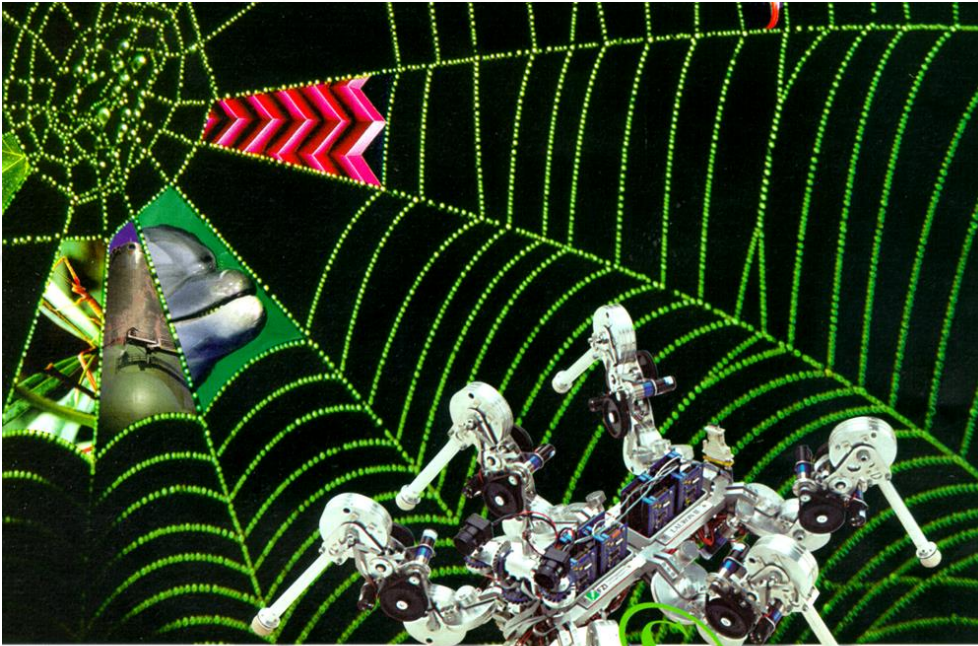




Copyright by Nature

BIOMIMETICA = INNOVATIEVE OPLOSSINGEN uit de BIOLOGIE voor de PROBLEMEN van de TOEKOMST

Eize J. Stamhuis

Instituut voor Energie & Duurzaamheid - Universiteit van Groningen



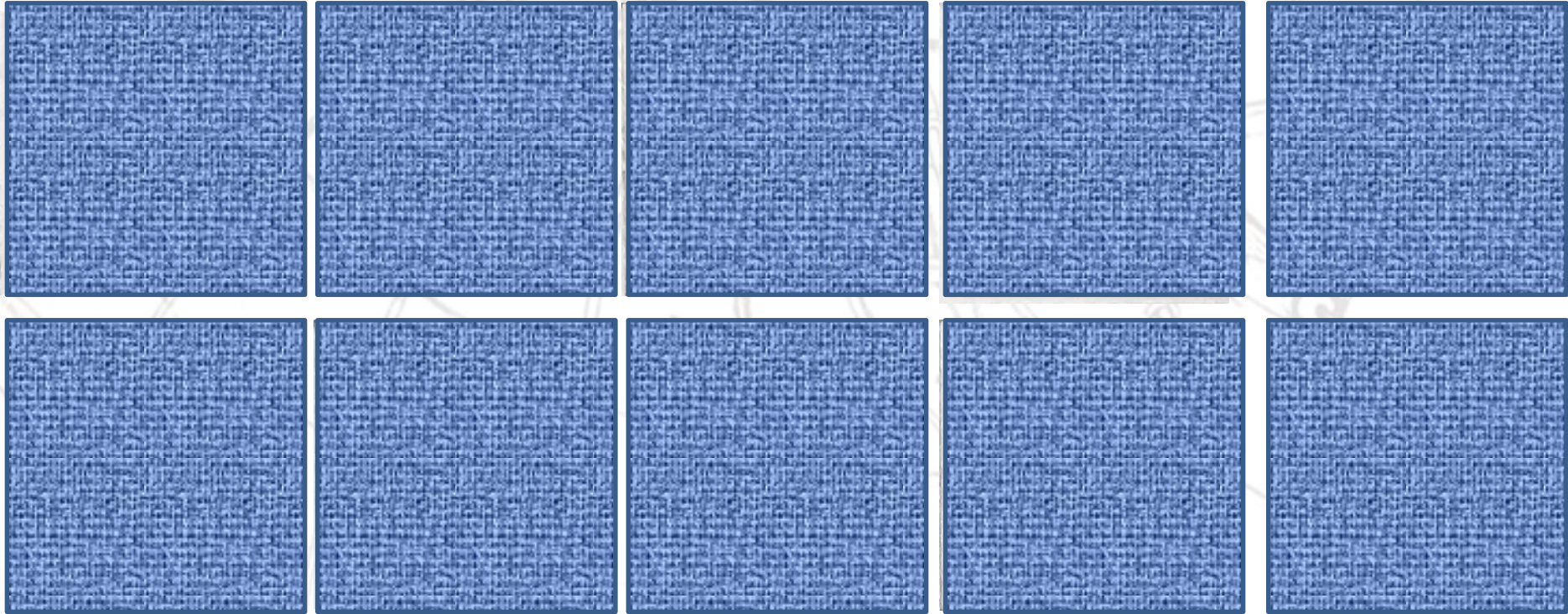
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Laten we beginnen met een spelletje.... Memory...

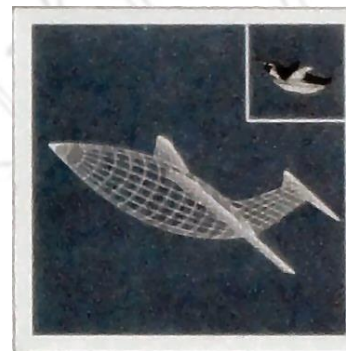


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Biomimetica

Bionica / Biomimicry

WAT is dat eigenlijk ???



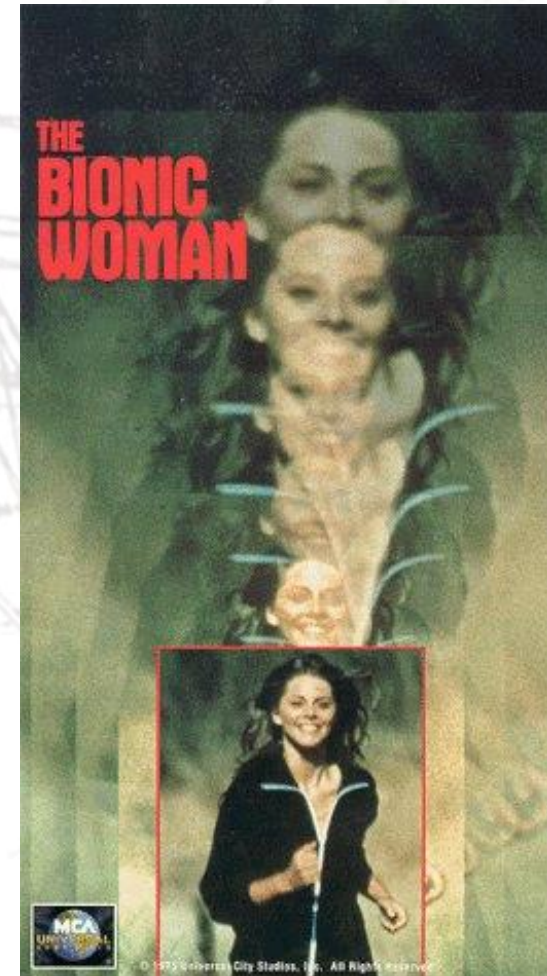
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Biomimetica... wat is dat eigenlijk ???



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Of is het....



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Of is het....



CLARION® CII Bionic Ear™ System



BIONIC ARM



BLADE RUNNER

Biomedische BIONICA
Streeft naar behoud van functionaliteit
middels vervanging, meestal gebaseerd
op t originele 'ontwerp' ...



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BIOMIMETICA =

ABSTRAHEREN van het

ONTWERP of MECHANISME

van een

BIOLOGISCH OBJECT

met als doel de

TOEPASSING van de

ESSENTIE in

**⇒ Probleem-oplossend
& Innovatie-georiënteerd**

TECHNOLOGIE



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Voorbeeld:

Ontwerp van het 'Crystal Palace'
door Joseph Paxton
voor de 1^{ste} Wereldtentoonstelling in
1851 in London (England)



Reuzewaterlelie
(*Victoria amazonica*)

