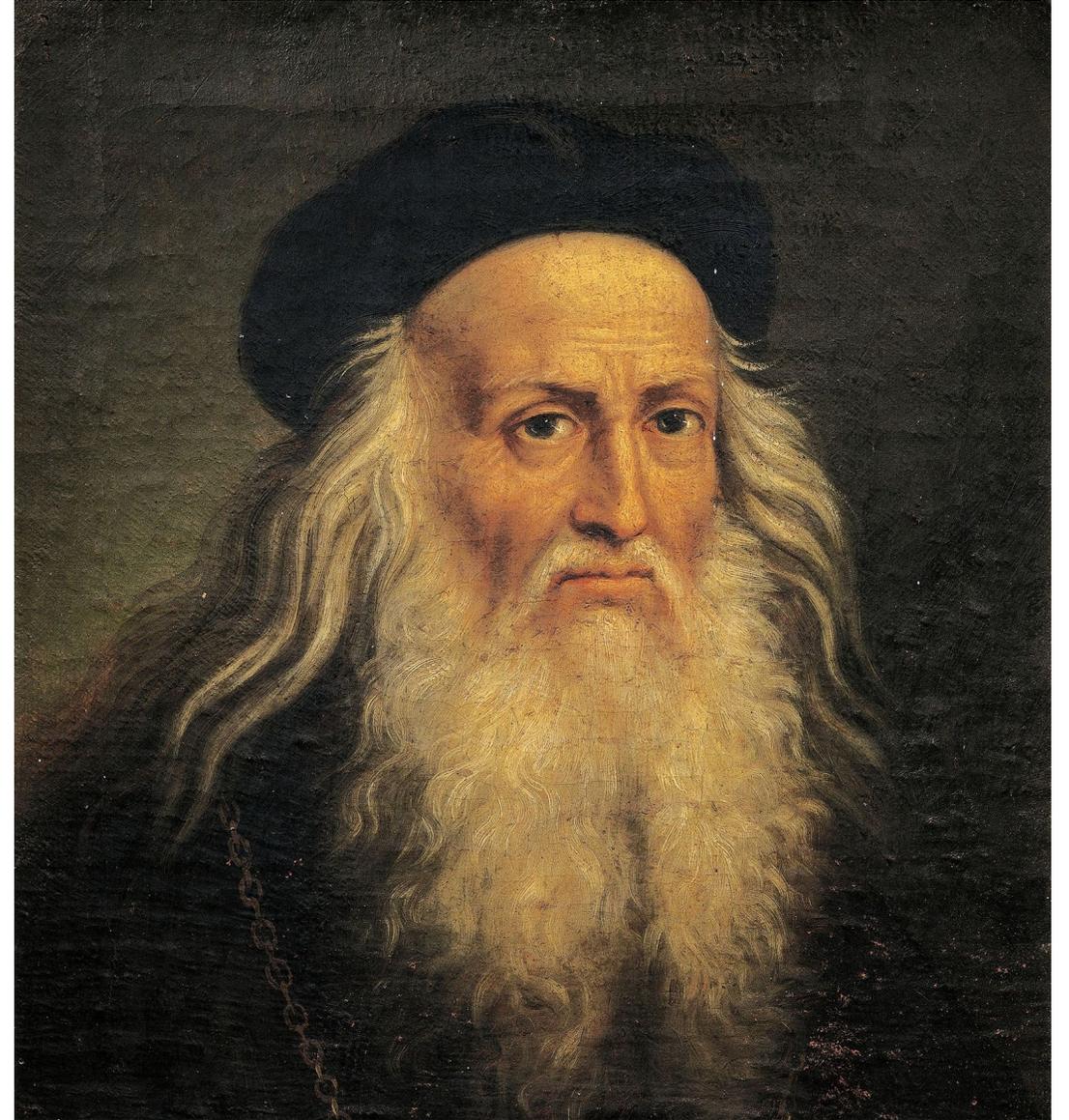


Figura 2: Exemplos de supressores de VIE. Reproduzido de Blevins (1990).





Leonardo Da Vinci
(1452 – 1519)



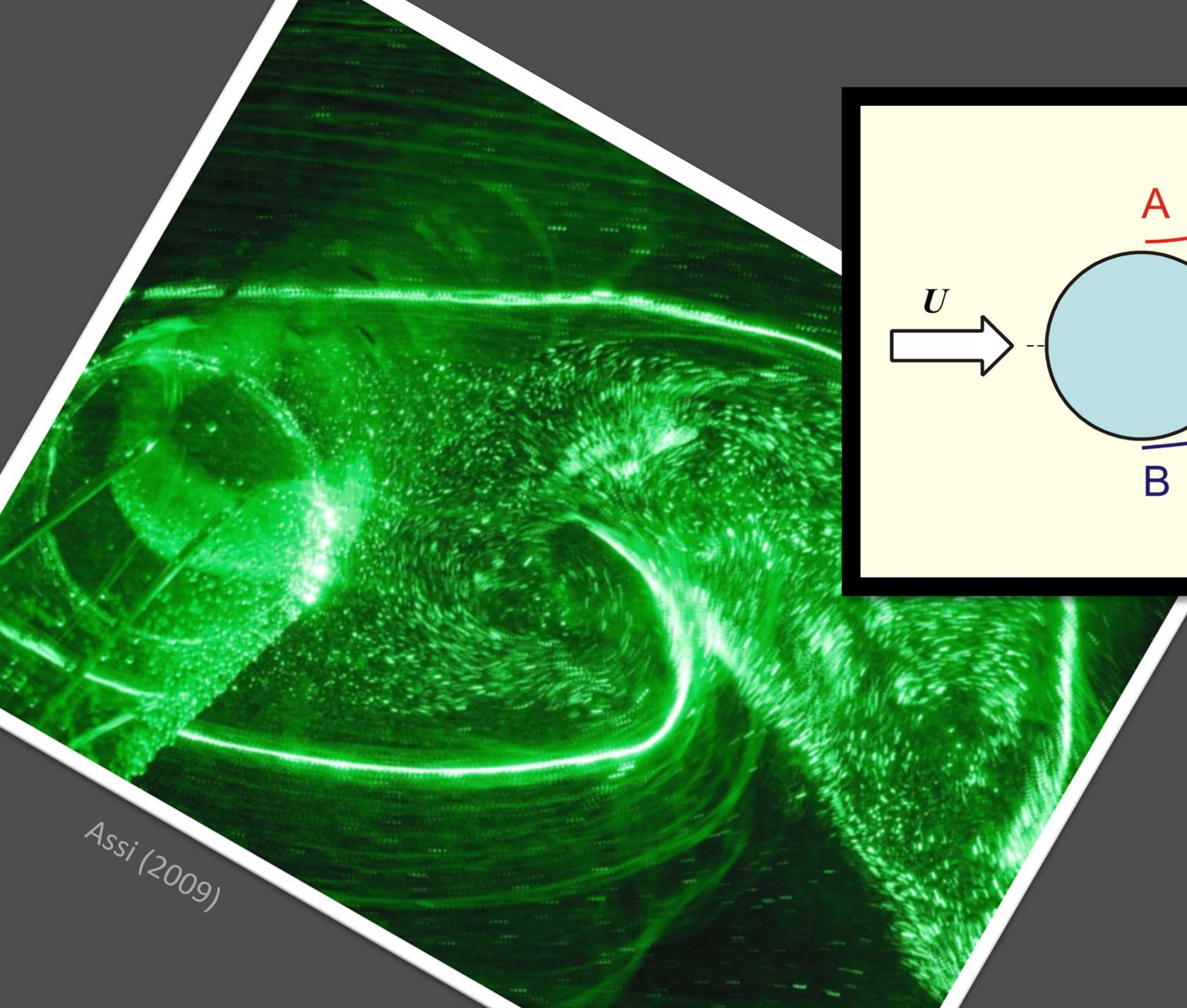
CONHECIMENTO
CIENTÍFICO
(INVESTIGAÇÃO)

CONHECIMENTO
EMPÍRICO
(EXPERIÊNCIA)

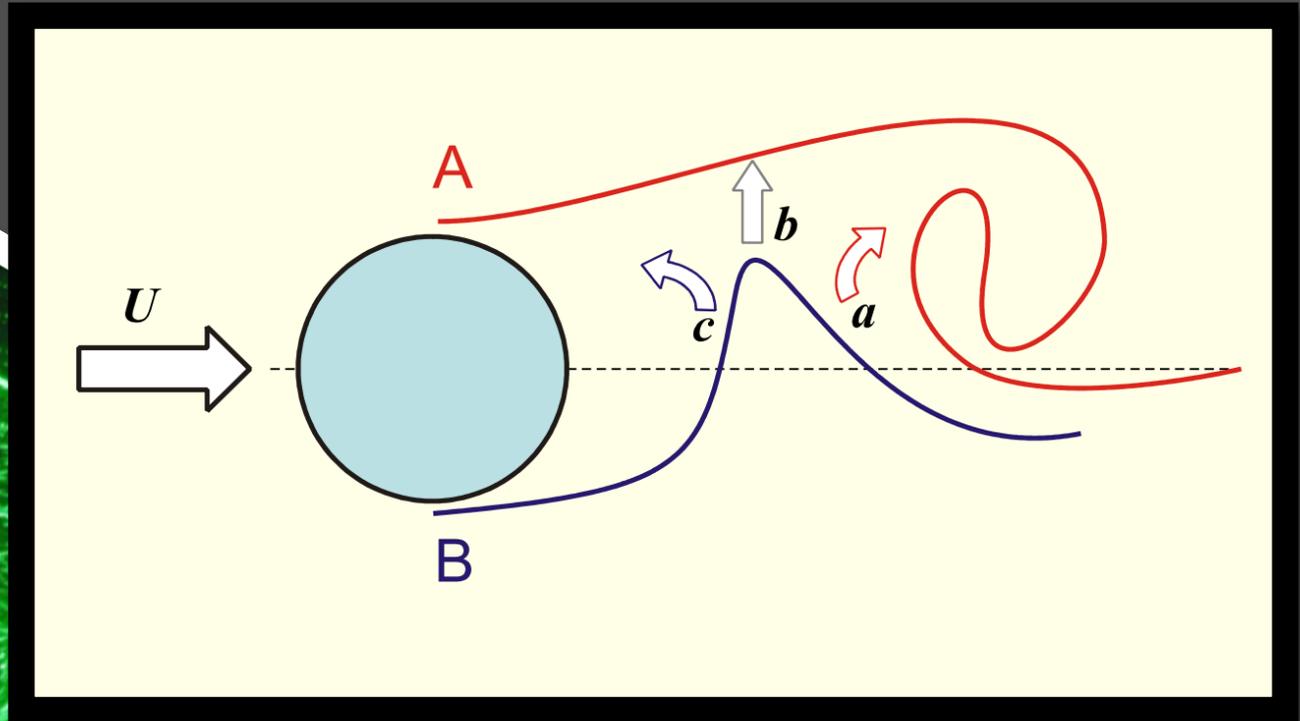
DESENVOLVIMENTO
TECNOLÓGICO

UTILIDADE





Assi (2009)



Gerrard (1966)



KARAKA!

"Cientistas estudam o mundo como ele é.

Engenheiros criam o mundo que nunca houve."

OBSERVAR

MEDIR

COMPREENDER

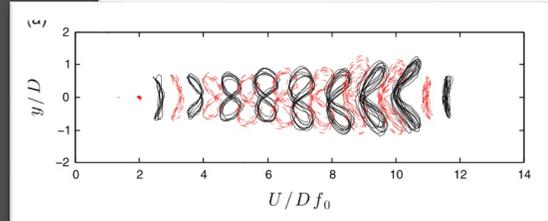
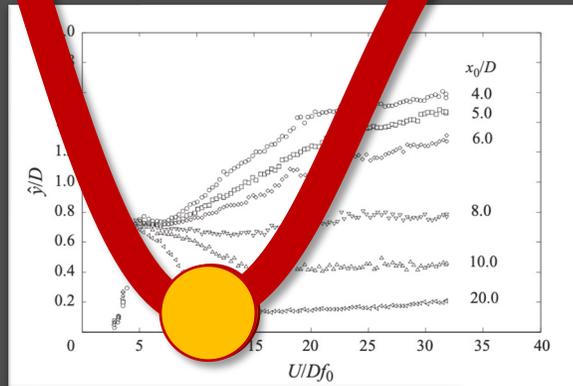
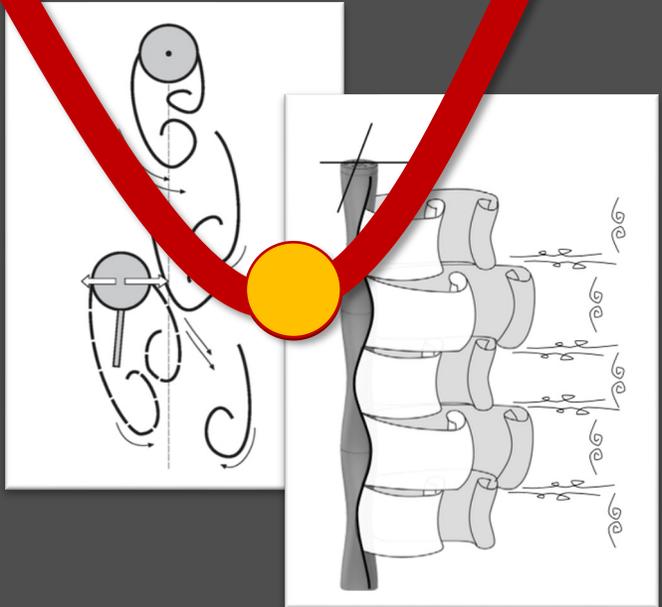
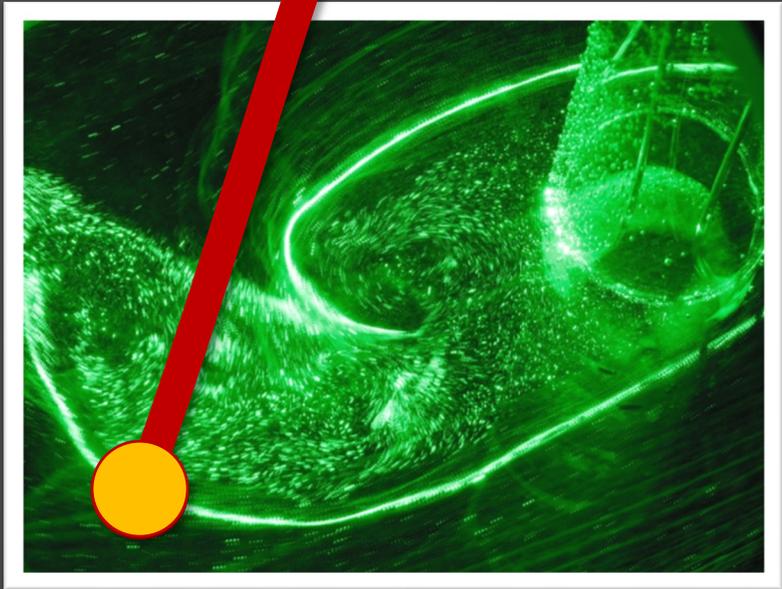
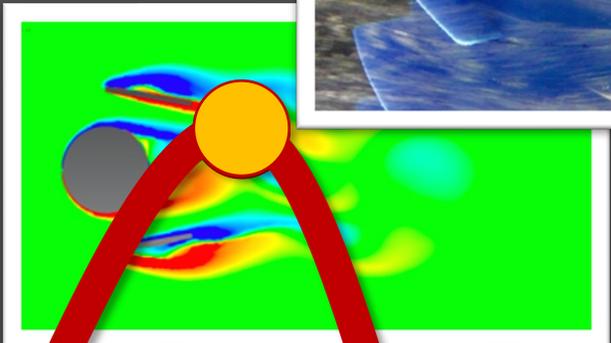
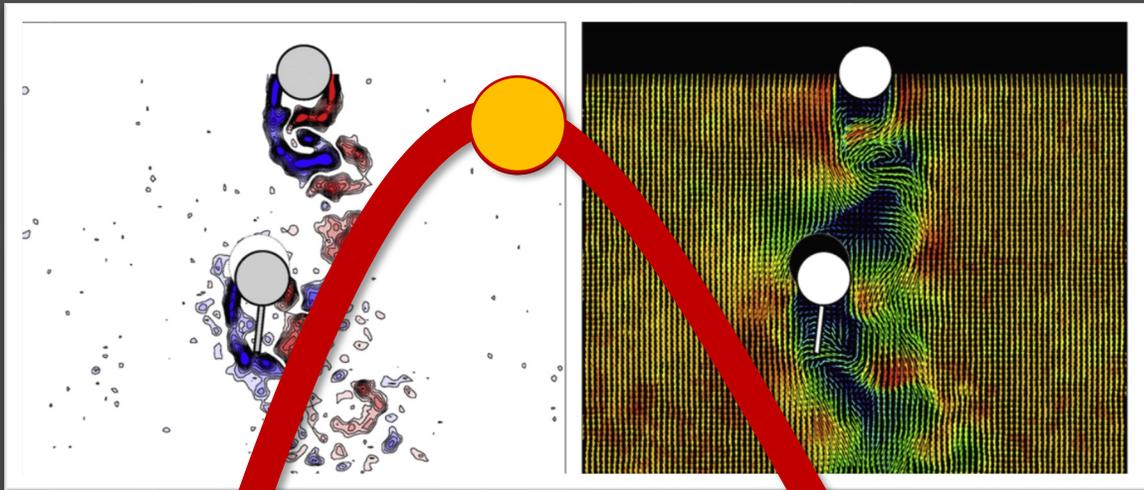
CRIAR