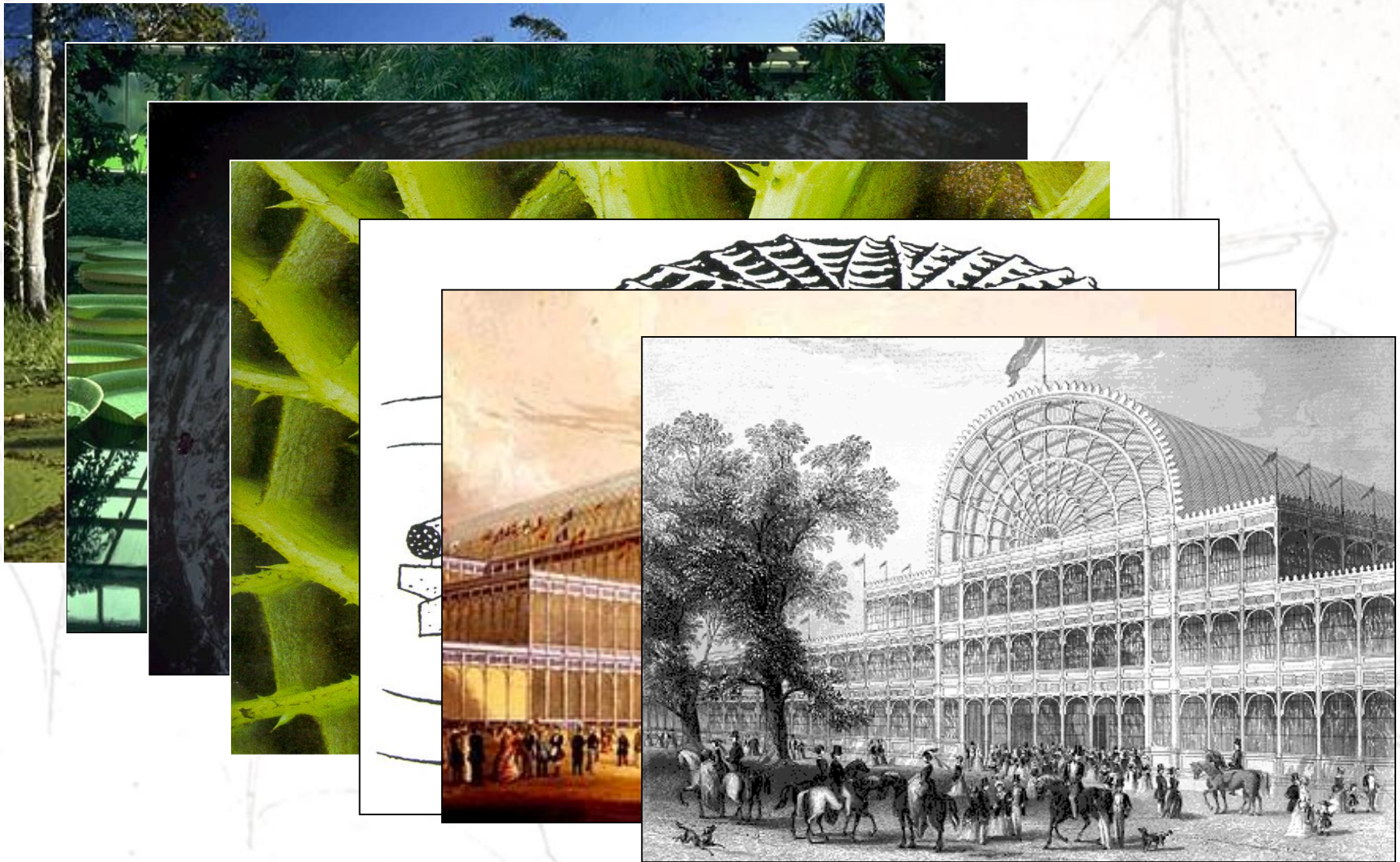


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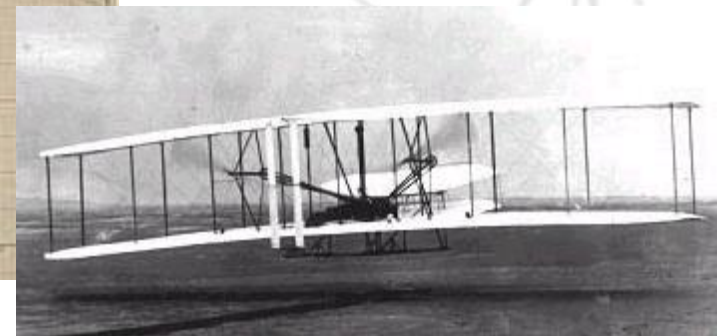
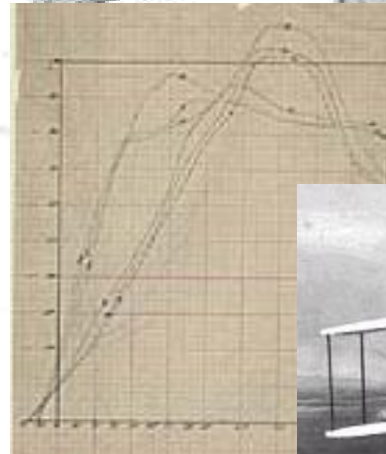
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Voorbeeld:



Gebroeders Wright (1903)
Otto Lilienthal (1880)



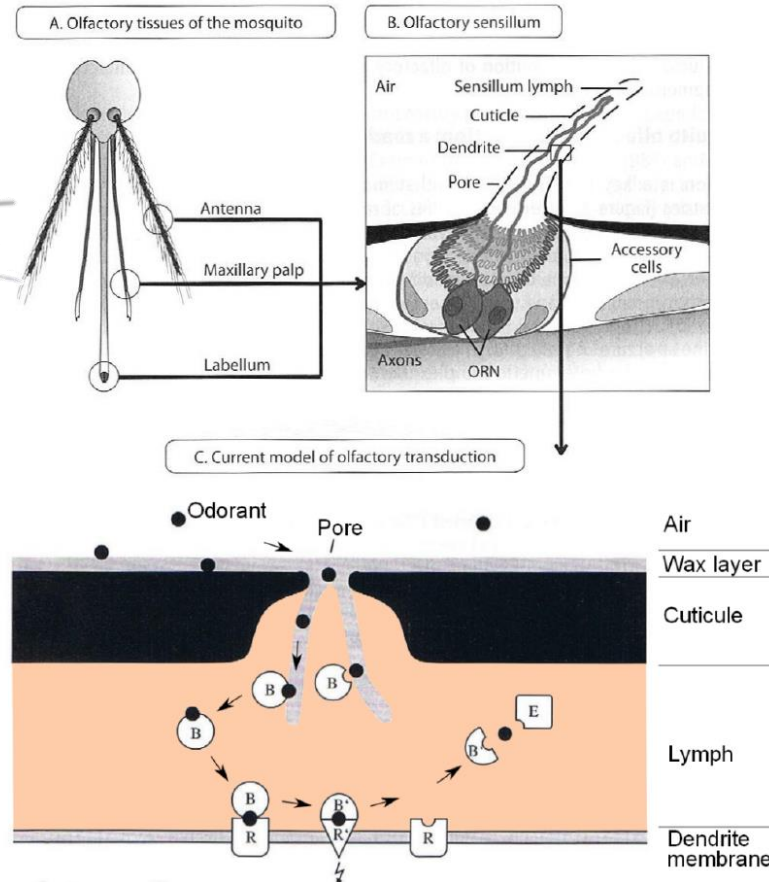
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Voorbeeld: Ultra-kleine CO₂-sensor



CO₂-molecule....
Enters wax layer
Enters pore
Migrates to fluid
Dissolves in lymph
Binds to carrier
Diffuses to membrane
Binds to receptor
Compound changes shape
Opens Ca-channels
Induces charge-differential
Membrane depolarizes
Nerve cell is activated.....
Ca-flow induces orig. shape
Receptor releases carrier
Carrier diffuses away
Carrier binds to degrader
CO₂ = degraded
Ca-pump restores Ca eq.
Membrane repolarizes
Next CO₂-molecule.....



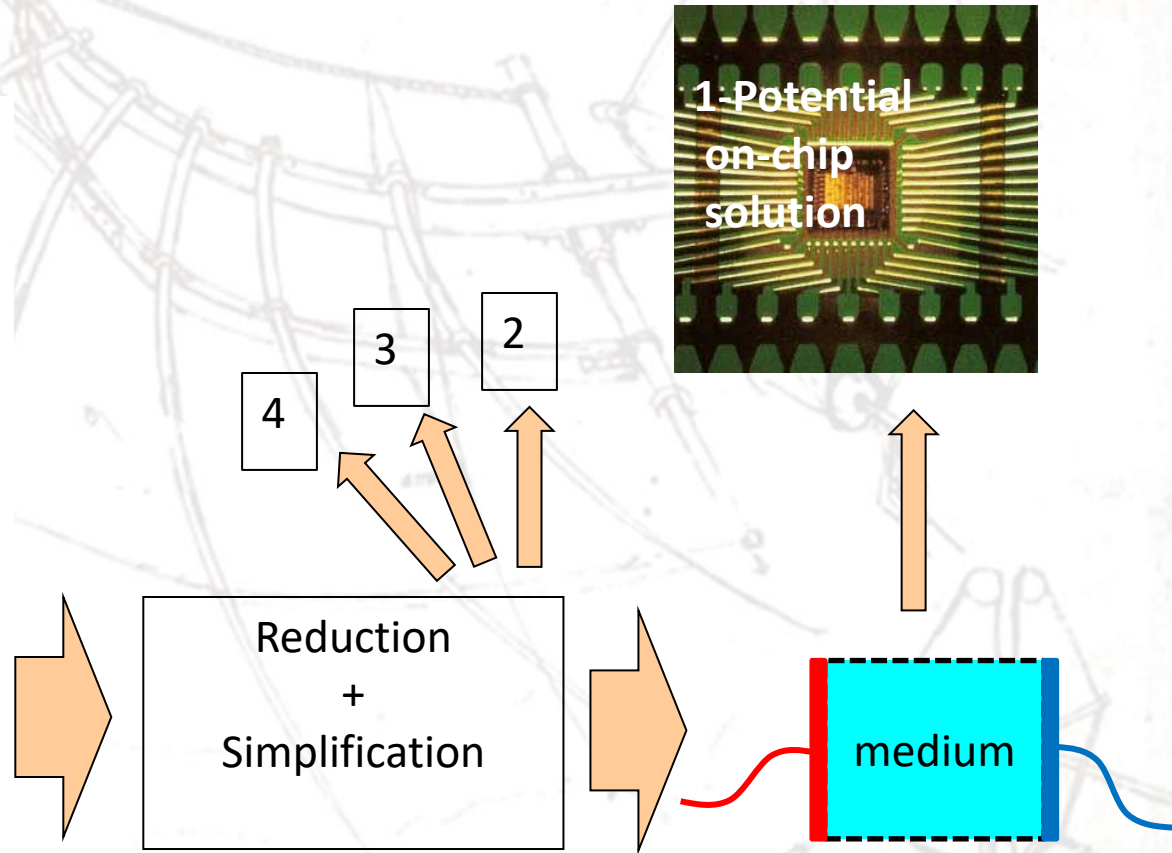
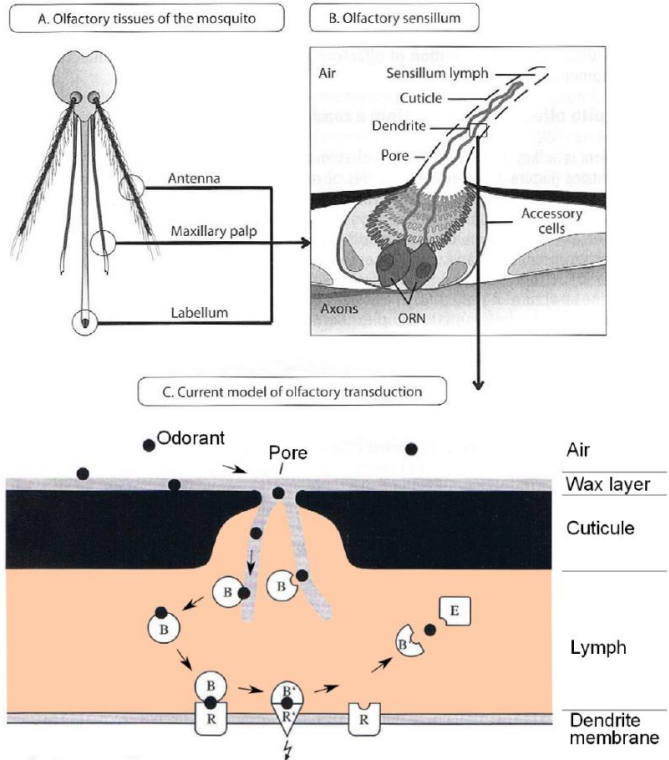
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Example: Low-Energy small CO₂-sensor



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Waarom BIOMIMETICA ??

- 1) Bewezen technologie**
- 2) Optimisatie naar laag energie verbruik**
- 3) Duurzaam gebruik van materialen**
- 4) Tijd-besparend ontwerp-traject**



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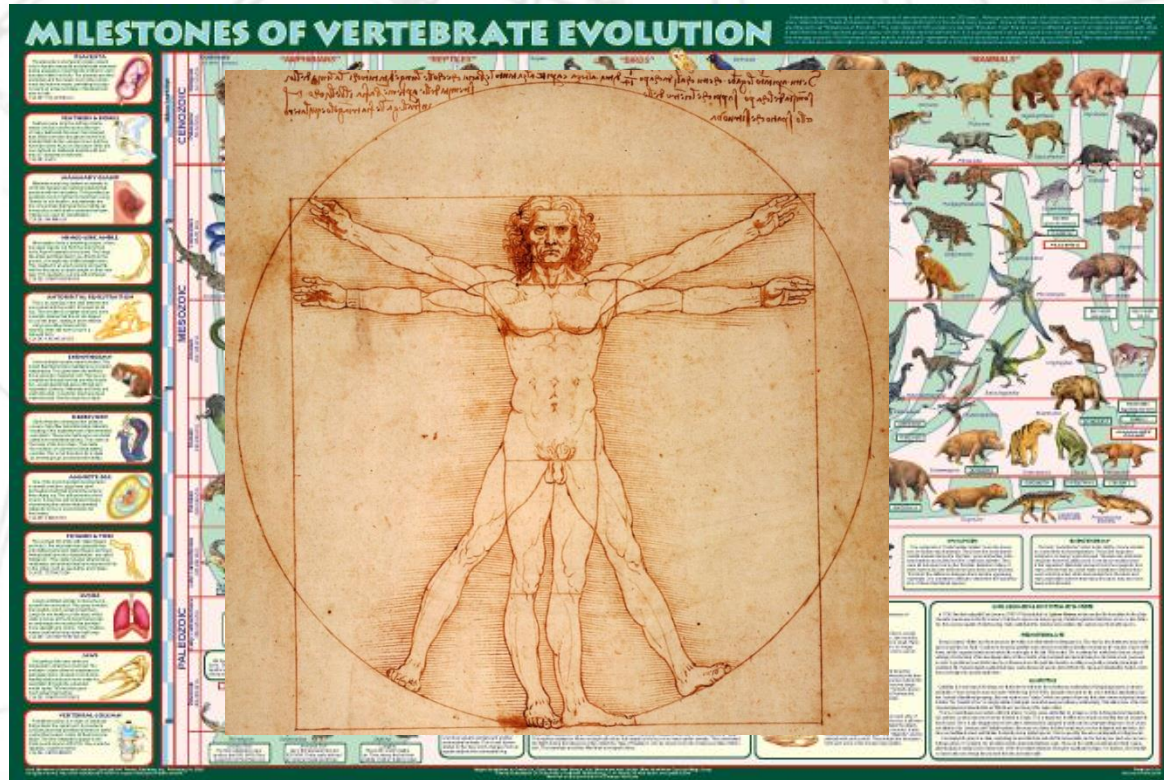
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1) Bewezen technologie:

**3.8 GJr optimisatie + experimentatie (= R&D)
slechts ca 10 kJr significante aanwezigheid vd mens**



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Bewezen technologie:

parallelle in veel technische disciplines:

- **Observatie**
- **Weerstandverlaging**
- **Boren en Graven**
- **Voortbeweging**
- **Vliegen**
- **Adhesie-mechanismen**
- **Water-zuivering**
- **Filtratie**
- **Energie-opwekking**
- **Energie-transport**
- **Energie-fixatie**
- **Lichtgewicht construeren**
- **Klimaat-beheersing**
- **Bescherming**
- **Reparatie-mechanismen**
etc....



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Bewezen technologie: een paar voorbeelden...



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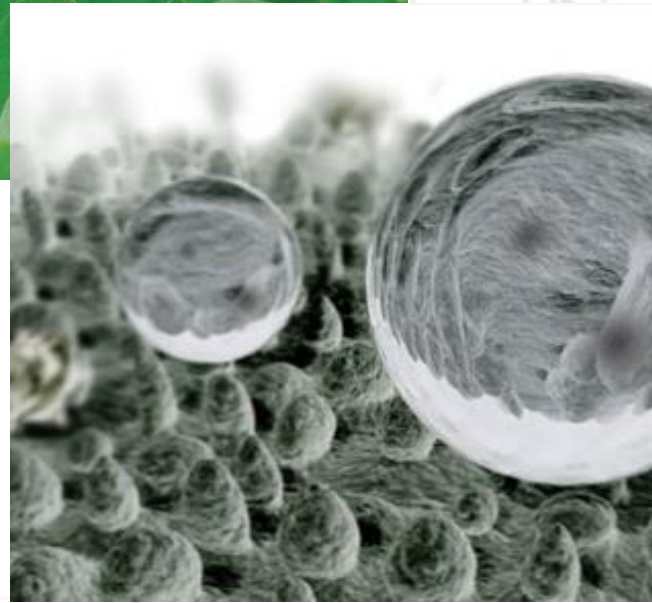


Bewezen technologie: Zelf-reinigende oppervlakken



Lotus-effect

Vuil hecht niet en spoelt weg met regen/water...



**Bespaart water,
energie, zeep,
Oplosmoddellen...**



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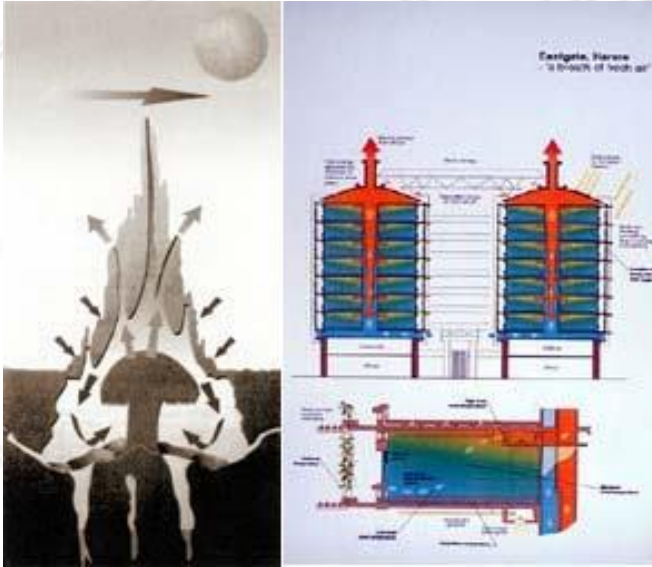
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Laag Energie-verbruik:

Zelf-climatizerende gebouwen



Gebruik natuurlijke ventilatie:

Gedoseerde ventilatie door 'toestaan' or 'stoppen' van natuurlijke ventilatie, i.c.m. passief koelen en warmte-wisselaars...

(model = Termiet-burcht)



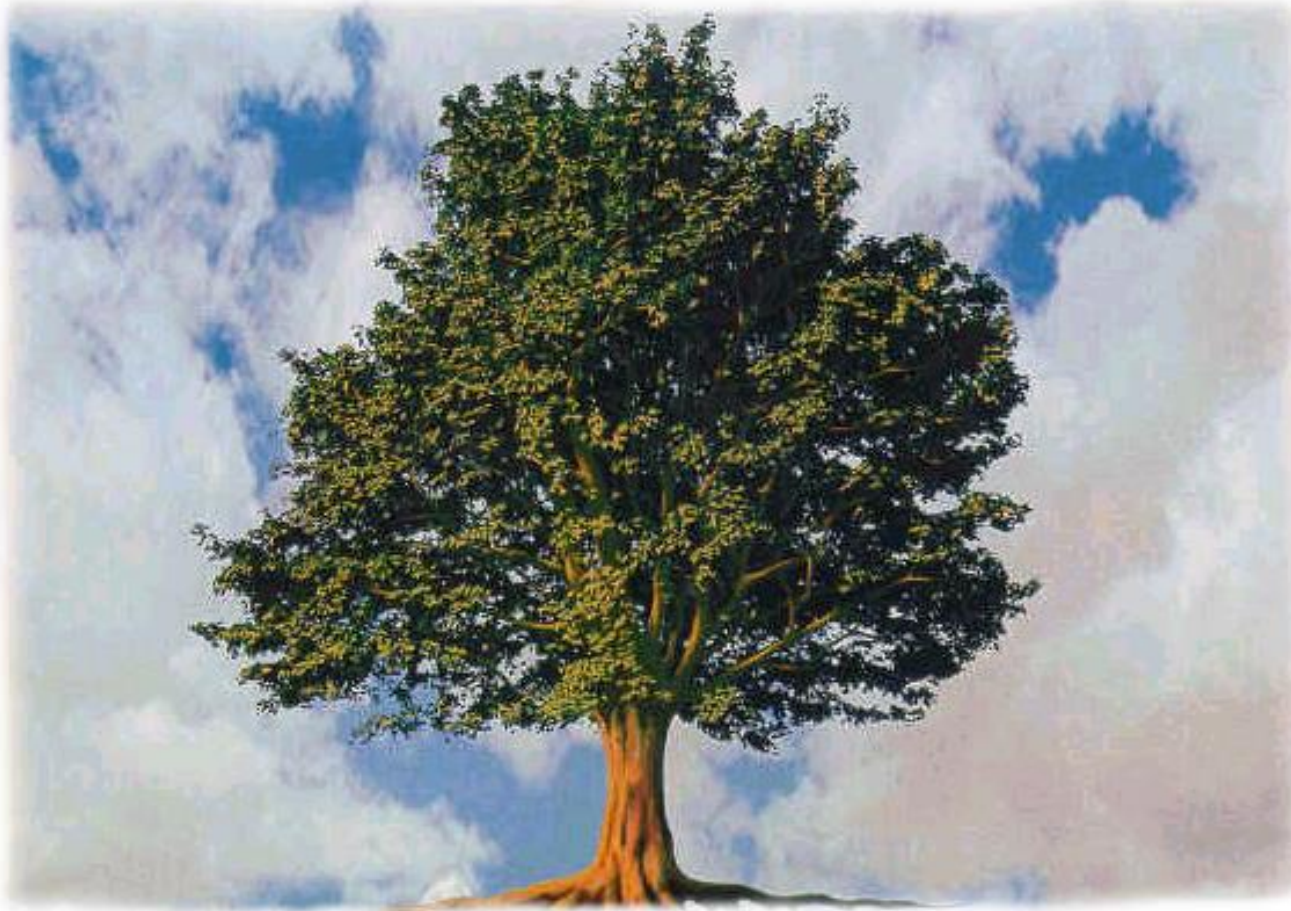
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3) Optimaal gebruik van materialen: Bomen & Botten



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Optimaal gebruik van materialen: Bomen



Bomen groeien zodanig dat excessive spanningen in bochten en vertakkingen worden voorkomen of gerepareerd...

ex: *bifurcation/tweesplitsing*

C. Mattheck, 1992



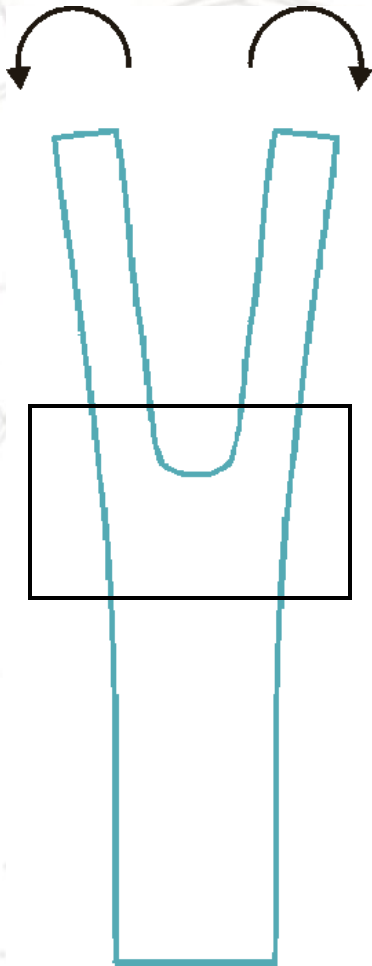
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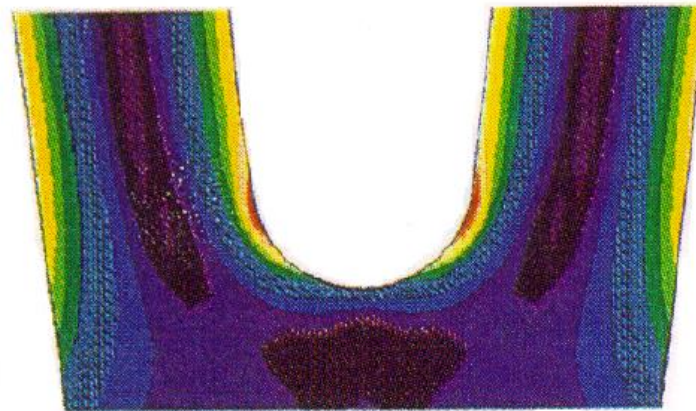


Optimaal gebruik van materialen: Bomen



Bifurcatie in technische constructie:

Vaak HOGE SPANNINGEN !