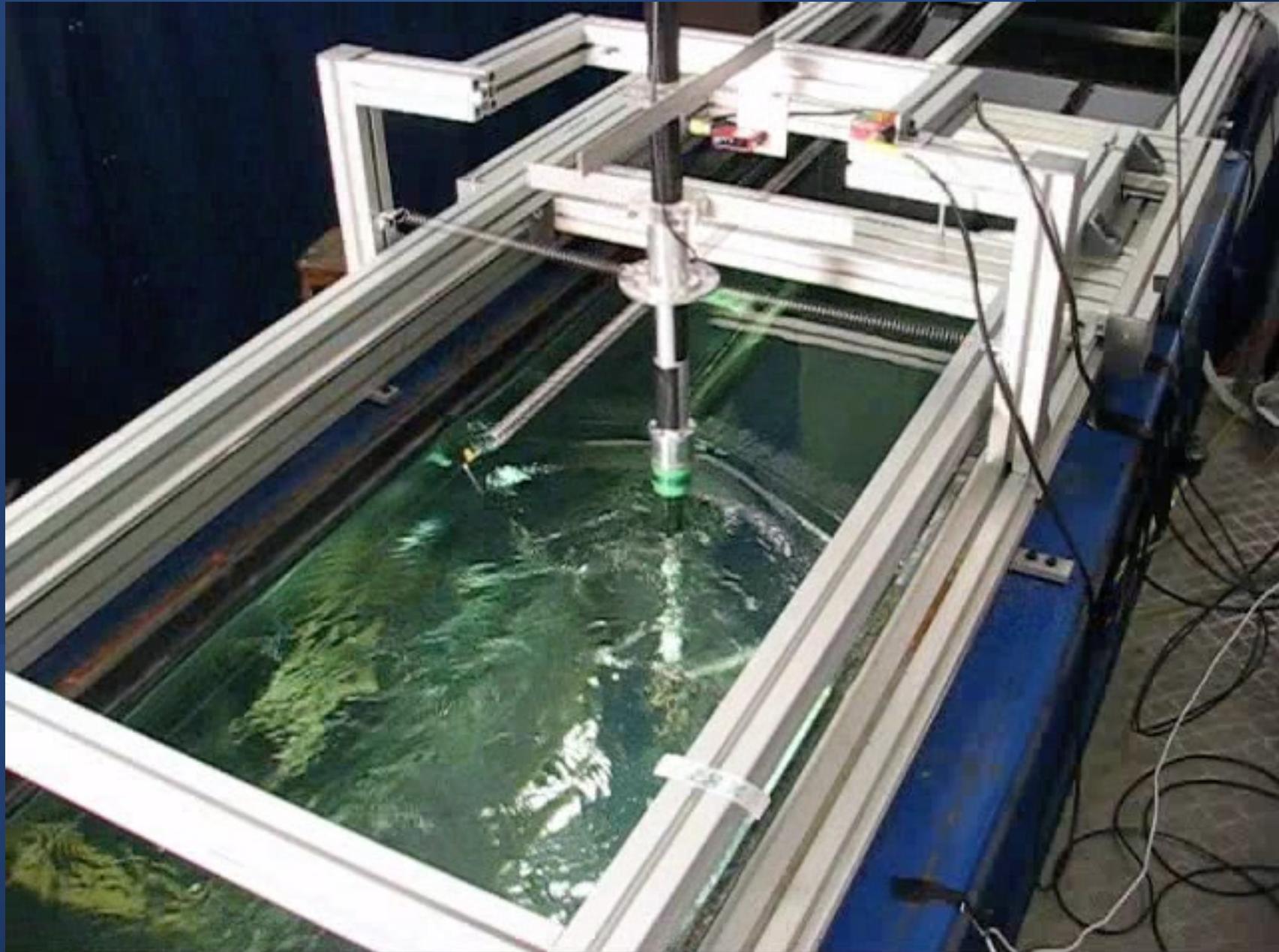
AVALIAR

UTILIZAR



Theodore Von Karman
(1881 – 1963)





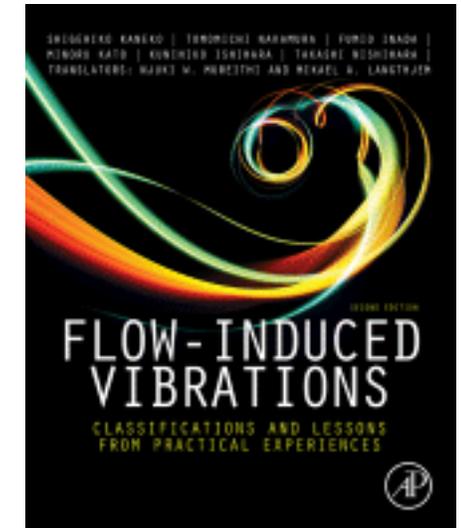
The background features a dark blue field with intricate, glowing patterns of light blue and white. These patterns consist of concentric, wavy lines and scattered particles, creating a sense of dynamic movement and depth, reminiscent of fluid flow or wave propagation.

Flow-induced vibration

PNV5301

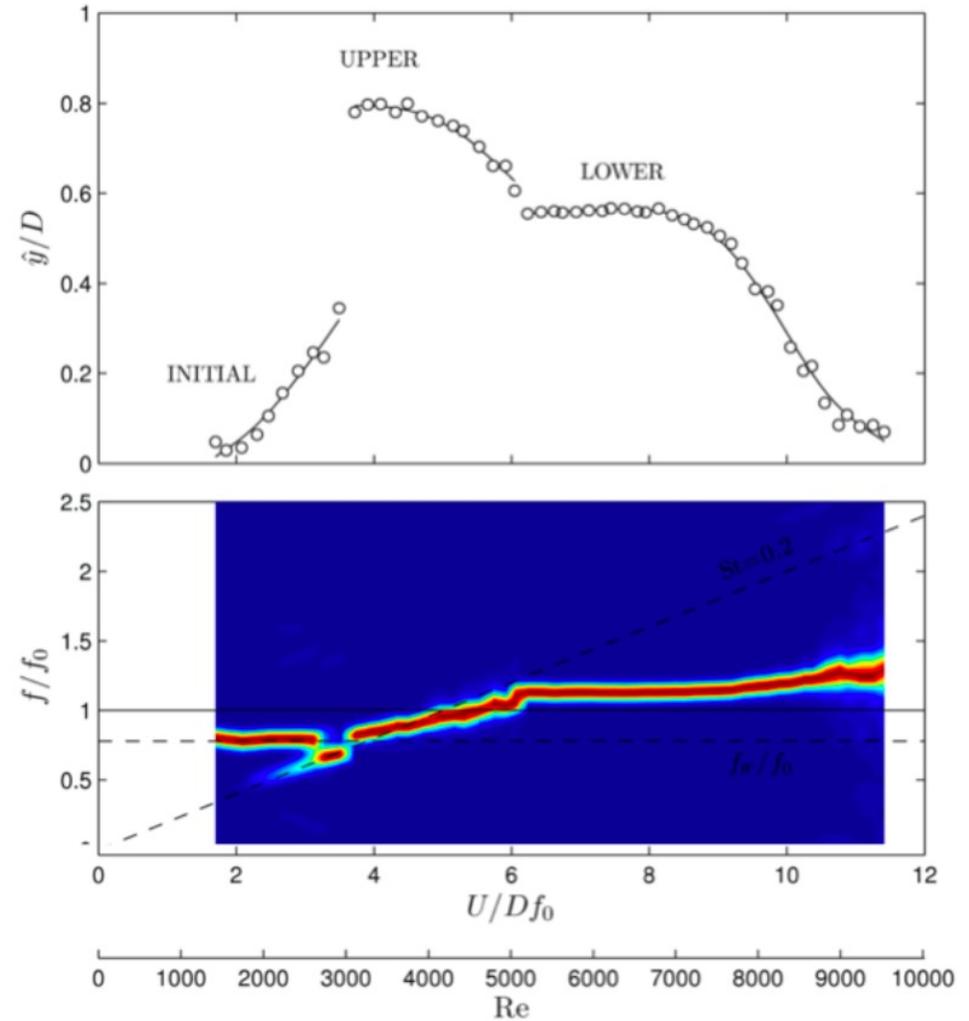
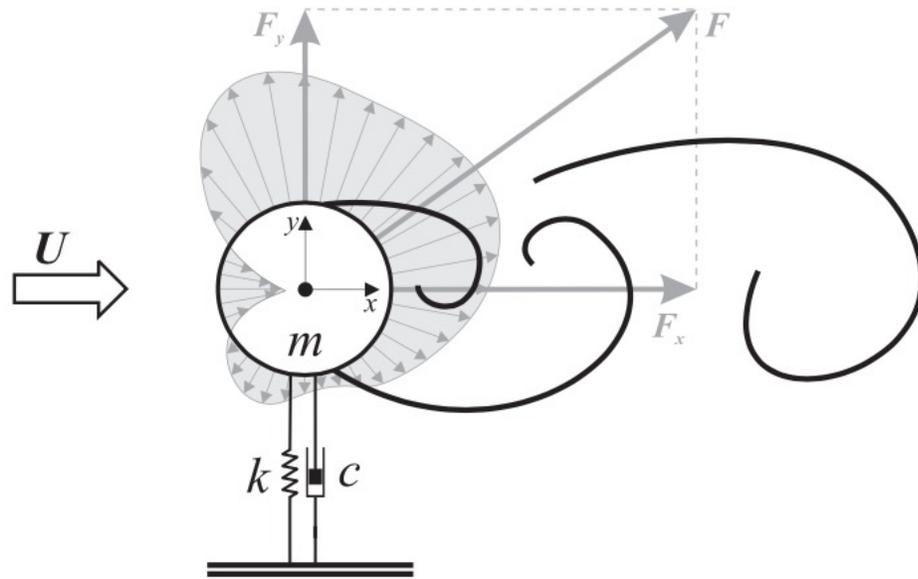
Gustavo R. S. Assi

Fluid and flow	Flow field	Vibration mechanism	Example	Corresponding section number(s)
Single-phase flow	External flow	Vortex induced vibration (VIV)	<ul style="list-style-type: none"> Resonant vibration Forced vibration 	2.1, 2.2
		Acoustic resonance	<ul style="list-style-type: none"> Acoustic resonance Cavitation 	2.5 5.5
Steady flow	Internal flow	Fluidelastic vibration	<ul style="list-style-type: none"> Wing flutter and galloping Fluidelastic vibration of tube arrays Vibrations induced by seals 	2.4, 3.1, 3.2, 3.3, 7.1 2.3 7.3
		Surging	<ul style="list-style-type: none"> Compressor surge Pump surging 	5.1 5.2
Unsteady flow	Pulsating flow	Vibration of piping	<ul style="list-style-type: none"> Piping, bellows, collapsible tubes 	4.1, 4.2, 4.3
		Forced vibration	<ul style="list-style-type: none"> Vibration due to internal fluid oscillations 	4.1, 5.1 4.1, 5.1
	Acoustically induced vibration	<ul style="list-style-type: none"> Combustion-induced vibration 	6.1	
	Turbulent flow	Random vibration	<ul style="list-style-type: none"> Buffeting Vibration of reactor internals 	2.1, 2.2, 2.3, 2.4, 3.2, 6.1 2.3, 3.1, 3.2
	Sudden change in flow	Pressure pulsation	<ul style="list-style-type: none"> Valve vibration Water hammer 	5.4 5.3
Two-phase flow	Bubble-induced vibration		<ul style="list-style-type: none"> Sloshing 	8.2
		Thermal-hydraulic vibration with phase change	<ul style="list-style-type: none"> Vibration caused by condensation Instability caused by boiling 	6.2 6.3
	Vibration of piping by two-phase flow			2.2, 2.3, 4.1



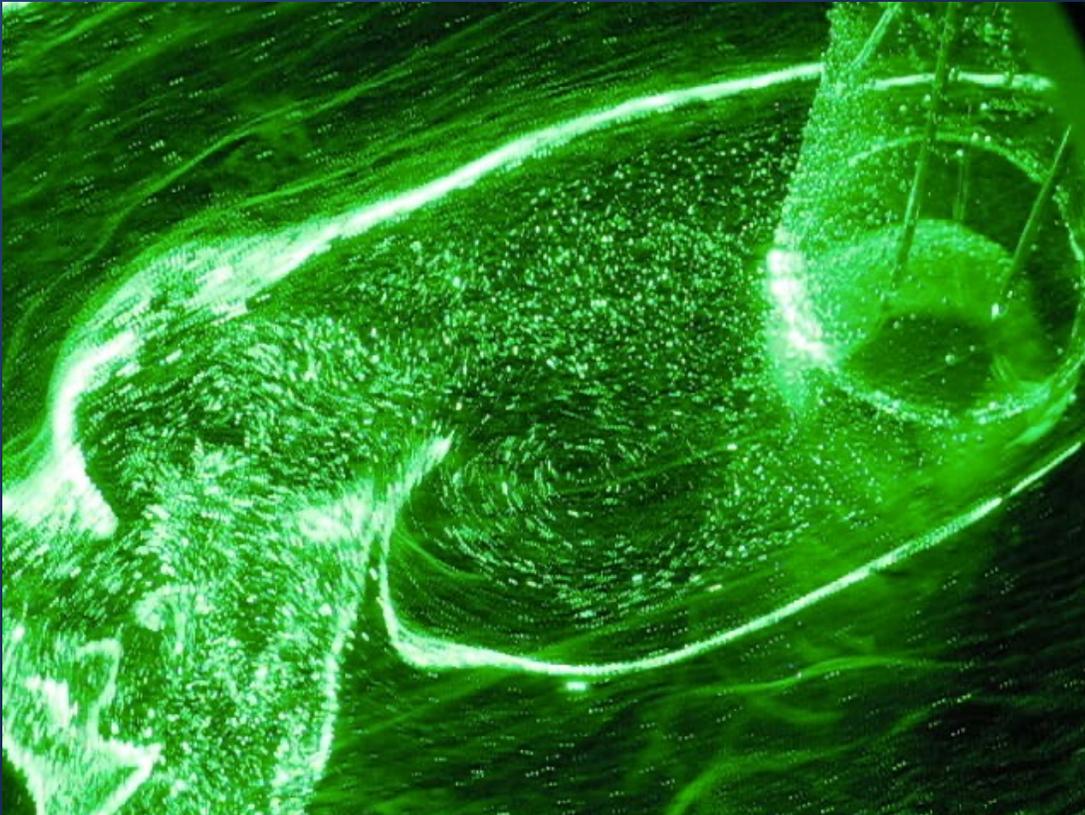
Supressão de Vibrações Induzidas pelo Escoamento

Vibrações Induzidas por Vórtices

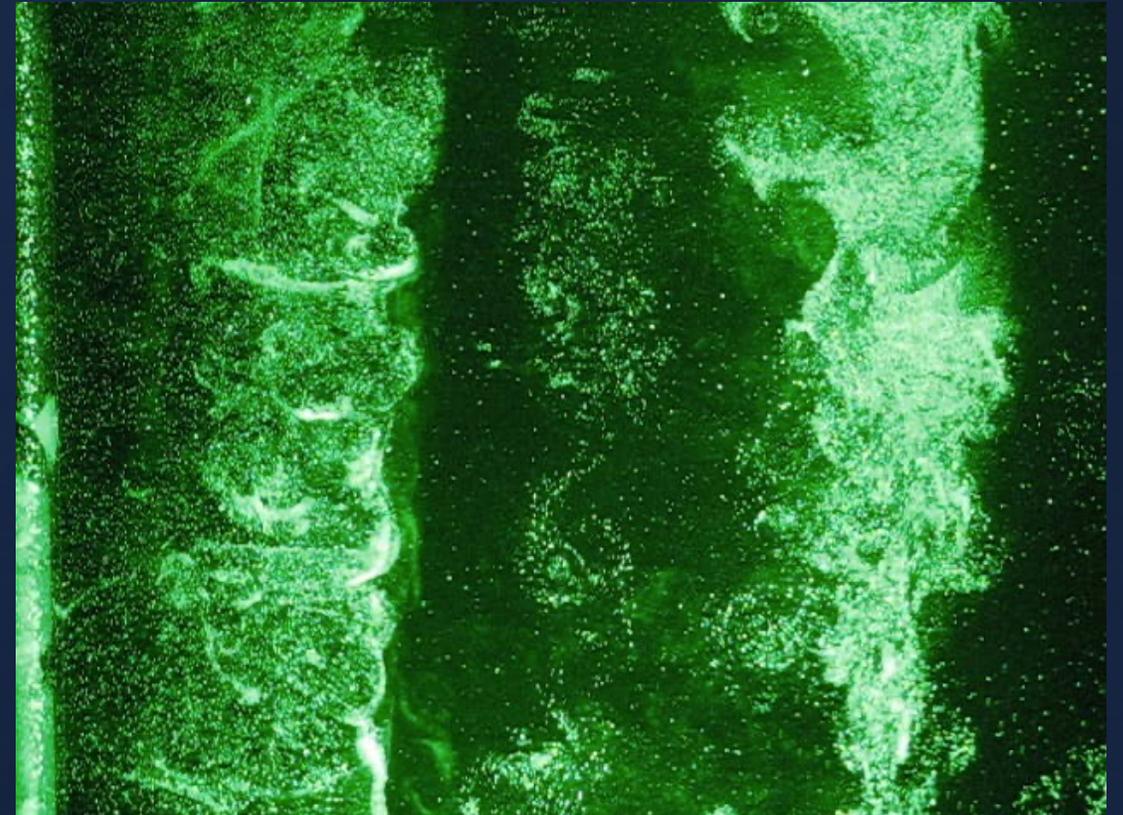


SUPRESSORES COM MECANISMOS DE NATUREZA

BIDIMENSIONAL



TRIDIMENSIONAL



SUPRESSORES BIDIMENSIONAIS

SISTEMAS PIVOTANTES

PLACA PLANA

FAIRINGS

PLACAS INCLINADAS

PLACAS PARALELAS

PLACAS OBLÍQUAS

CILINDRINHOS DE CONTROLE
ROTATIVOS

SUPRESSORES TRIDIMENSIONAIS

STRAKES HELICOIDAIS

STRAKES CONVENCIONAIS

STRAKES NÃO CONVENCIONAIS

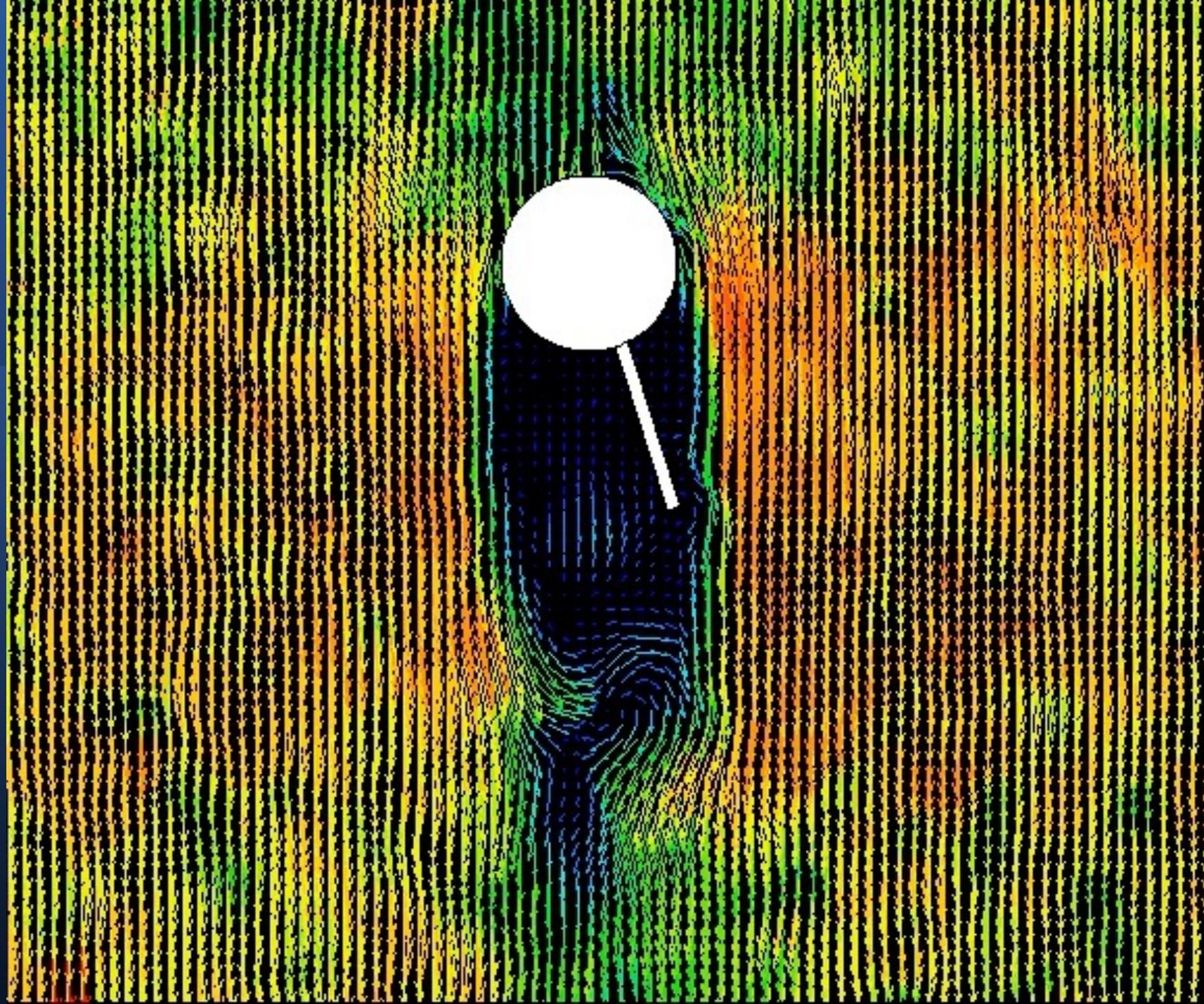
MALHAS PERMEÁVEIS

“VENTILATED TROUSERS”

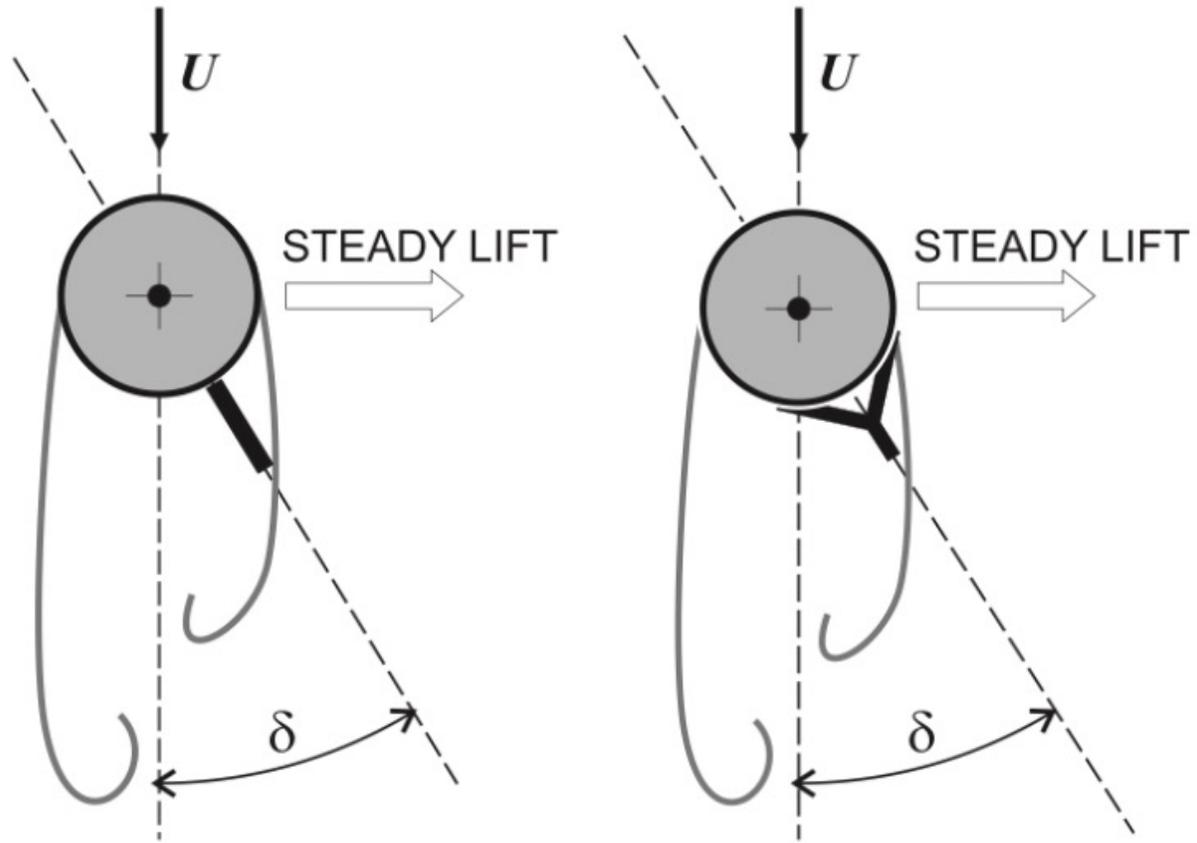
OUTRAS MALHAS

CILINDRO ONDULADO E ELÍPTICO

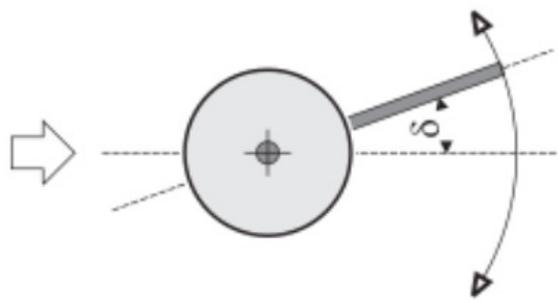
2D PIVOTANTES



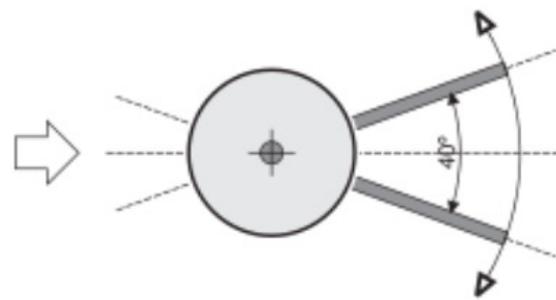
2D | PIVOTANTES



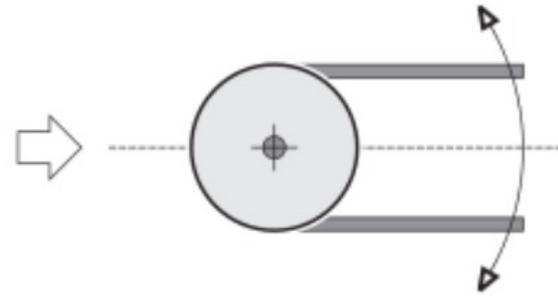
2D | PIVOTANTES



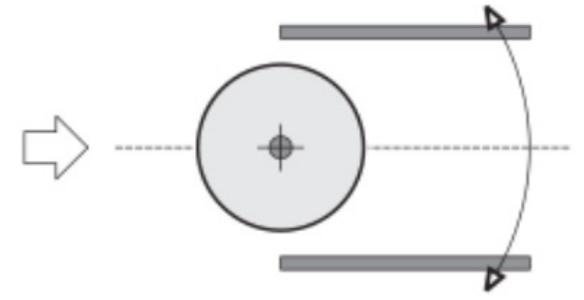
SINGLE SPLITTER PLATE



DOUBLE SPLITTER PLATES

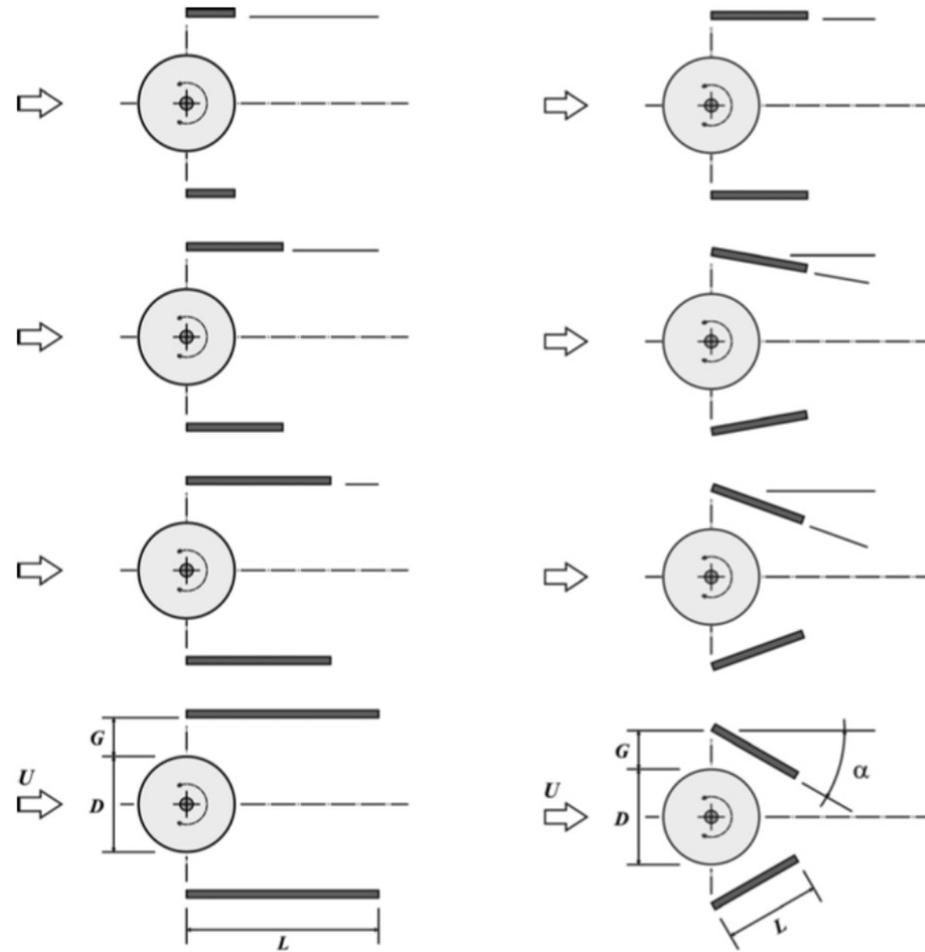


PARALLEL PLATES

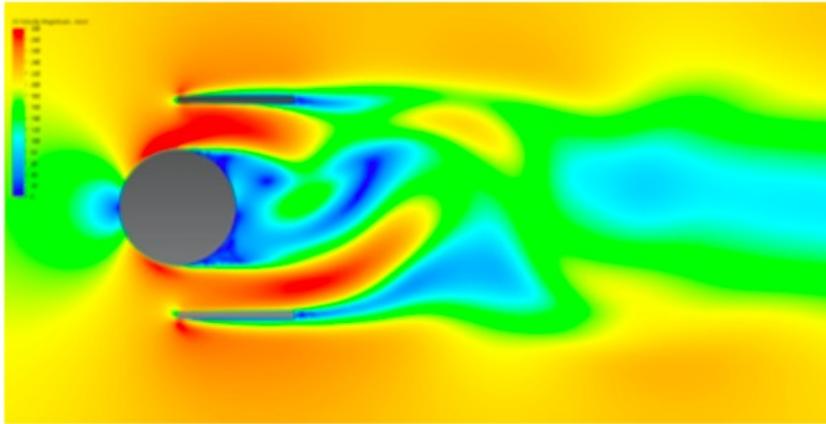


PARALLEL PLATES WITH GAP

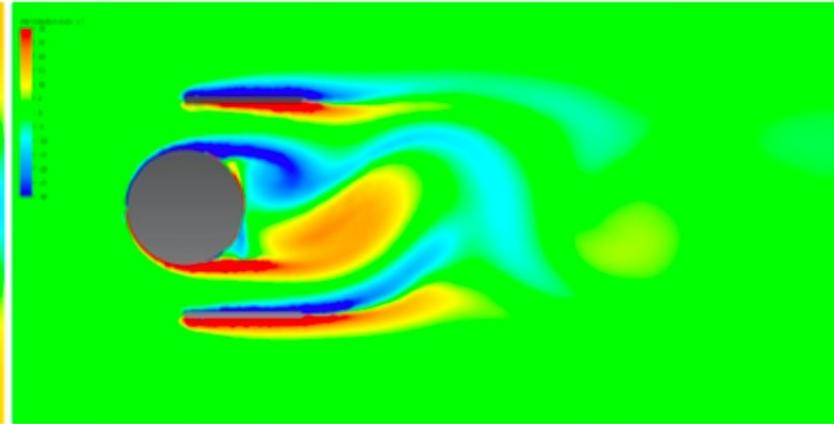
2D | PIVOTANTES



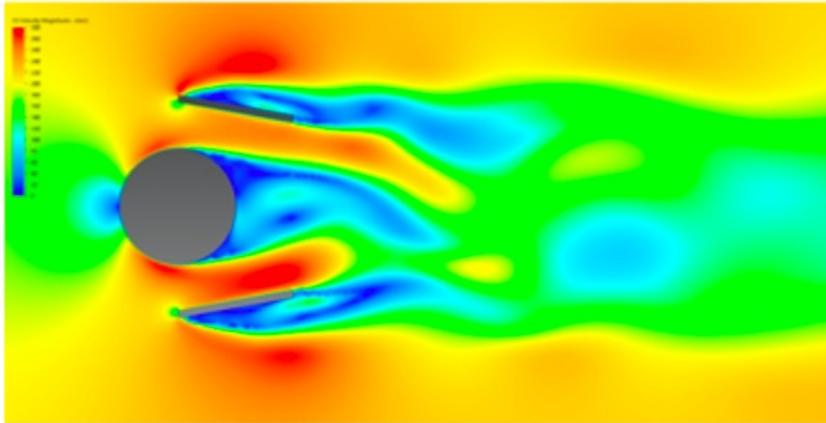
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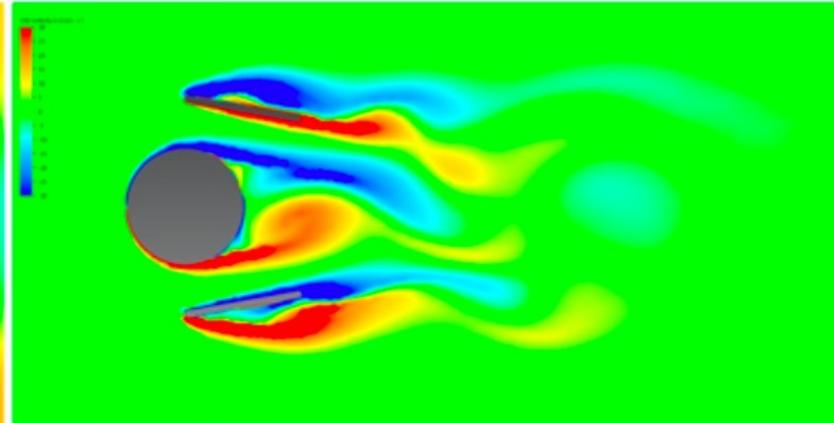
(a)