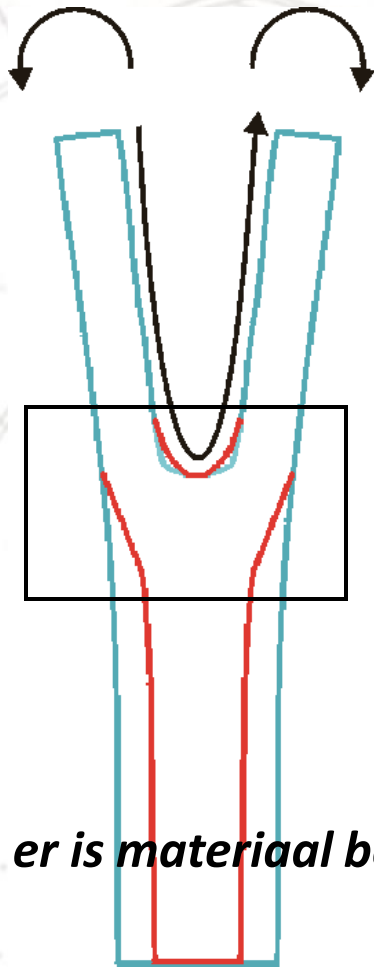
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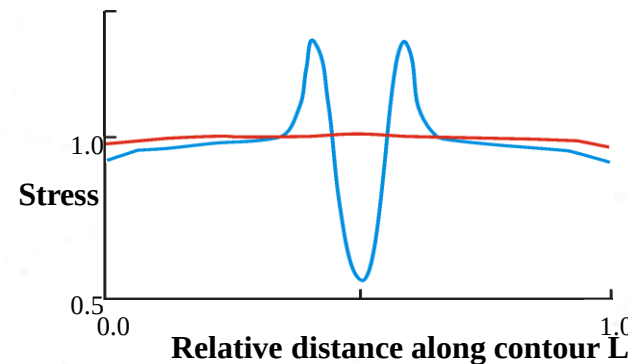
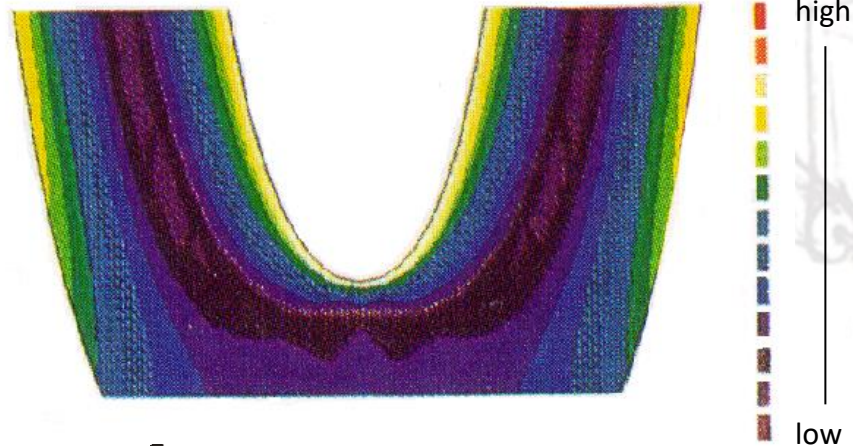
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Optimaal gebruik van materialen: Bomen



*Na optimalisatie volgens 'boom-principes':
Spanningen zijn meer gelijk verdeeld...*



..EN... er is materiaal bespaard!



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Optimaal gebruik van materialen: Bomen



*Medische Technologie voorbeeld:
buigpunt-stress =>
fracturen in implantaten*



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Besparen van Ontwerp-tijd: Genetische ontwerp-algorithmen



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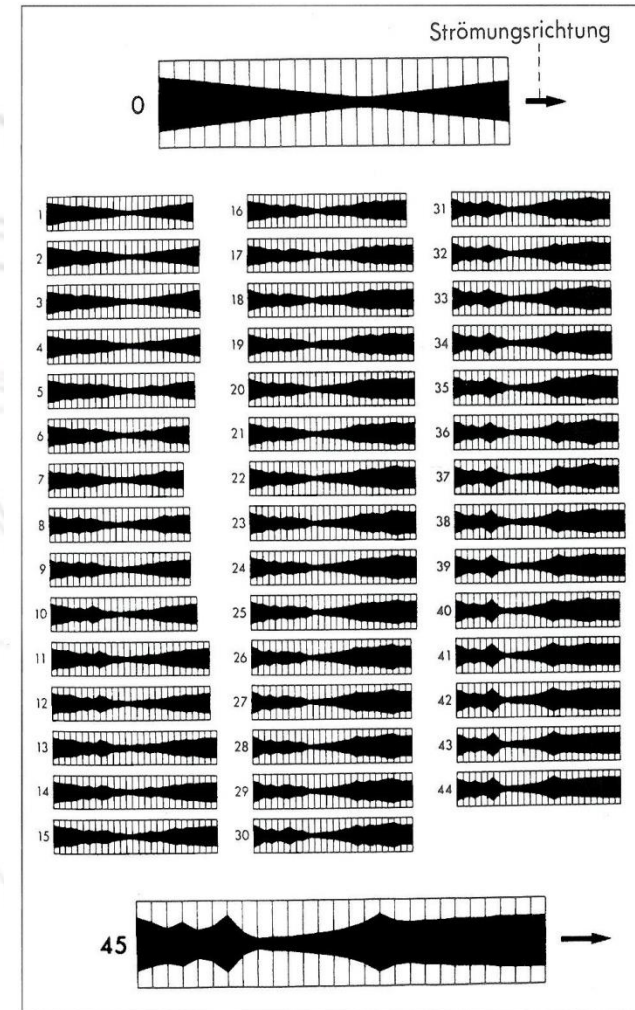
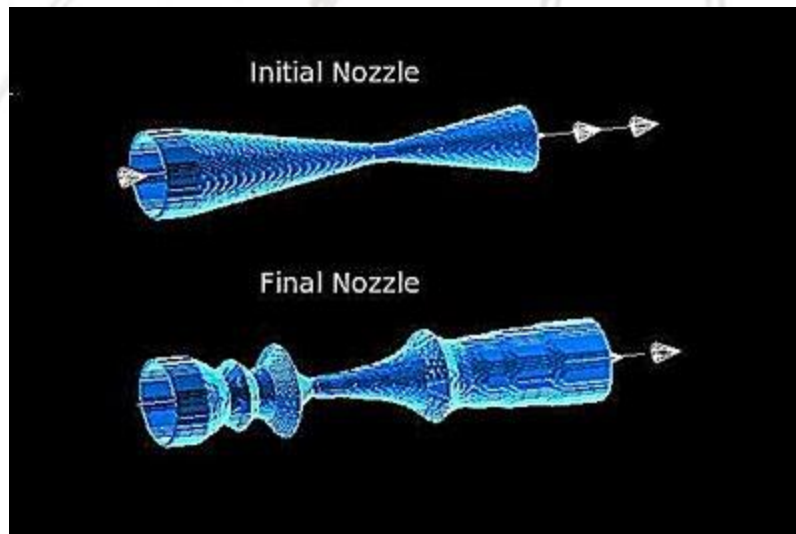
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Besparen van Ontwerp-tijd: Genetische ontwerp-algorithmen

Optimalizeren spuitstuk van een
MHD-generator...

(rocket-science)



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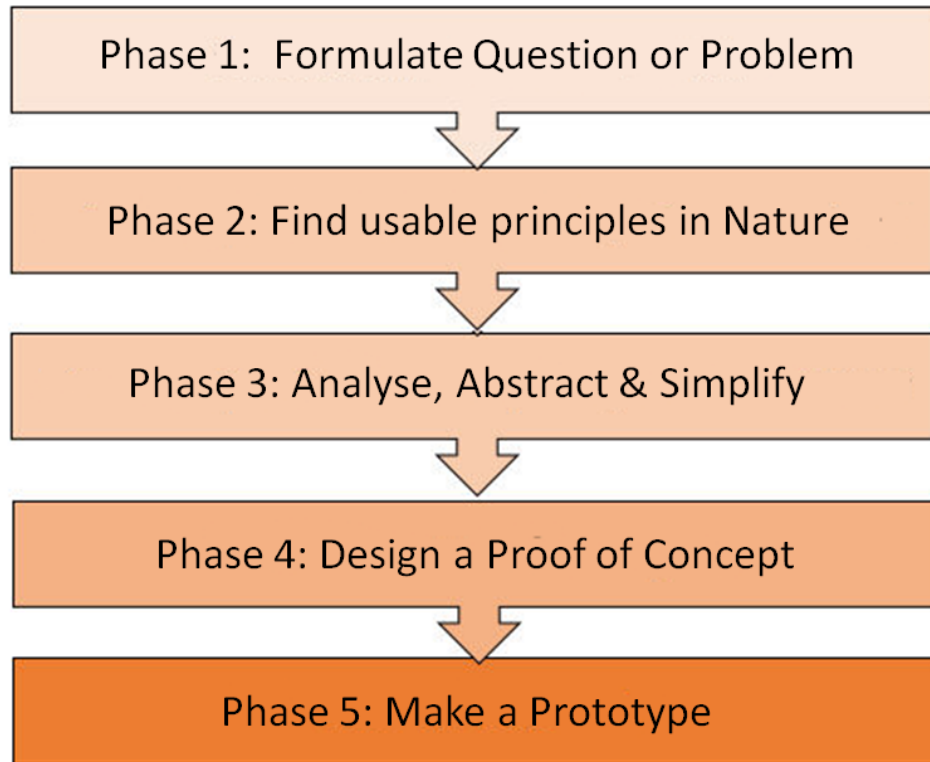
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Is er een standaard procedure voor een Gedegen **BIOMIMETICA** - studie ???' **JA !**

Biomimetics Innovation Method (BIM)



- 1) *Formaliseer probleem,*
- 2) *Vindt biologische parallel*
- 3) *Bestudeer*
- 4) *Abstraheer en Simplificeer*
- 5) *Verwerk tot toepassing.*



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BIOMIMETICA in mijn eigen werk:

2 voorbeelden...