(b)

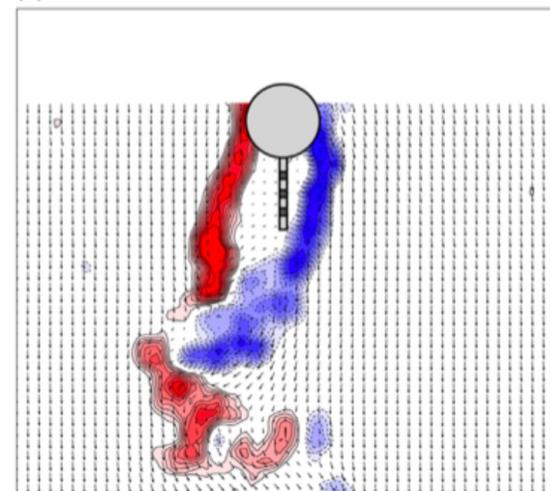
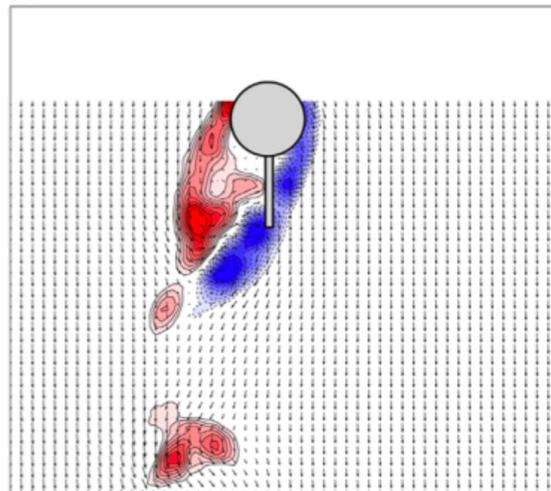
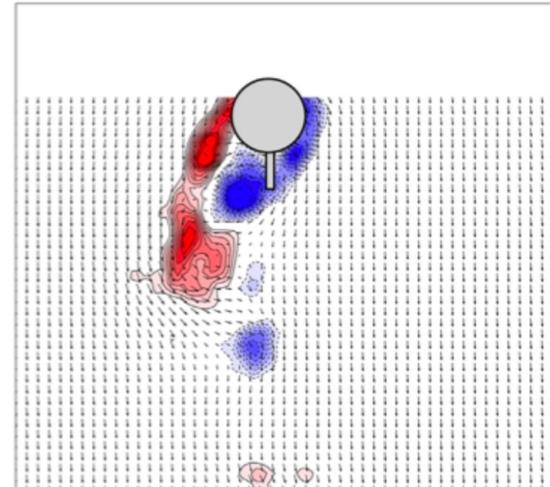
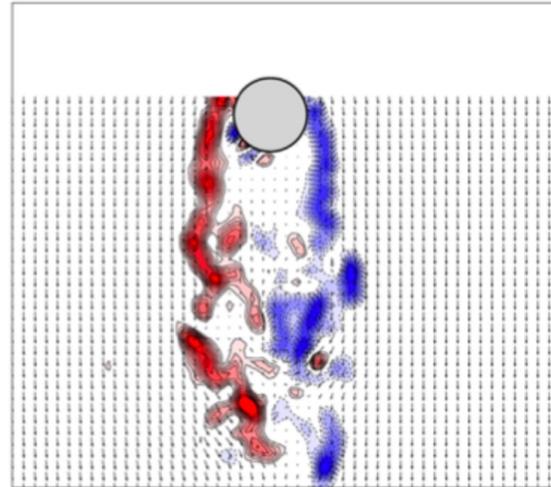


(c)

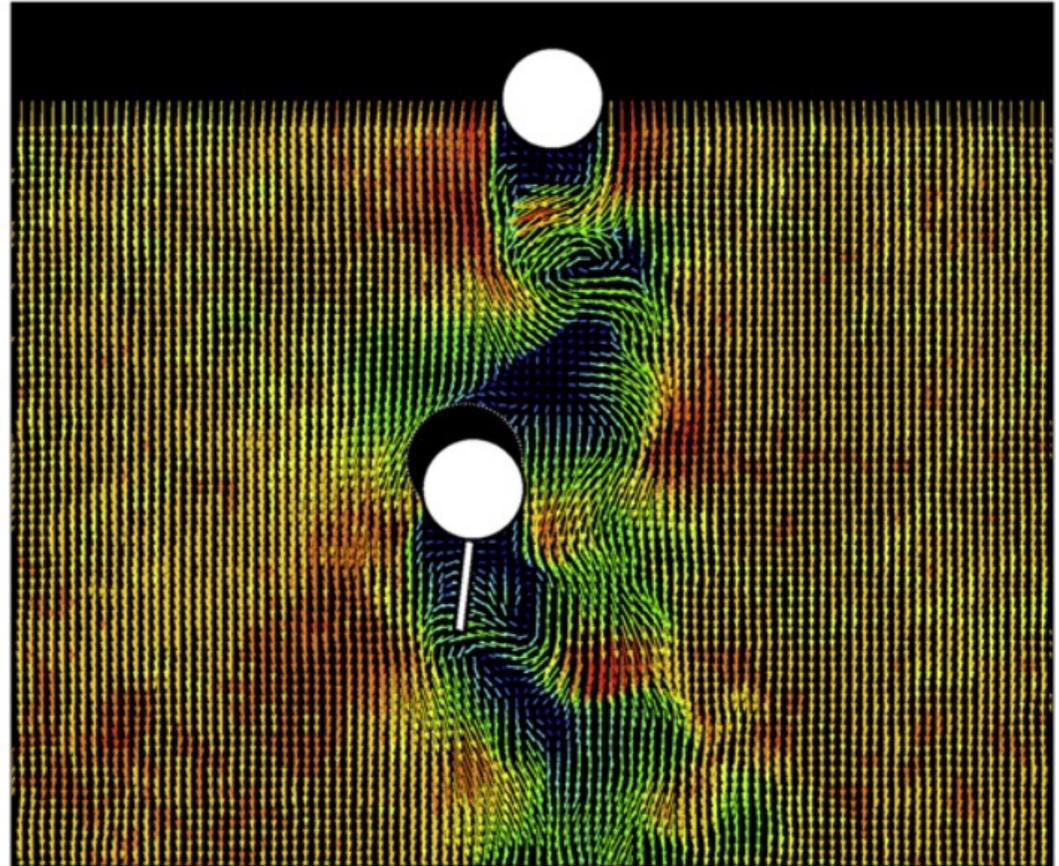
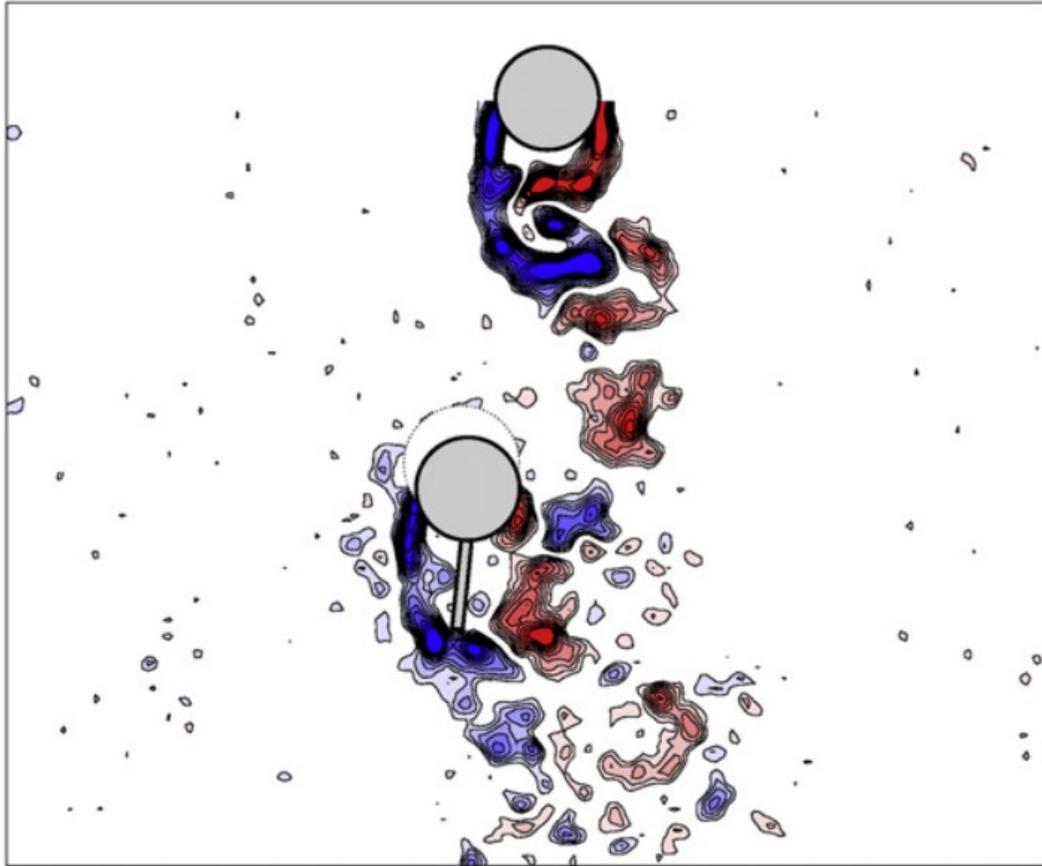


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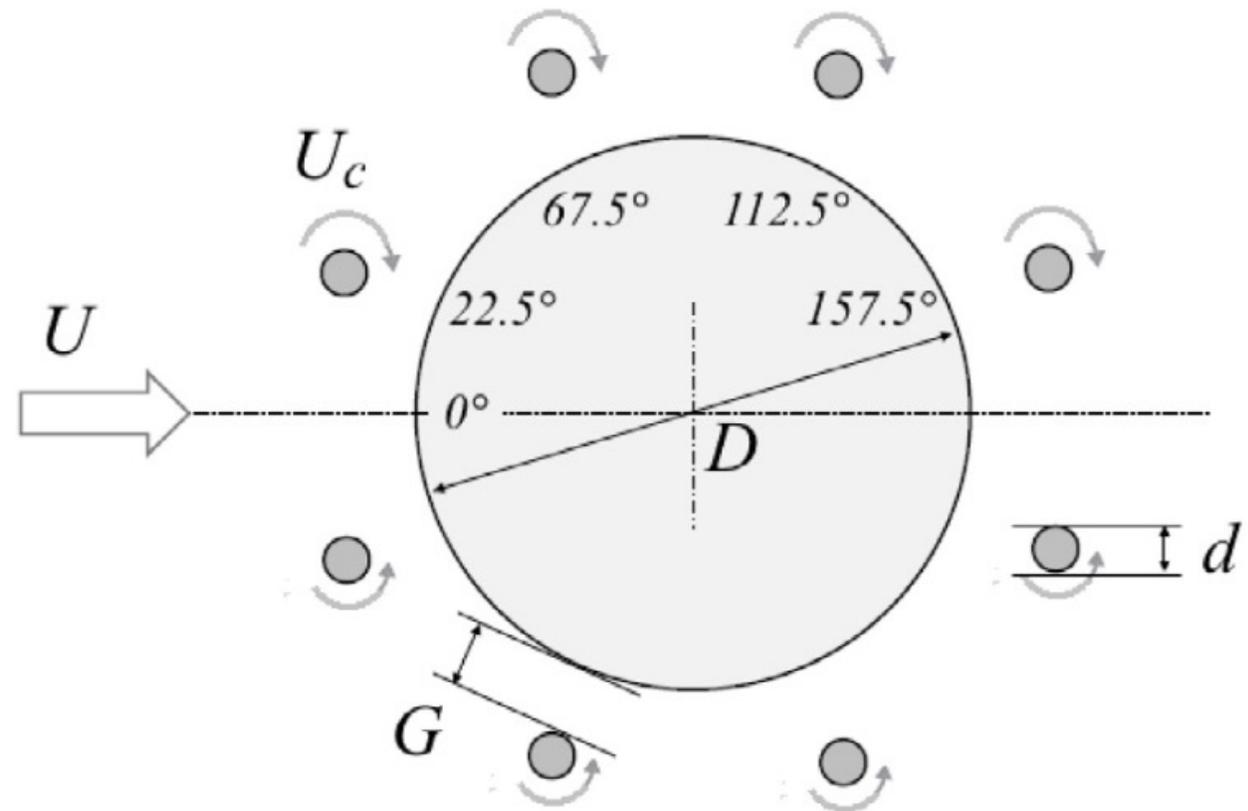
2D | PIVOTANTES



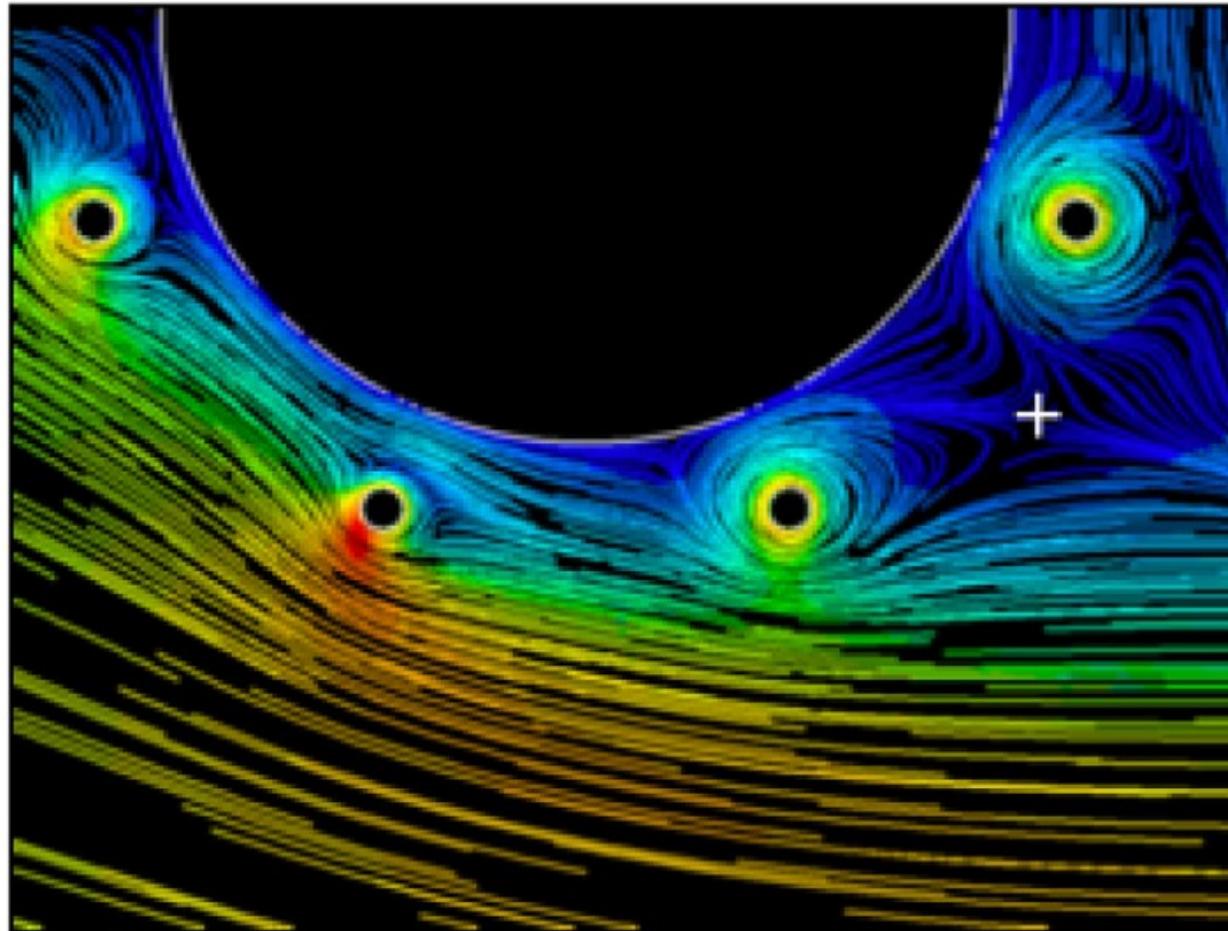
2D | PIVOTANTES



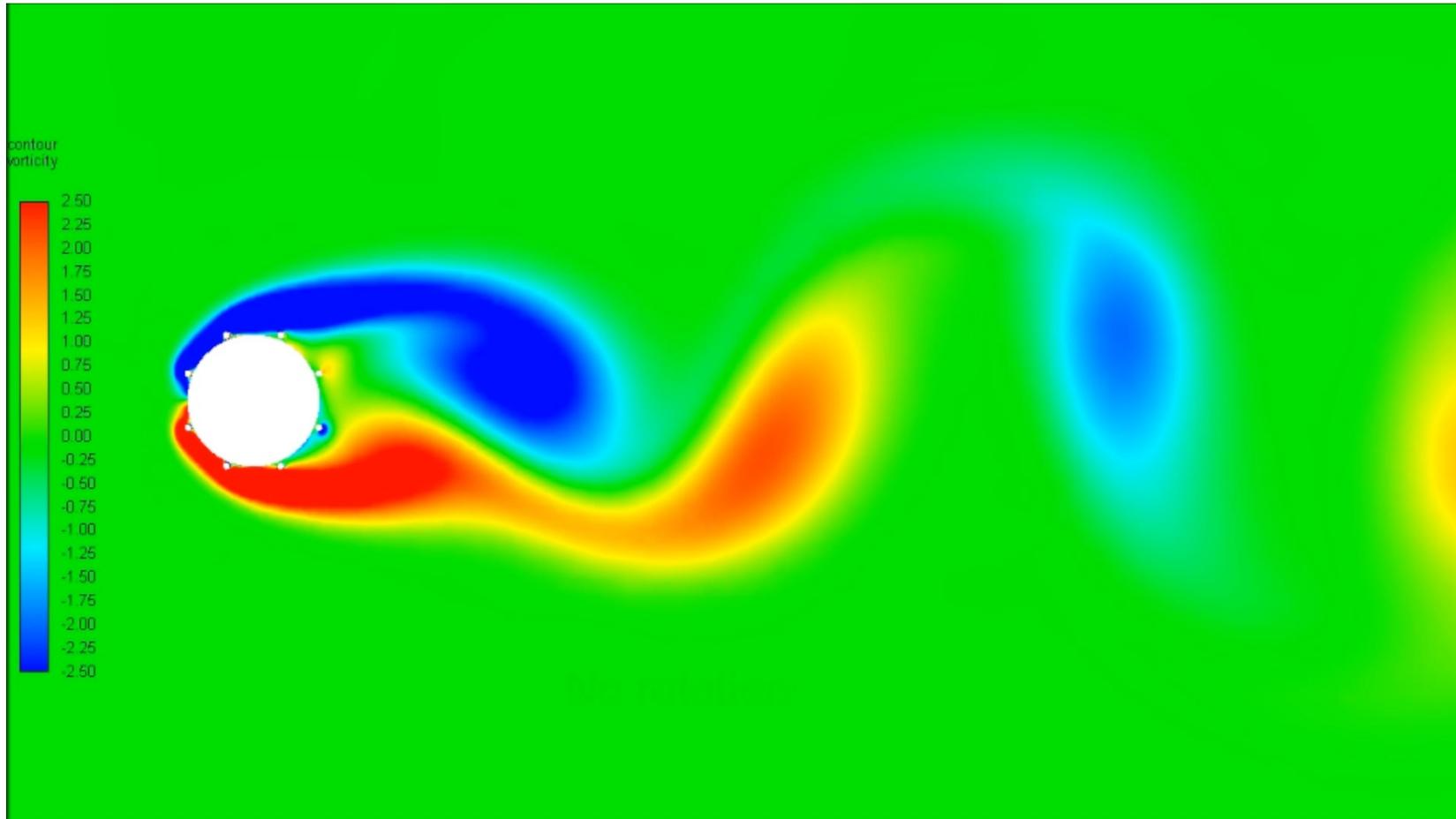
2D CILINDRINHOS ROTATIVOS



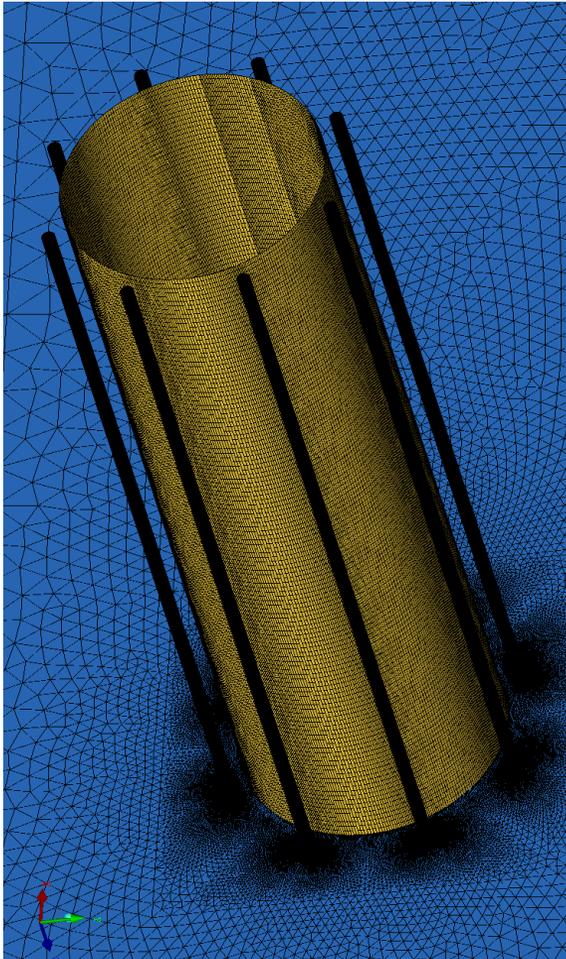
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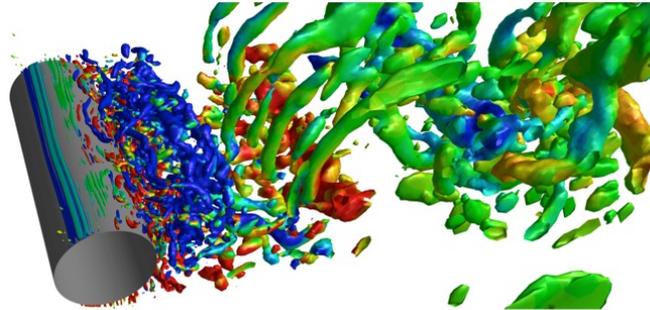
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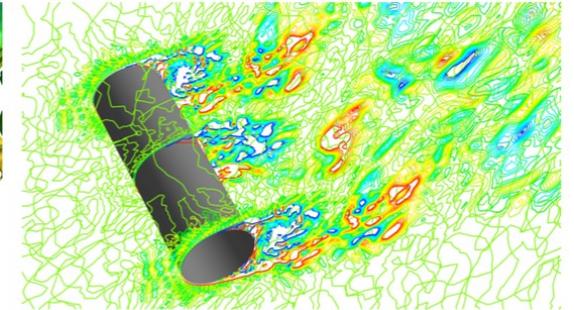
2D | CILINDRINHOS ROTATIVOS



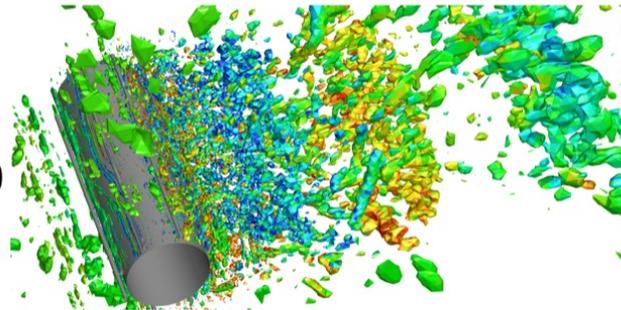
BARE CYLINDER



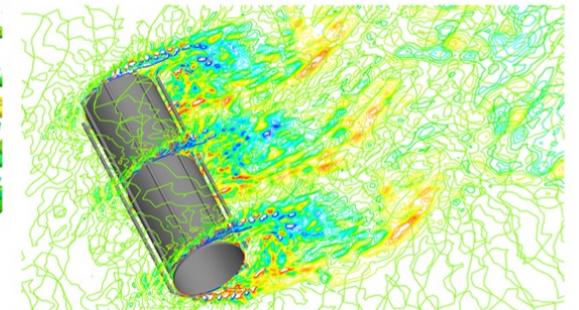
(a) Bare cylinder



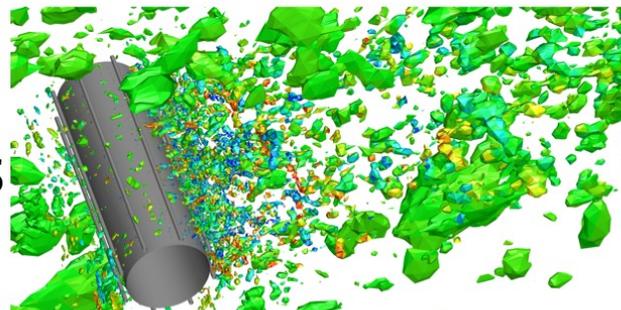
$U_c/U = 0$



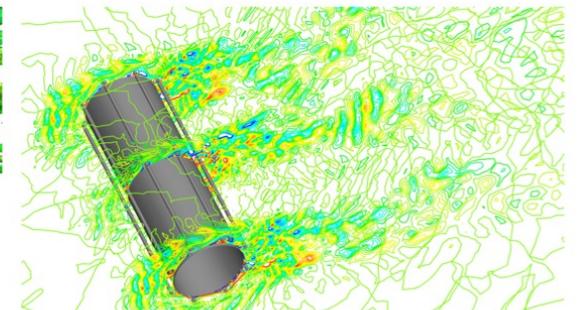
(b) $U_c/U = 0$



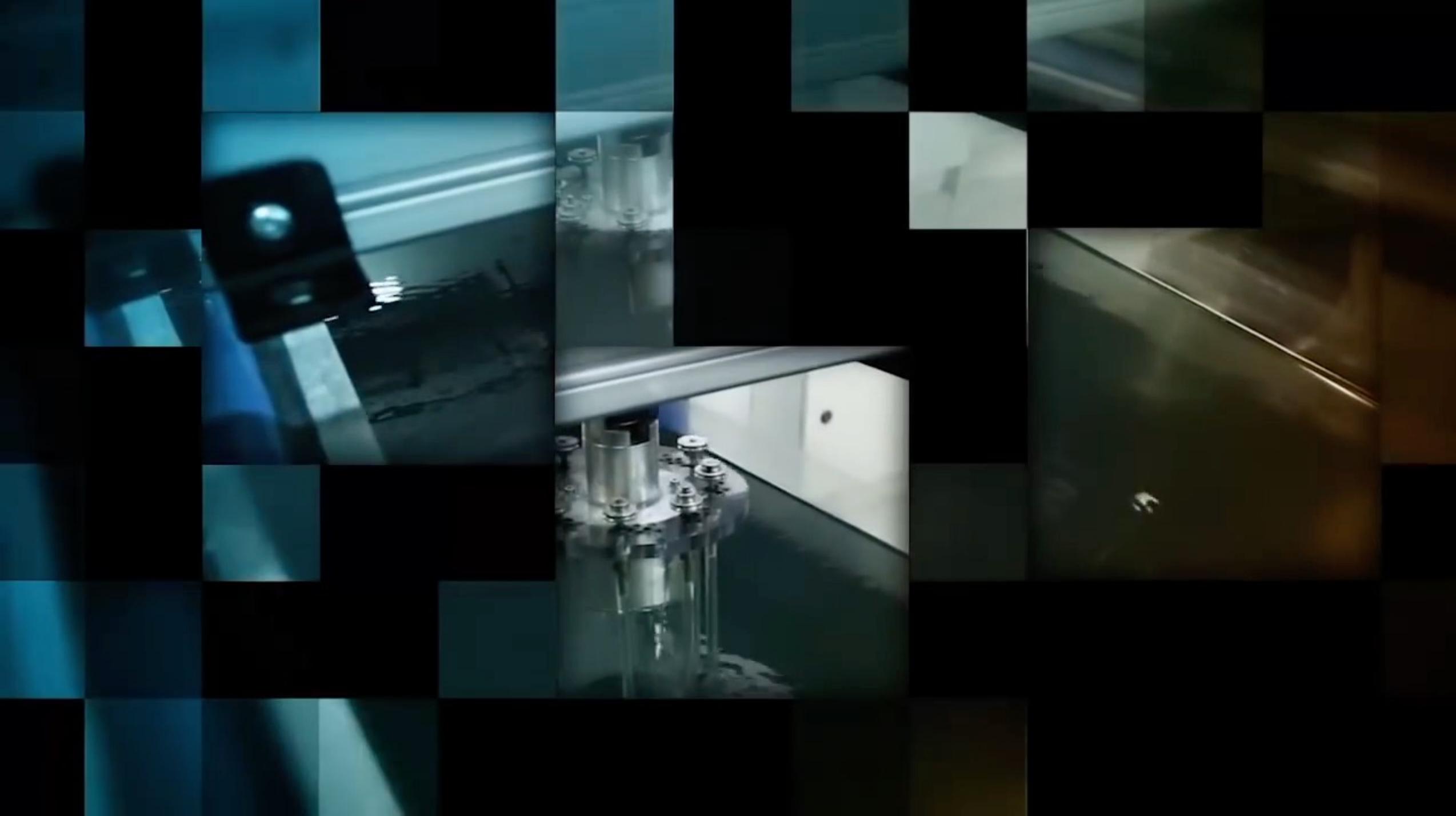
$U_c/U = 5$



(c) $U_c/U = 5$









FPSO Sevan Piranema
Courtesy of PETROBRAS

SUPRESSORES BIDIMENSIONAIS

SISTEMAS PIVOTANTES

PLACA PLANA

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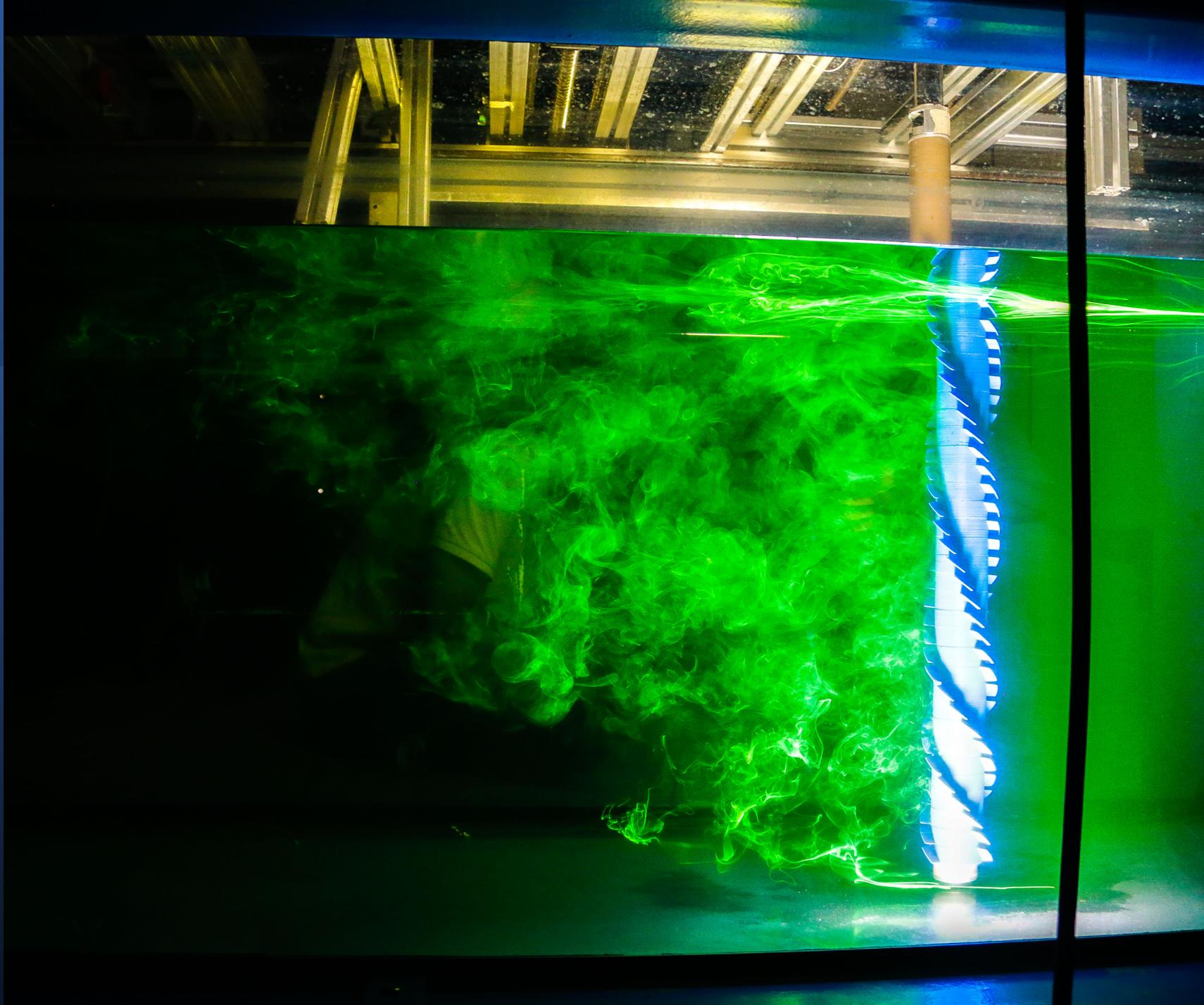
MALHAS PERMEÁVEIS