Wind Turbine Optimalisatie

&

Scheeps-voortstuwing Optimalisatie



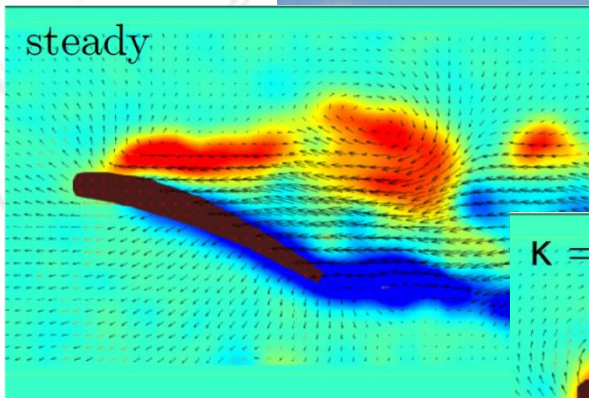
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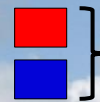
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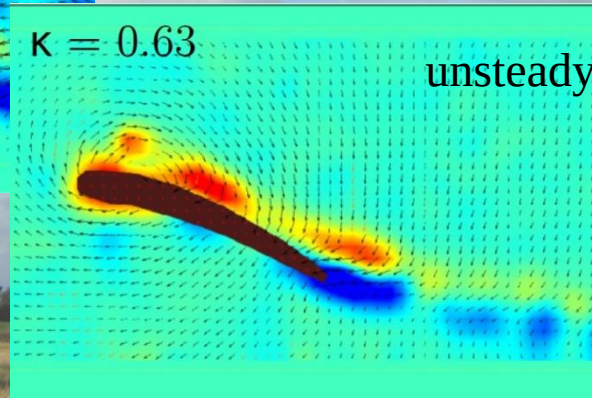


1) Biomimetische Ontwerp Optimalisatie van Windturbines...



 } vorticity (+/-)
= rotation rate

$\kappa = 0.63$



Potentieel
> 20 % toename v
aerodynamische
krachten v
wind turbines



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Max onttrekbaar wind vermogen (theor.):

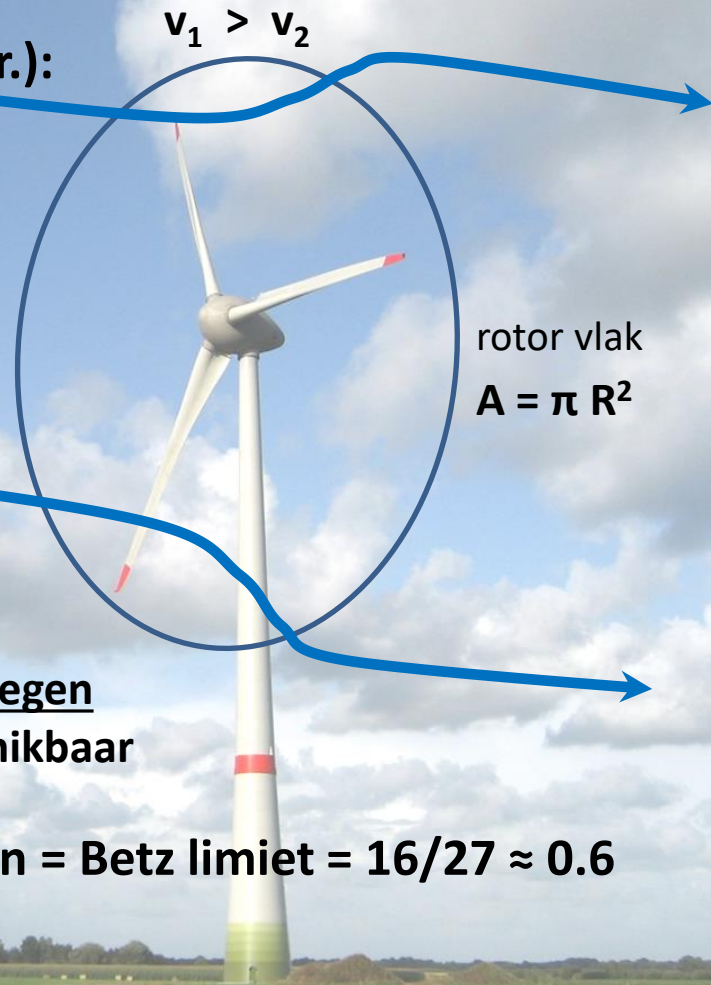
$$P_{\max} = \frac{1}{2} m v_0^2 / t = \frac{1}{2} \rho A v_0^3 \quad (\text{kin energie})$$

(bij $v_1 = v_\infty$ en $v_2 = 0$)

Maar.... $v_2 \neq 0$!!!

$\Rightarrow C_p = \text{vermogen ratio} = \frac{\text{Vermogen verkregen}}{\text{Vermogen beschikbaar}}$

Limiet om goed te kunnen werken = Betz limiet = $16/27 \approx 0.6$



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Betz limiet: $C_{p,max} = 0.6$

Hedendaags optimum ≈ 0.5

$\Rightarrow$ Nog 20 % te winnen !!!

Probleem-gebieden v moderne wind turbines:

- Lage wind snelheden (starten + lage opbrengst)
- hele hoge wind snelheden (wind-/storm-vlagen)



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- Zeer hoge wind snelheden (en vlagen) =
= blad verstelling niet snel genoeg -> *niet vandaag...*
= materiaal + vermoeidheids-problemen
- Lage wind snelheden (starten + lage opbrengst) =
= *systemische- + aerodynamische* problemen



Systemisch = draaiweerstand generator + rotor + etc. -> *niet vandaag...*

Aerodynamisch = Kunnen we de aerodynamische krachten bij weinig wind laten toenemen ??

of ook...: Kunnen we de aerodynamische krachten laten toenemen bij ALLE windsterktes ??



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Biomimetica-benadering = *Zijn er vogels die iets bijzonders doen/hebben waardoor de Lift toeneemt bij lage snelheden ?? (nb glijvlucht)*

GROTE ZEEVOGELS (bijv. Stormvogel & Albatros)



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WAT is zo SPECIAAL aan deze vogels (tijdens langzame glijvlucht) ??



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WHAT is so SPECIAL at these birds (during slow flight) ??



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WAAROM moeten ze sowieso iets bijzonders doen bij Lage Vliegsnelheden ??

Statische / Glijvlucht vleugel:

$$\text{Aerodynamische Lift} = \frac{1}{2} \cdot \rho \cdot v^2 \cdot A \cdot C_{L,\alpha} \cdot \alpha$$

dichtheid

snelheid

opp

Lift coefficient

aanstroomhoek

Lift $\propto$ snelheid in t *kwadraat*

-> snelheid is erg laag ...

Lift $\propto$ vleugel-oppervlak

-> vleugel-opp verandert niet...

Lift $\propto$ aanstroomhoek

-> aanstroomhoek kan toenemen...



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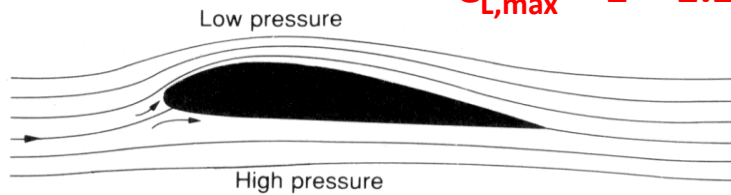
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WAT gebeurt er als de Aanstroomhoek toeneemt ??

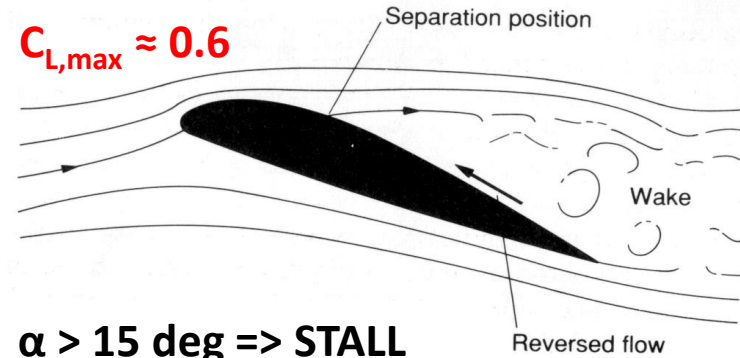
STATISCH:



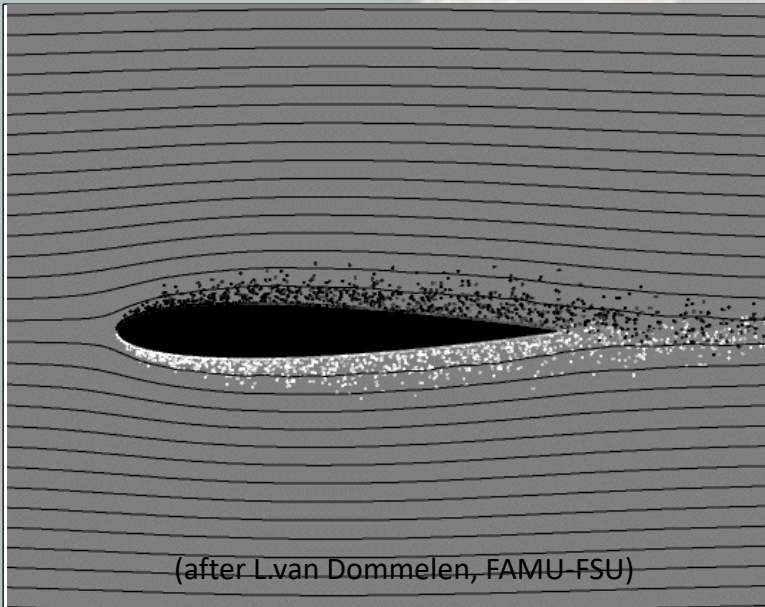
$$C_{L,max} \approx 1 - 1.2$$

$$0 < \alpha < 15 \text{ degrees}$$

$$C_{L,max} \approx 0.6$$

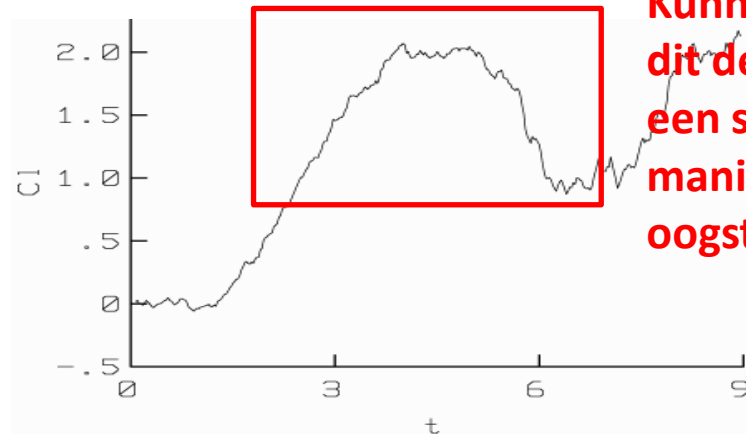


$$\alpha > 15 \text{ deg} \Rightarrow \text{STALL}$$



(after L.van Dommelen, FAMU-FSU)

$C_L(t)$



Kunnen we dit deel op een stabiele manier oogsten ???