“VENTILATED TROUSERS”

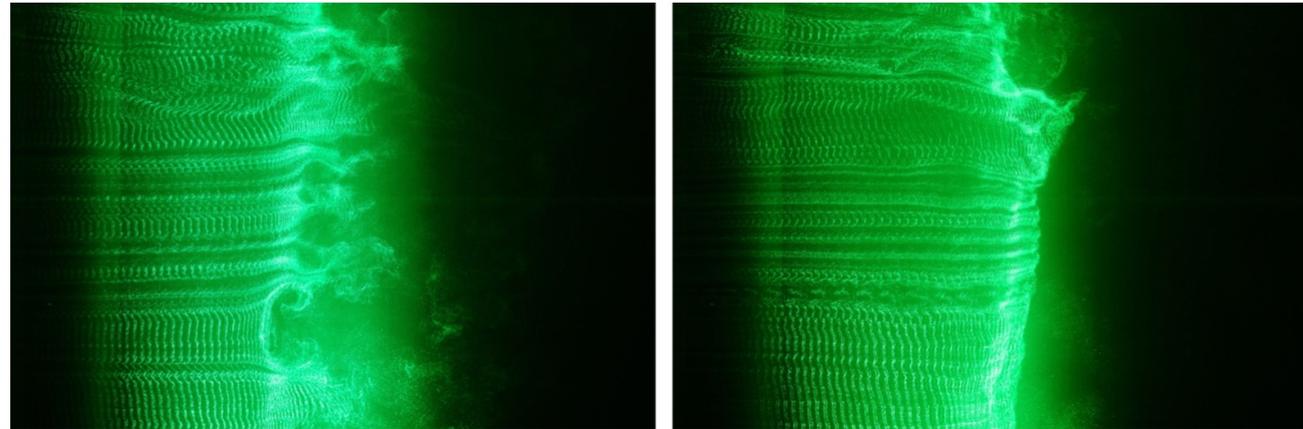
OUTRAS MALHAS

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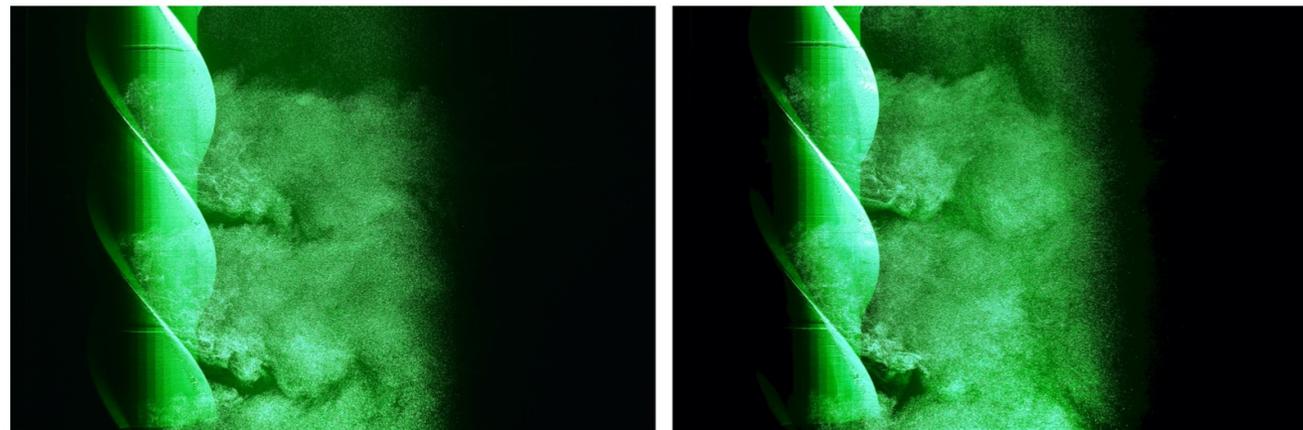
3D
STRAKES
HELICOIDAIS



3D | STRAKES HELICOIDAIS

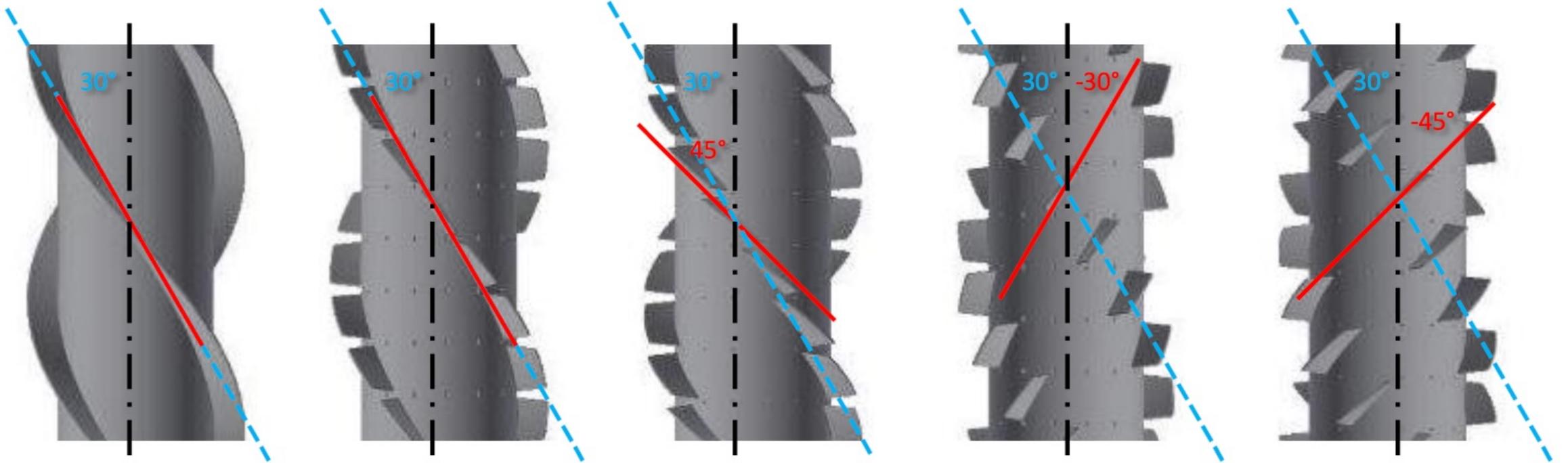


(a) Bare cylinder.



(b) CS continuous helical strake.

3D | STRAKES HELICOIDAIS



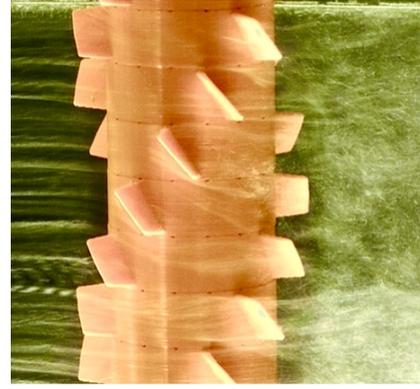
3D | STRAKES HELICOIDAIS



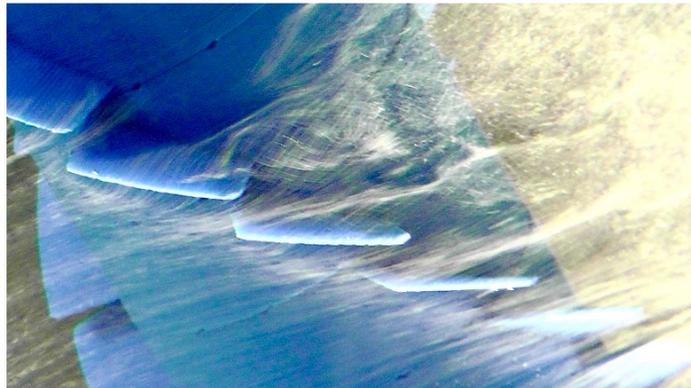
(a) S30 serrated 30-strake.



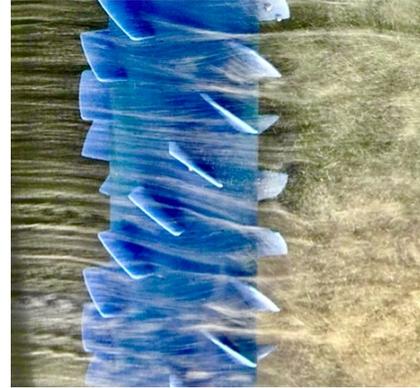
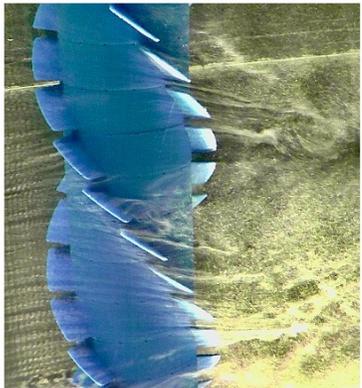
(a) I30 inverted 30-strake.



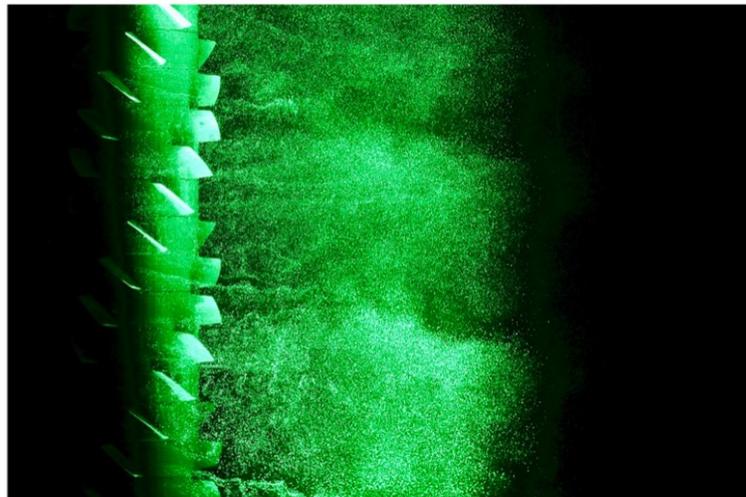
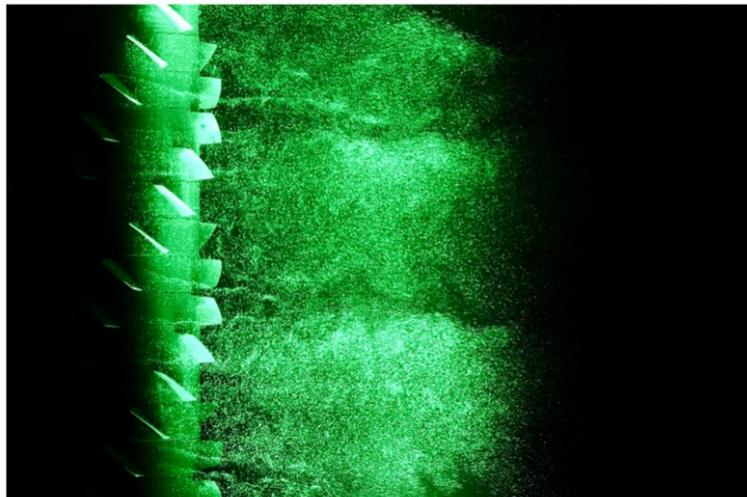
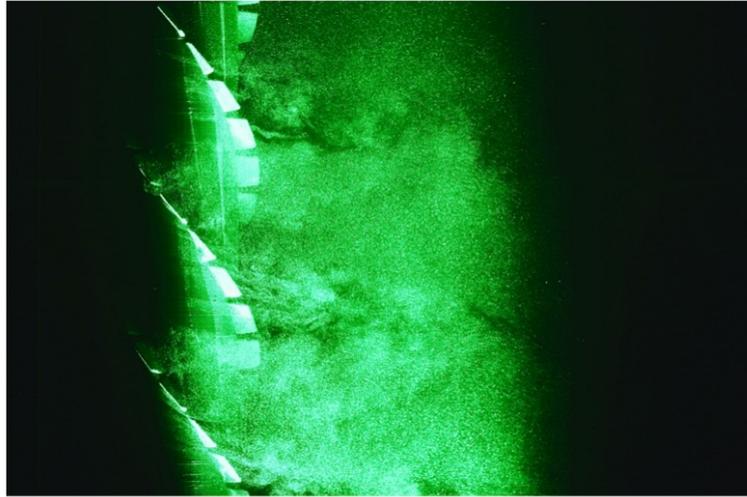
(b) S45 serrated 45-strake.



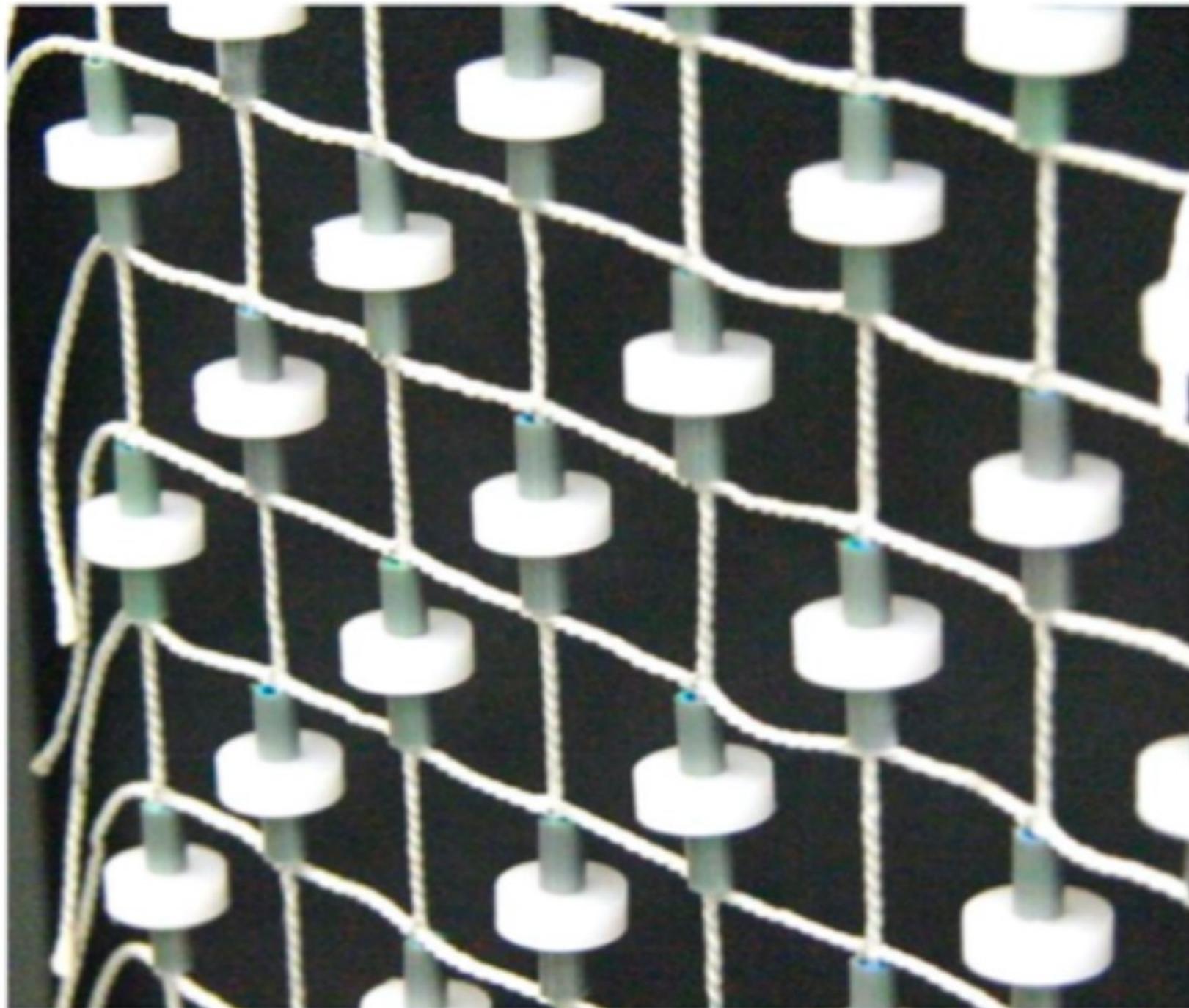
(b) I45 inverted 45-strake.