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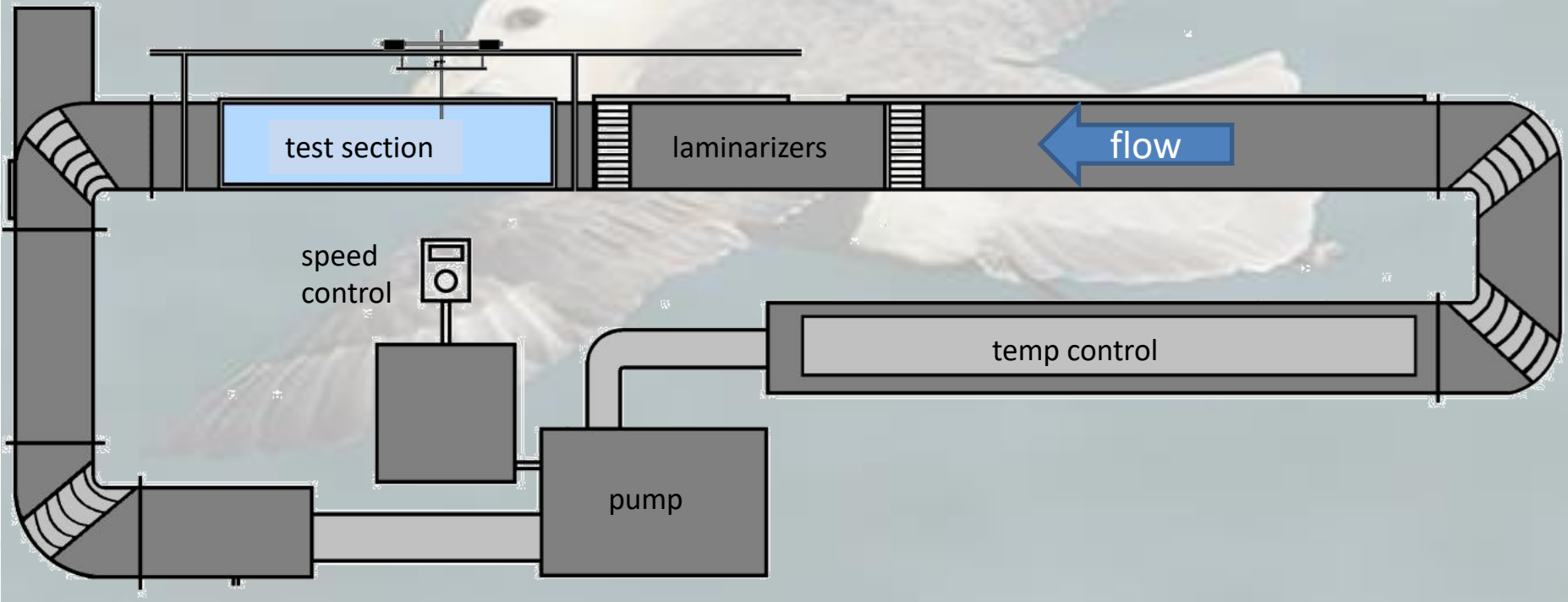
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Is het laten oscilleren van de vleugel (tilting) een truc om loslating te voorkomen ??



FLOW TANK EXPERIMENTS (at comp. Re & St)

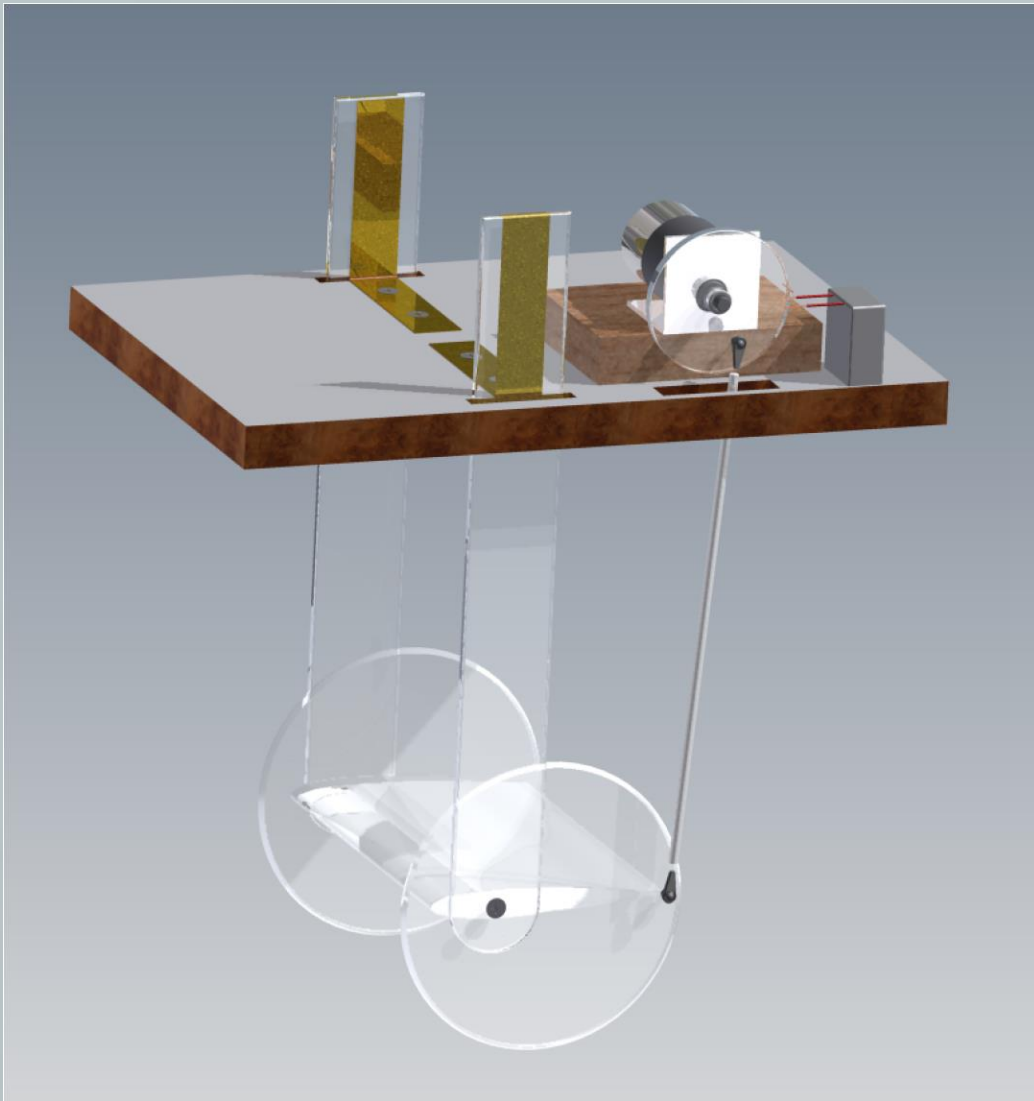


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Profiles

⇒ NACA 0012



⇒ Fulmar like (loaded)



$$Re = \frac{\rho v L}{\mu} = 46.000$$

3 red. frequencies:

$$\kappa = 2\pi f c / v = 2\pi St$$

$$= 0.25; 0.41; 0.63$$

Comp to 3; 5; 7.5 Hz in air

< 0.25 = quasi steady

0.33 = intermediate

> 0.5 = unsteady effs sign.

Oscilating 0 - 20°

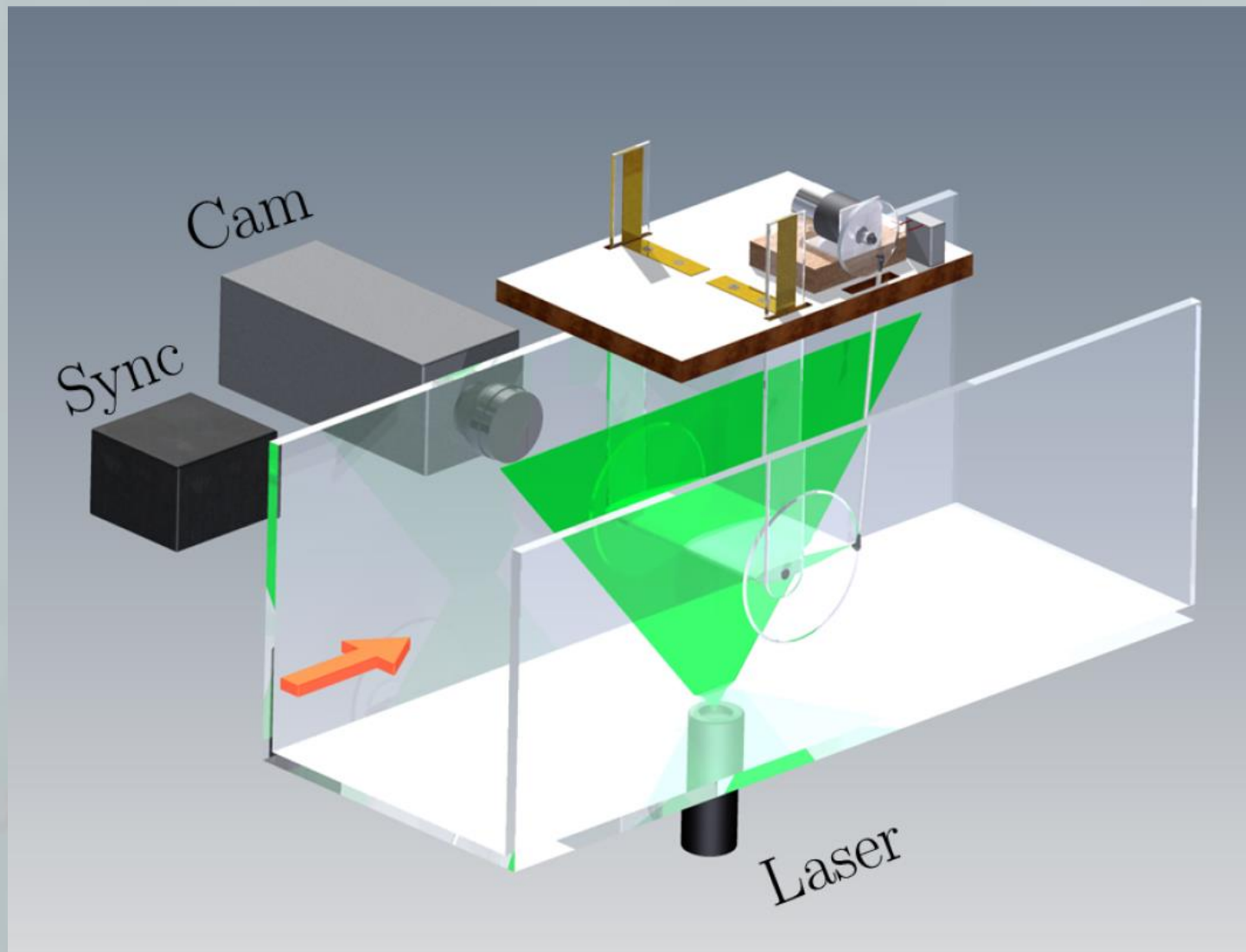


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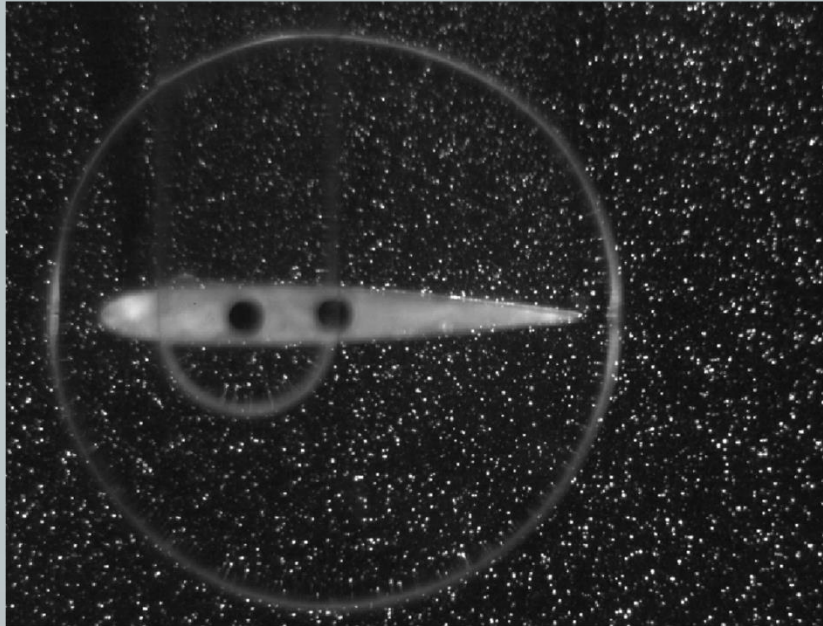
Opname + Analyse:

400 fps

1024 x 512 px

transparente houders

gesynchroniseerde Nd:YAG laser (532 nm)

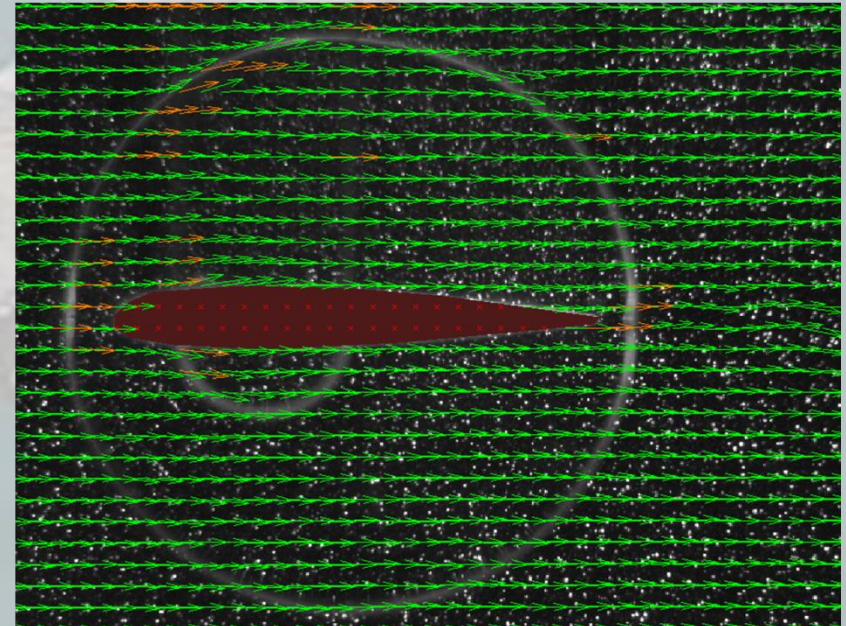


Digital Particle Image Velocimetry

PIVlab (Thielicke & Stamhuis)

32 x 32 px IA

50 % overlap



Lift berekening: Kutta-Jakowski-Theorema:
(oneindige vleugel)

$$L = \rho v \Gamma b$$

$b = \text{span}$

$$\Gamma = \oint v_t ds$$



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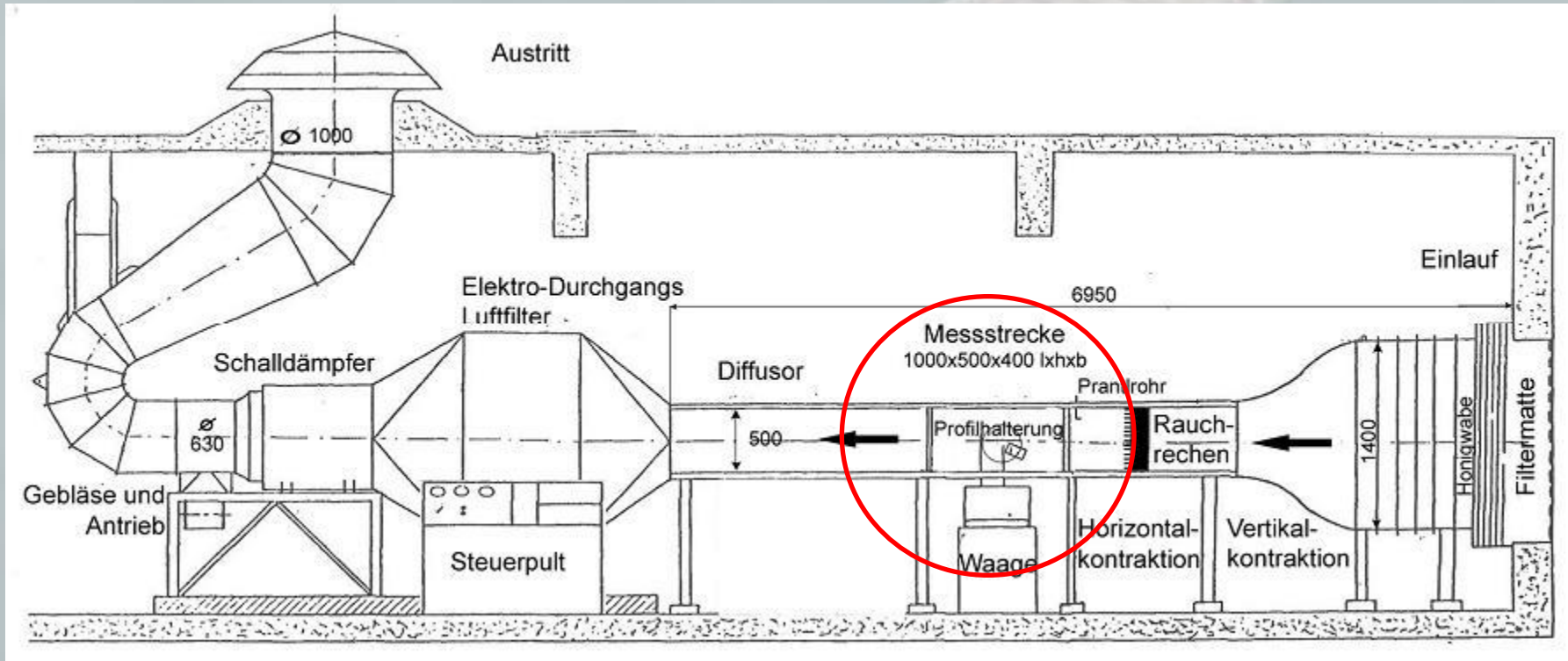
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En ook nog:

Directe kracht metingen in de wind tunnel.....

(niet vandaag....)



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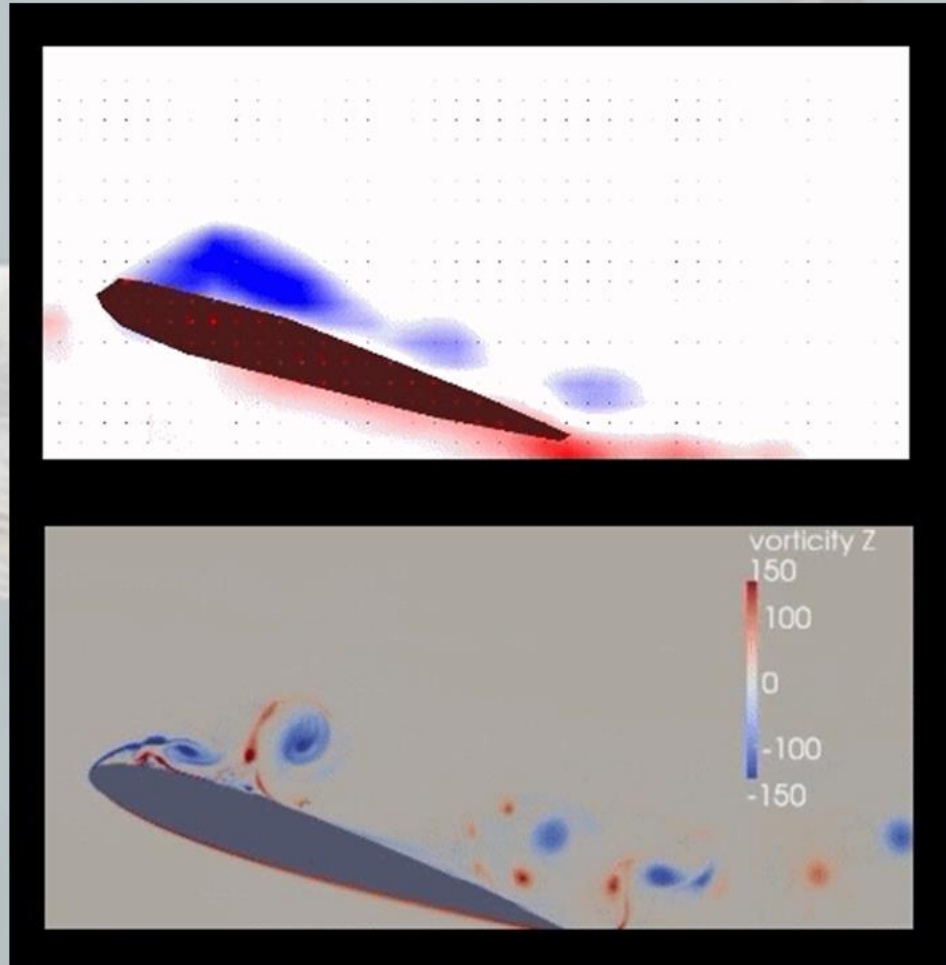


En ook nog: CFD numerieke simulaties NACA 0012
(samenwerking met A.Baars & D. Matz, Bremen)

(niet vandaag....)

Experimental....

Simulation....