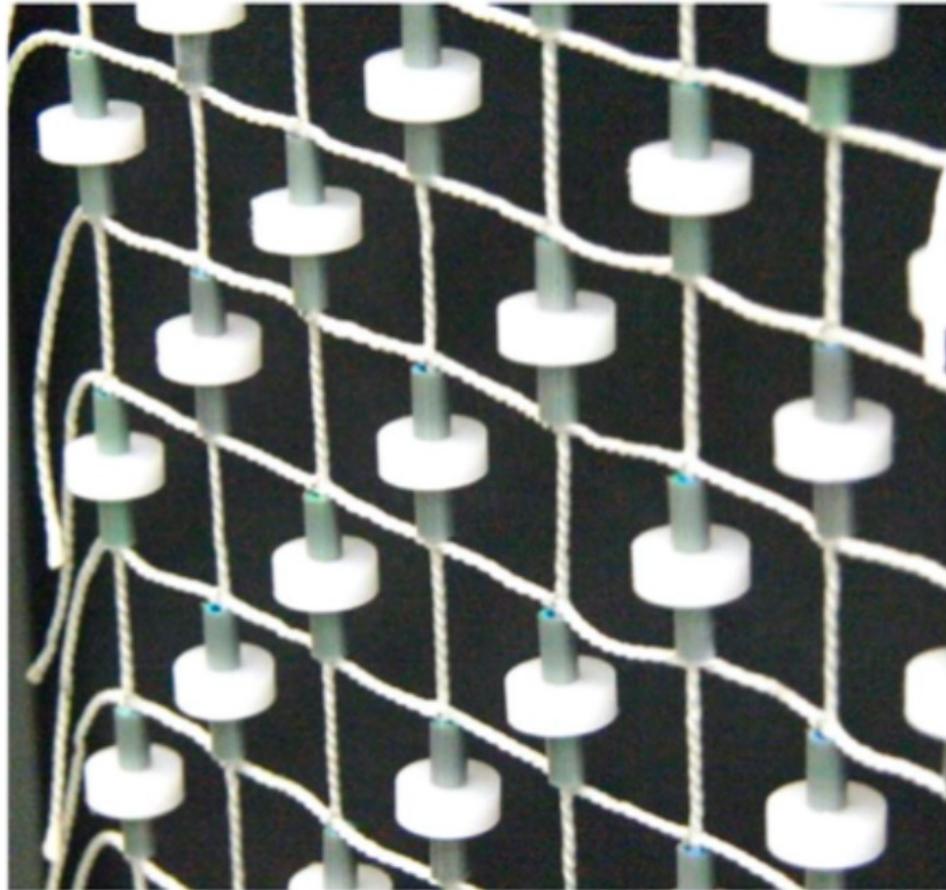
3D | STRAKES HELICOIDAIS



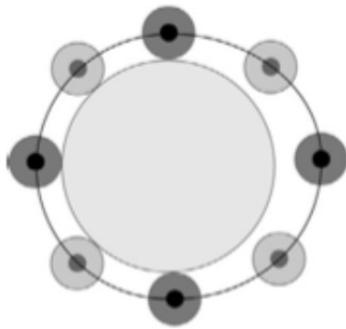
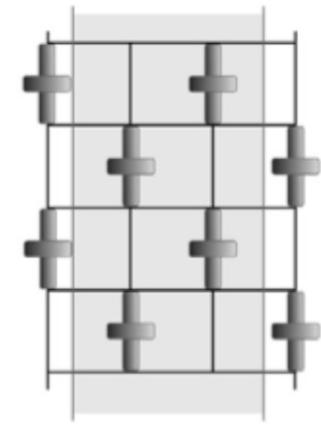
3D
MALHAS
PERMEÁVEIS



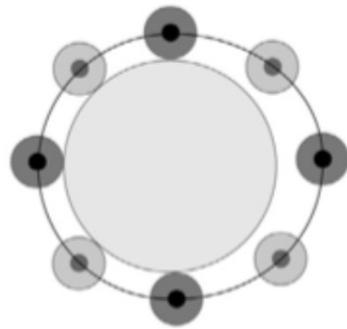
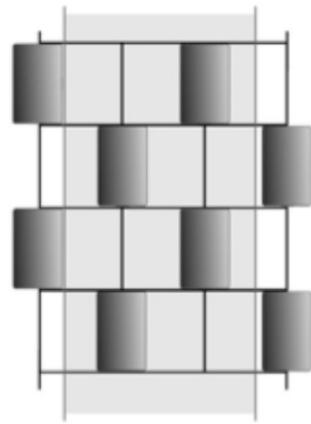
3D | MALHAS PERMEÁVEIS



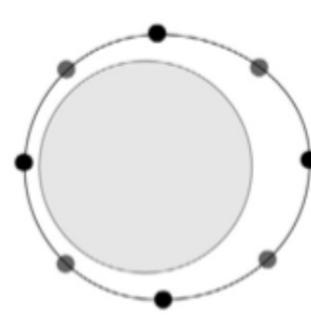
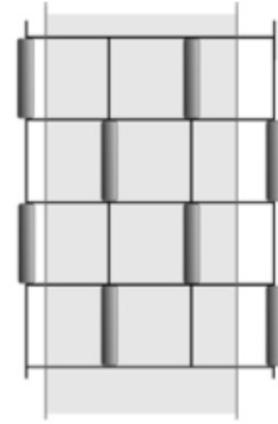
3D | MALHAS PERMEÁVEIS



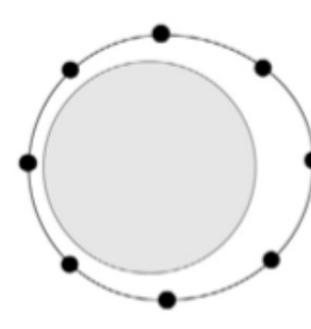
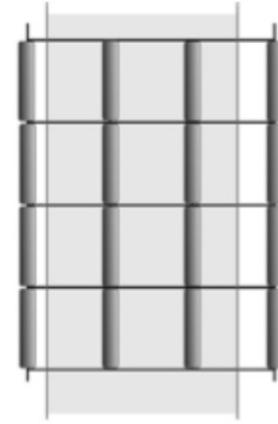
(a) VT mesh



(b) Thick-sparse mesh

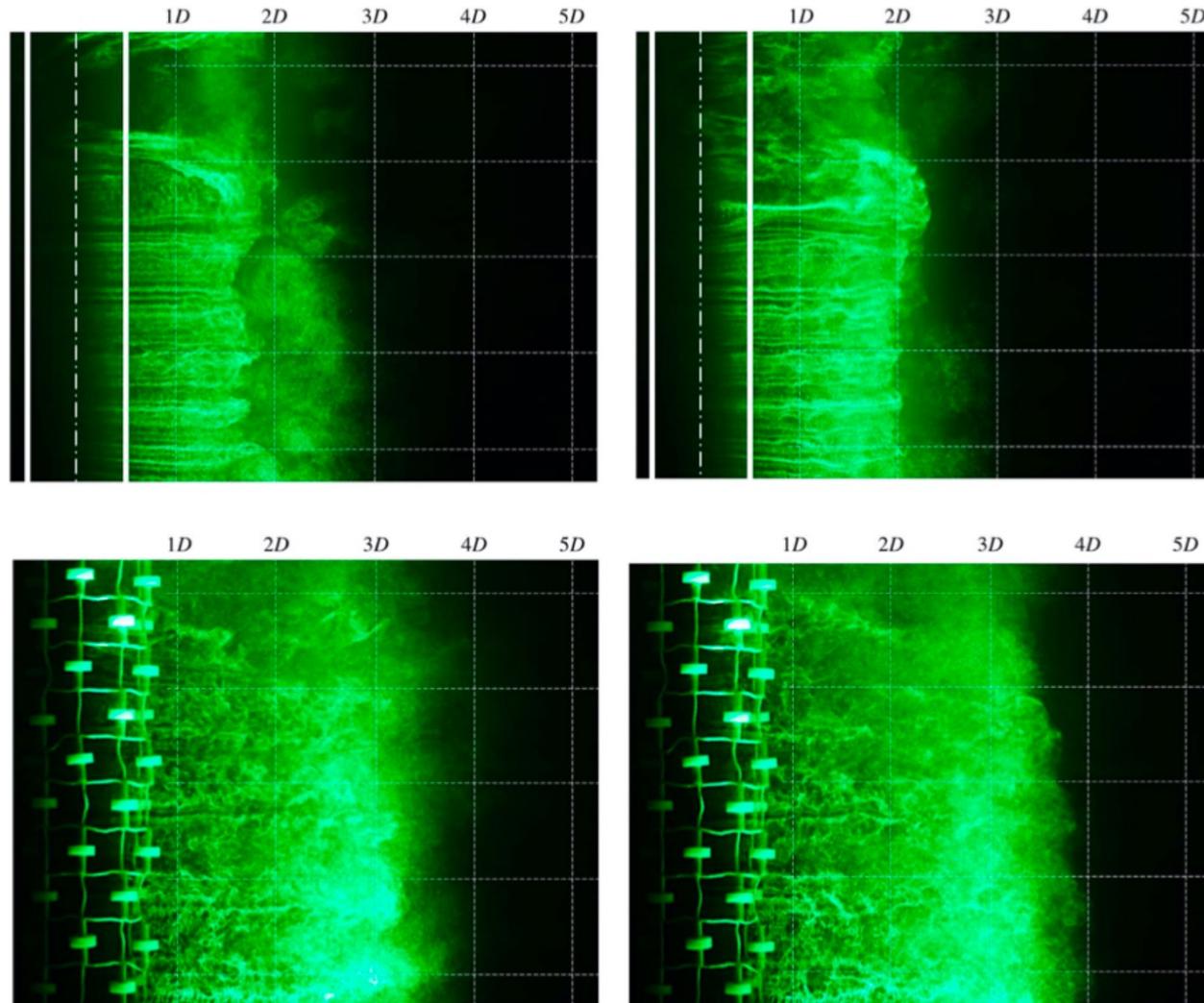


(c) Thin-sparse mesh

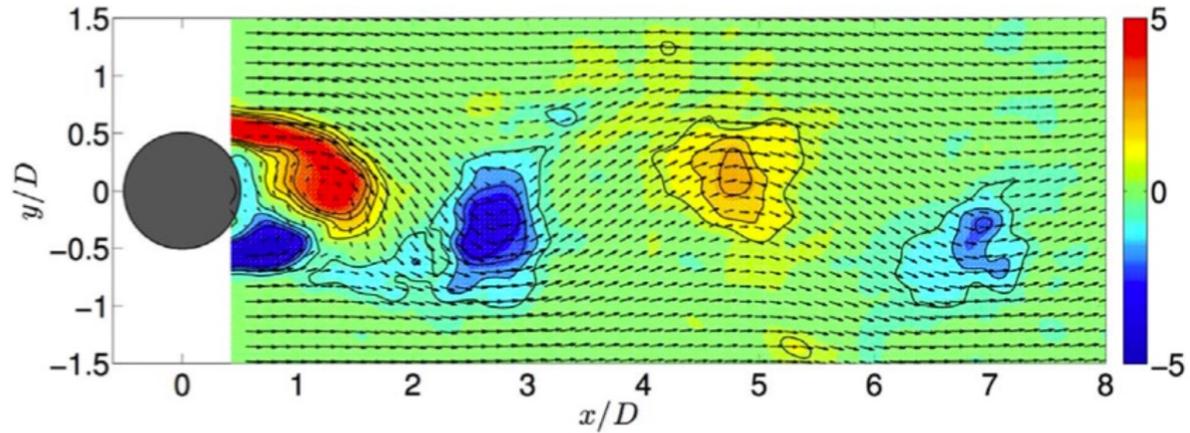


(d) Thin-dense mesh

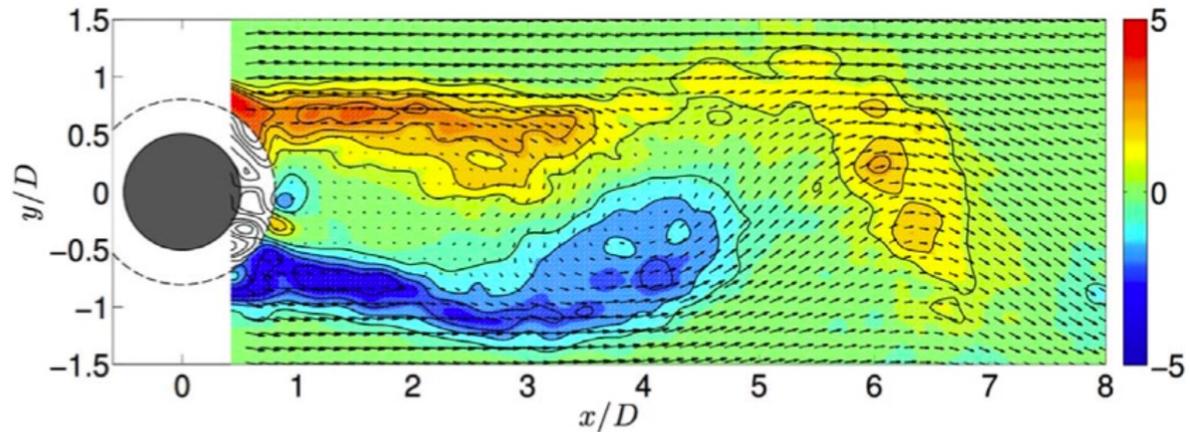
3D | MALHAS PERMEÁVEIS



3D | MALHAS PERMEÁVEIS

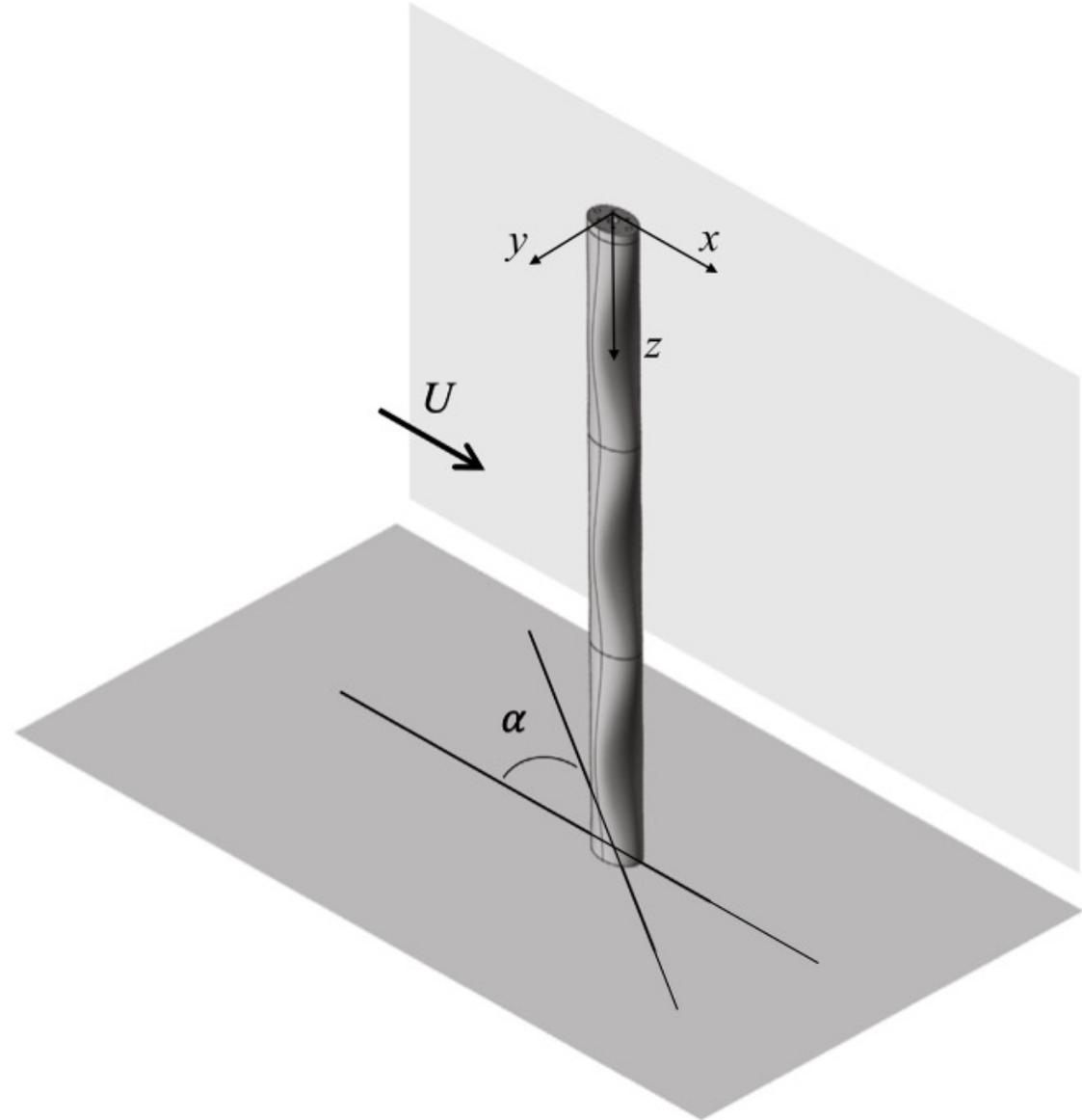


(a)

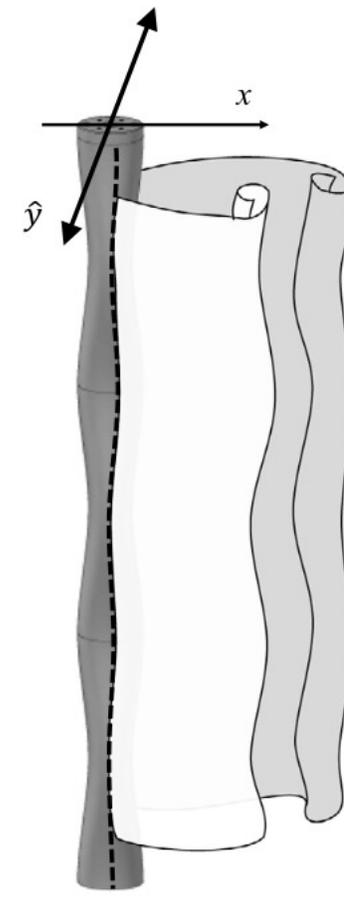
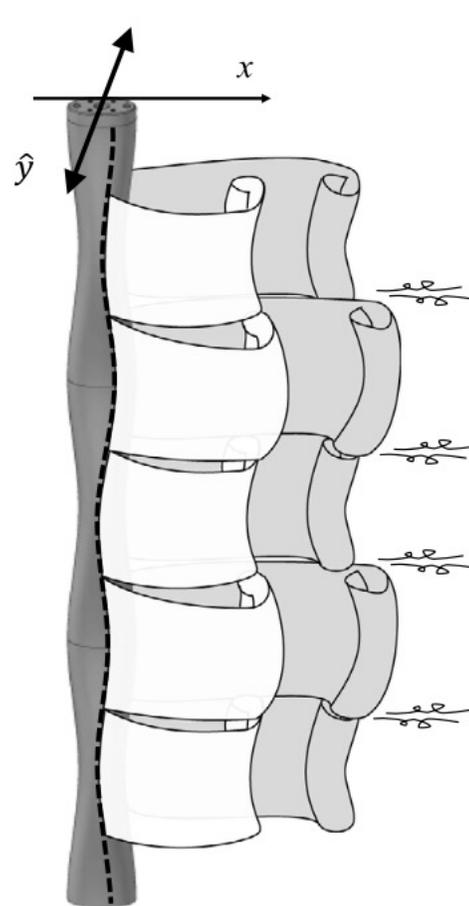
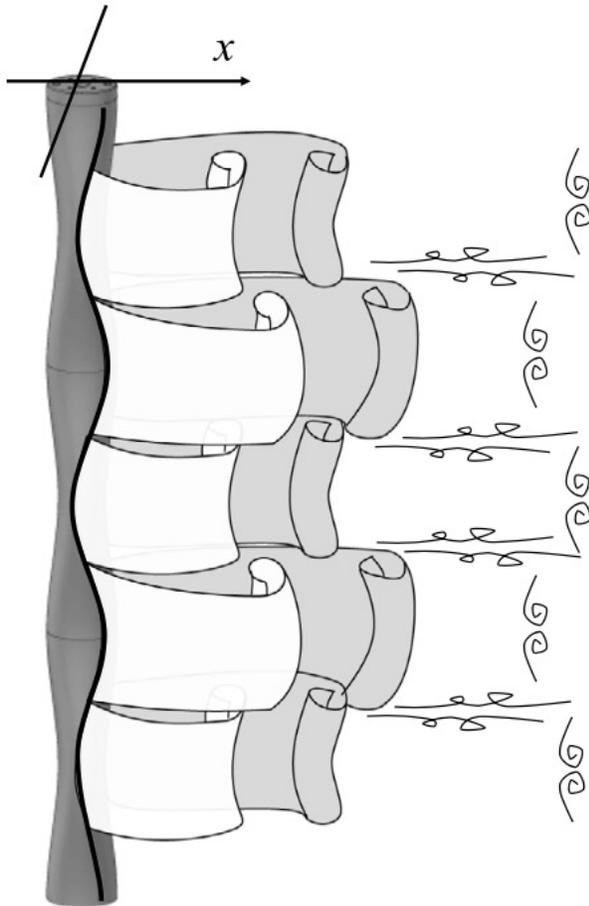


(b)

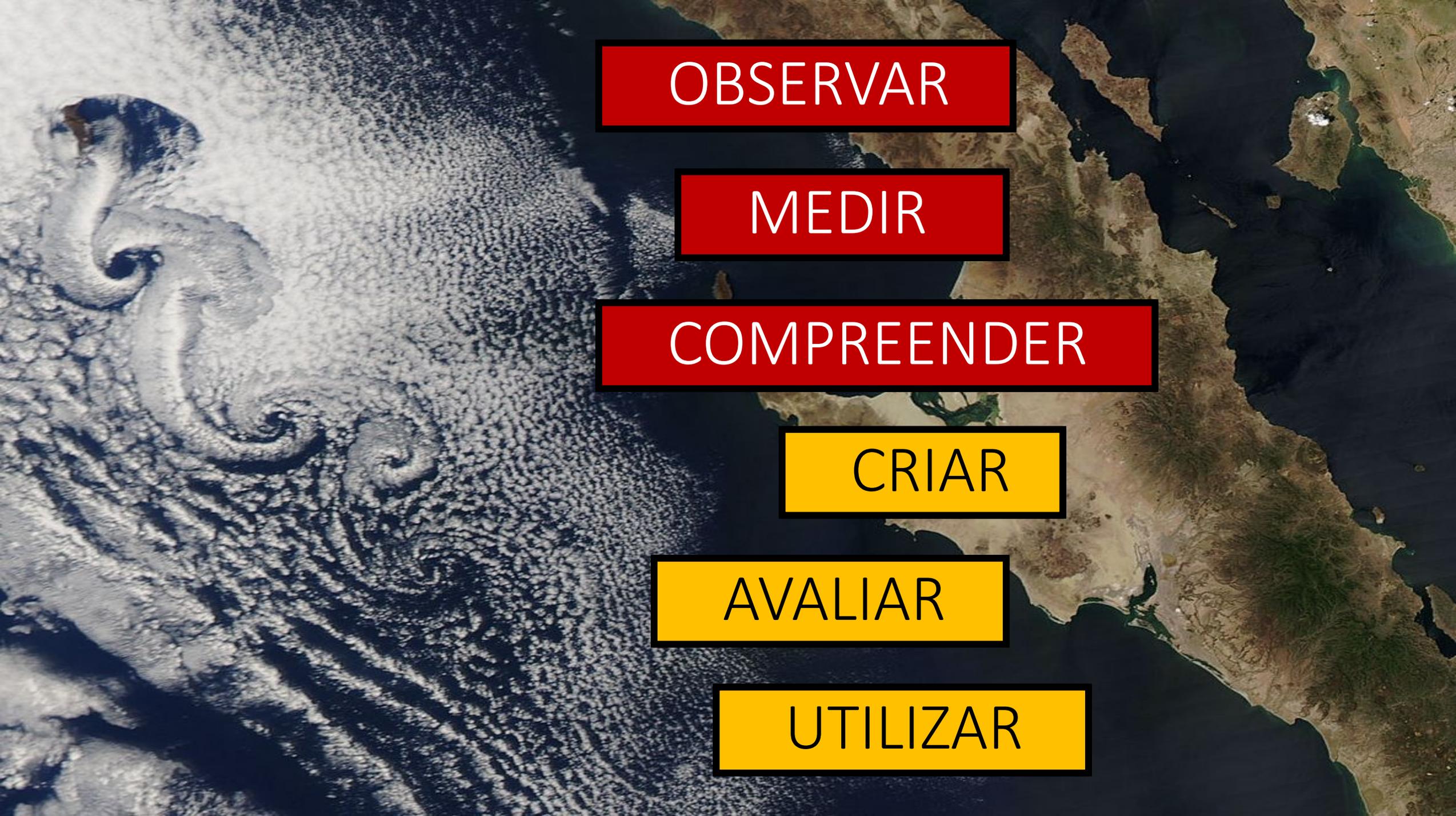
3D CILINDRO ONDULADO E ELÍPTICO



3D | CILINDRO ONDULADO E ELÍPTICO



E a amplificação!?

A satellite view of Earth showing a large, swirling cloud pattern over the Atlantic Ocean. The text is overlaid on the right side of the image, arranged in a vertical list. The first three items are in red boxes, and the last three are in yellow boxes.

OBSERVAR

MEDIR

COMPREENDER

CRIAR

AVALIAR

UTILIZAR

RENEWABLE OCEAN ENERGY

These devices turn the energy from moving water and wind into electricity. Underwater power cables carry the electricity to shore, where our homes, schools, and businesses can use it.



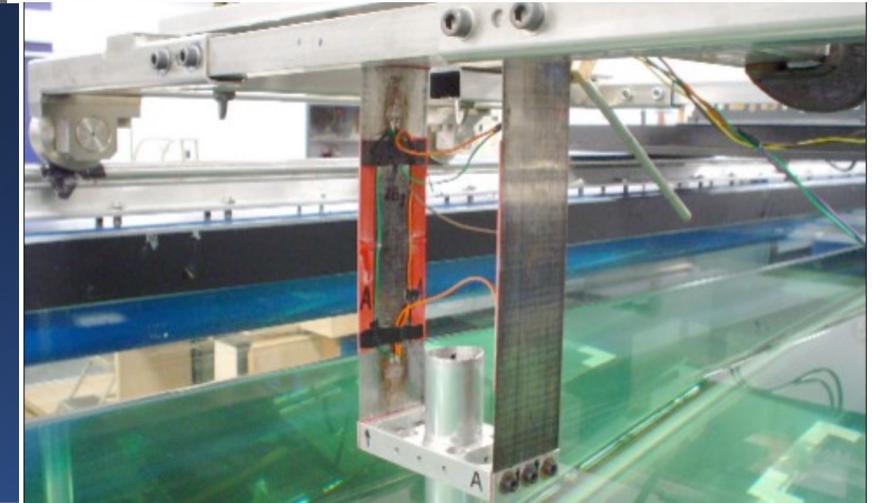
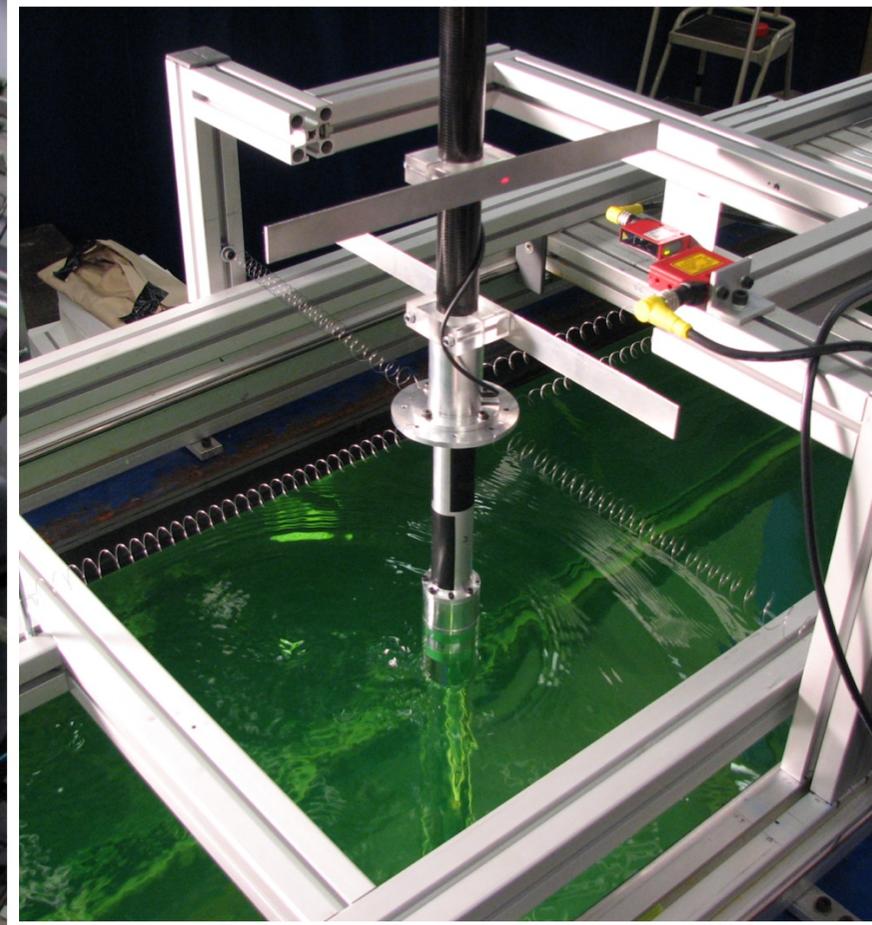
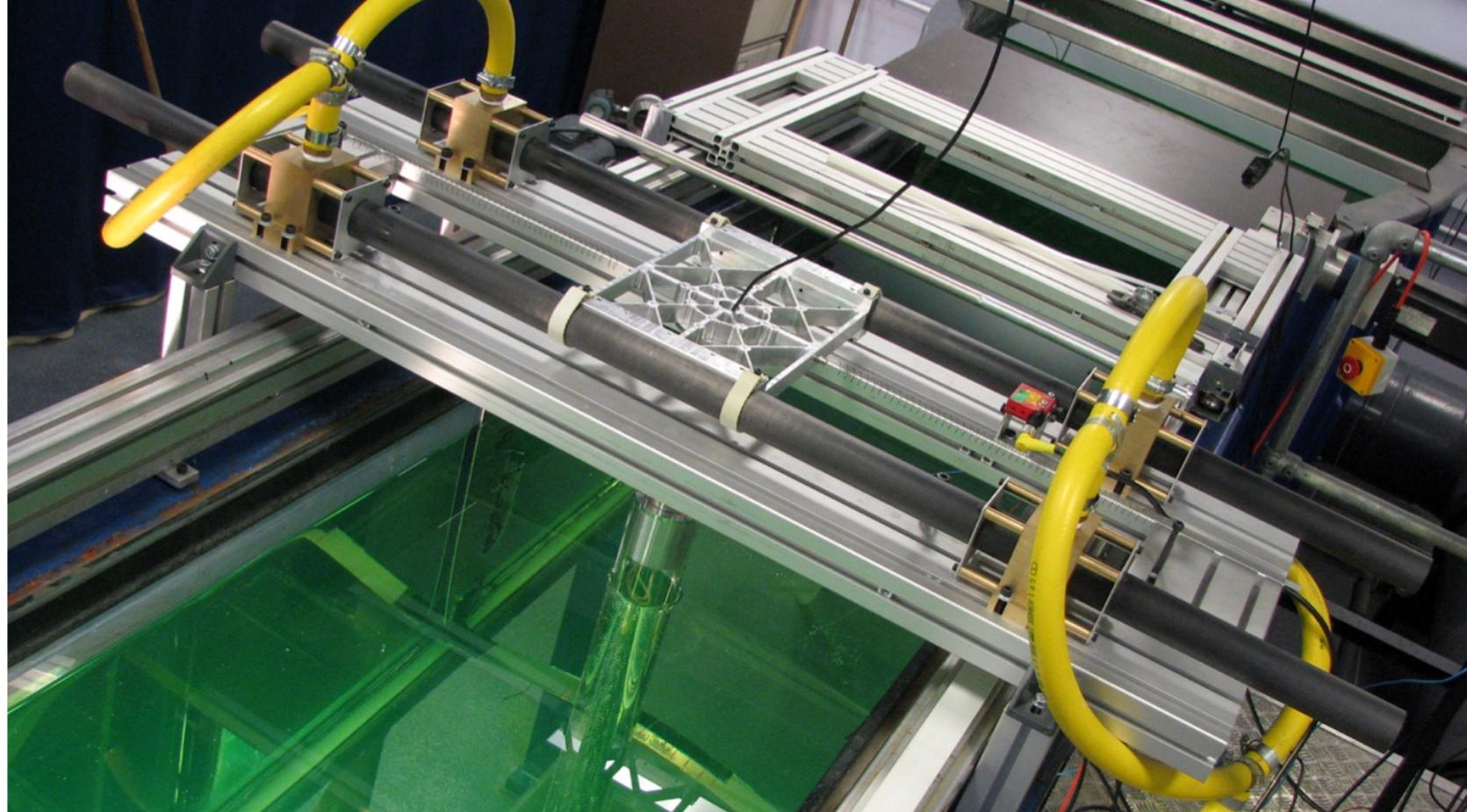
Equipamentos experimentais

Canal de
Água
Recirculante
do NDF



Canal
Recirculante
de baixo Re





Bases elásticas

g.assi@usp.br

obrigado