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RESULTATEN:
(oscillerende profielen)

NACA 0012:

Uitgestelde maar toch
sterke loslating

+

Reductie vd Lift
tot weer aanliggen

STORMVOGEL:

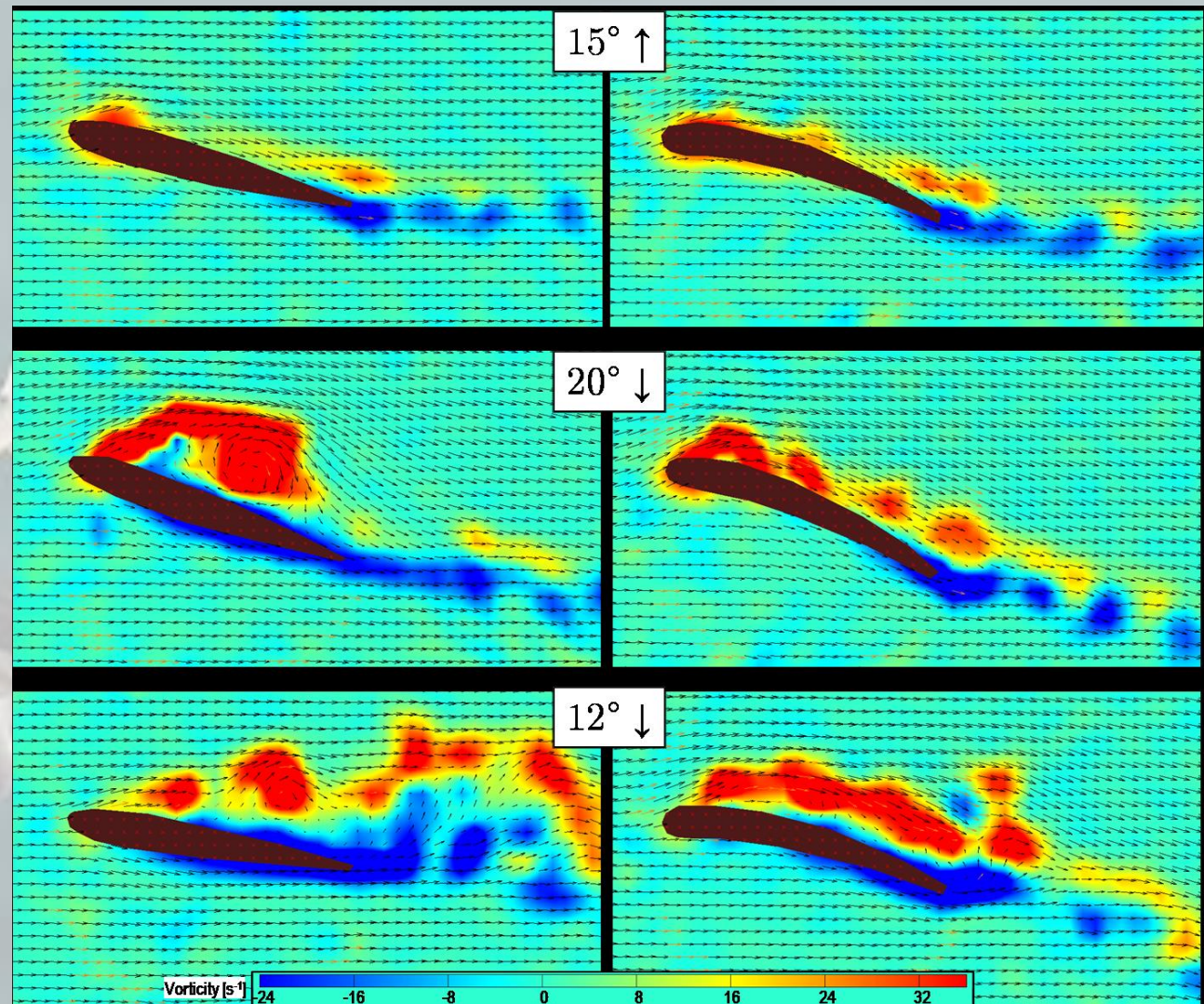
Toename CIRCULATIE
tijdens hele cyclus

->

Toegenomen downwash
(= Lift !)

NACA 0012

STORMVOGEL



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RESULTAAT:

(STORMVOGEL stabiel vs. oscillating)

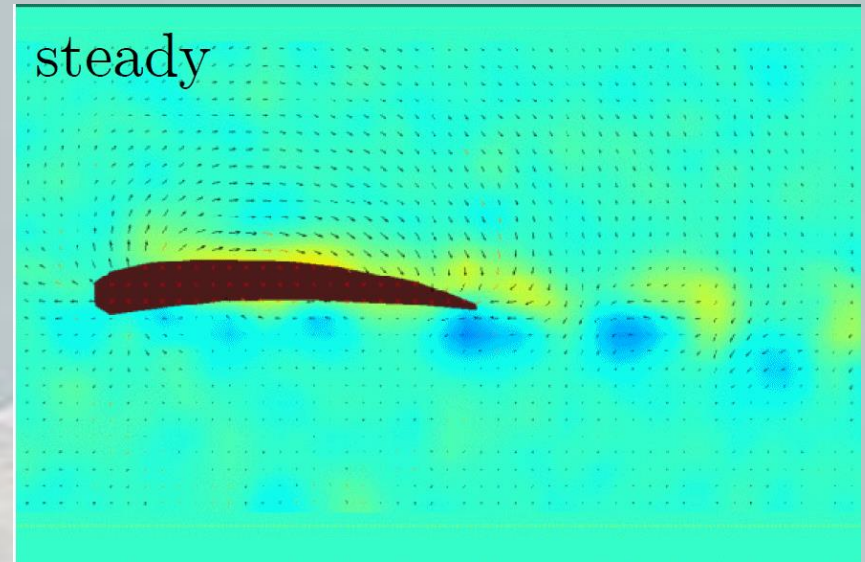
Volledige loslating bij $\alpha > 14 - 15^\circ$

$$C_{L,max} \approx 1.2$$

Boven stall hoek $C_L \approx 0.6$



steady



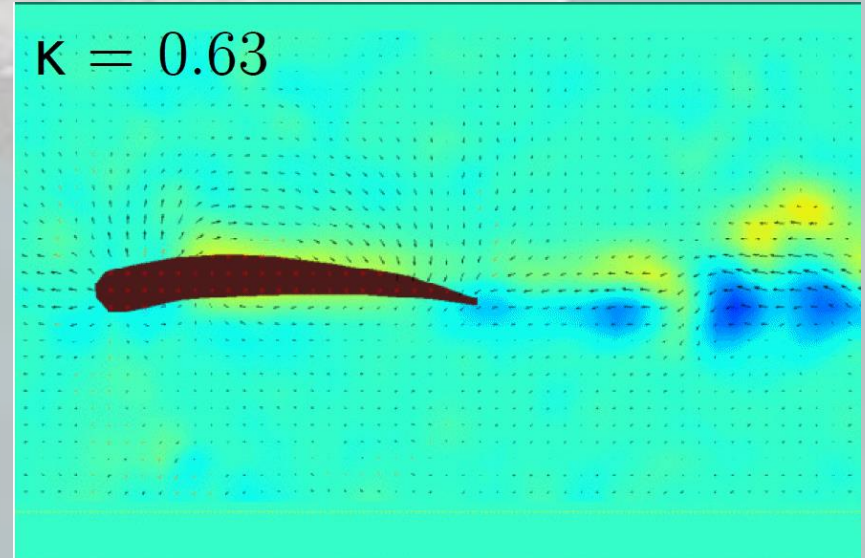
GEEN volledige loslating !!

Sterke TOENAME v Circulatie
bij alle aanstroomhoeken...

$$C_{L,max} \approx 1.9 - 2.0$$

Toename circulation blijft tot aan
grenslaag-verversing...

$\kappa = 0.63$



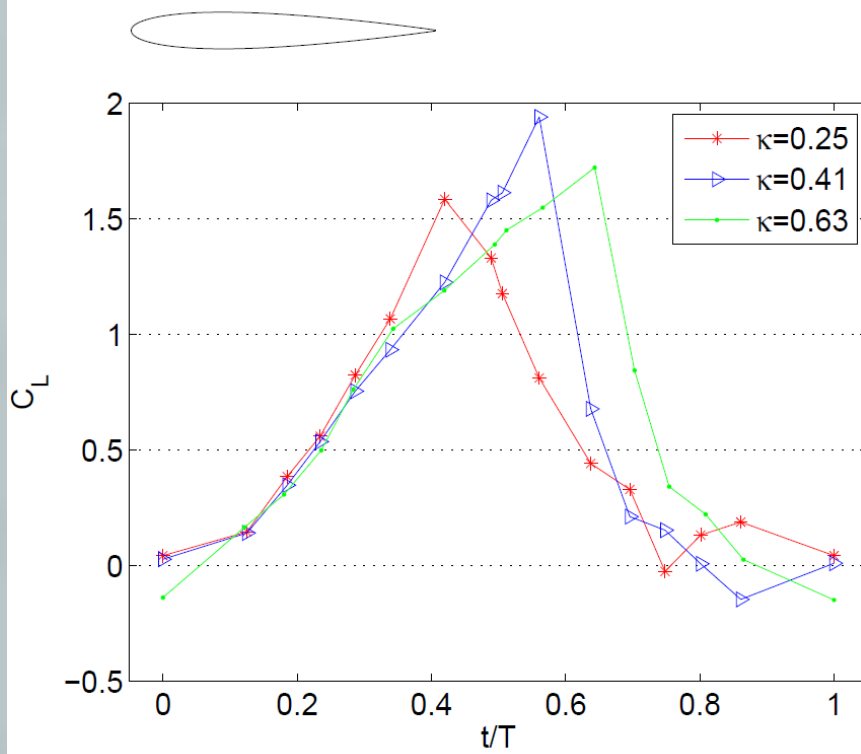
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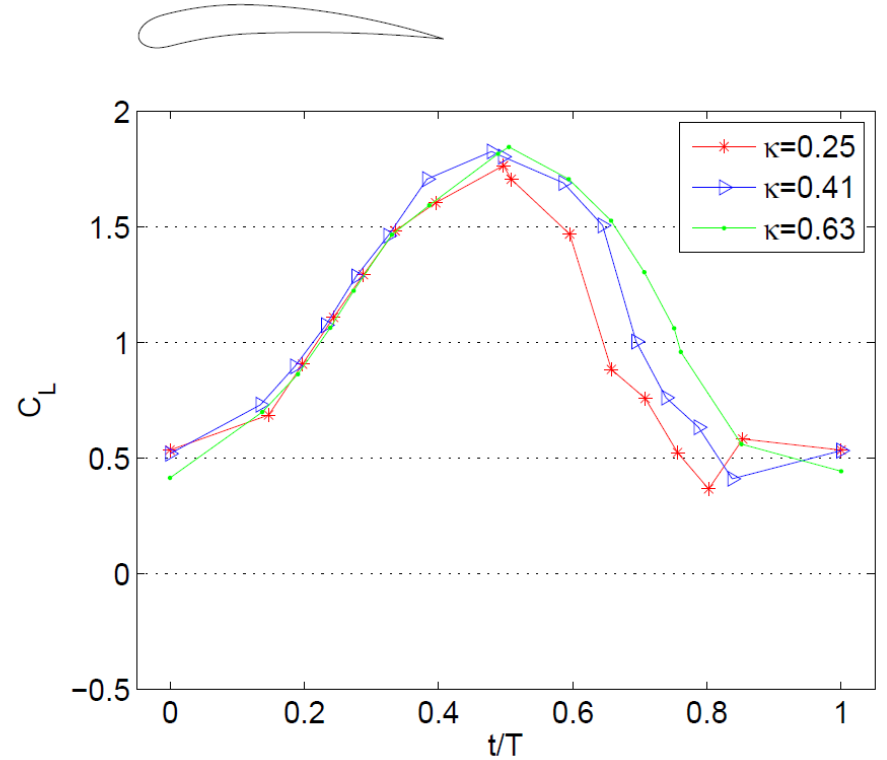
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RESULTAAT (oscillerende NACA & Stormvogel):



Hoge C_L -waarden tijdens deel cyclus
 Plotselinge loslating (stall)
 2e helft cyclus draagt nauwelijks bij
 Eff. neemt toe bij toename freq.



Hoge C_L -waarden tijdens gehele cyclus
 Langzame overgang naar lichte stall
 2e helft cyclus draagt veel bij
 Toen. Eff + totale kracht bij toen. freq.



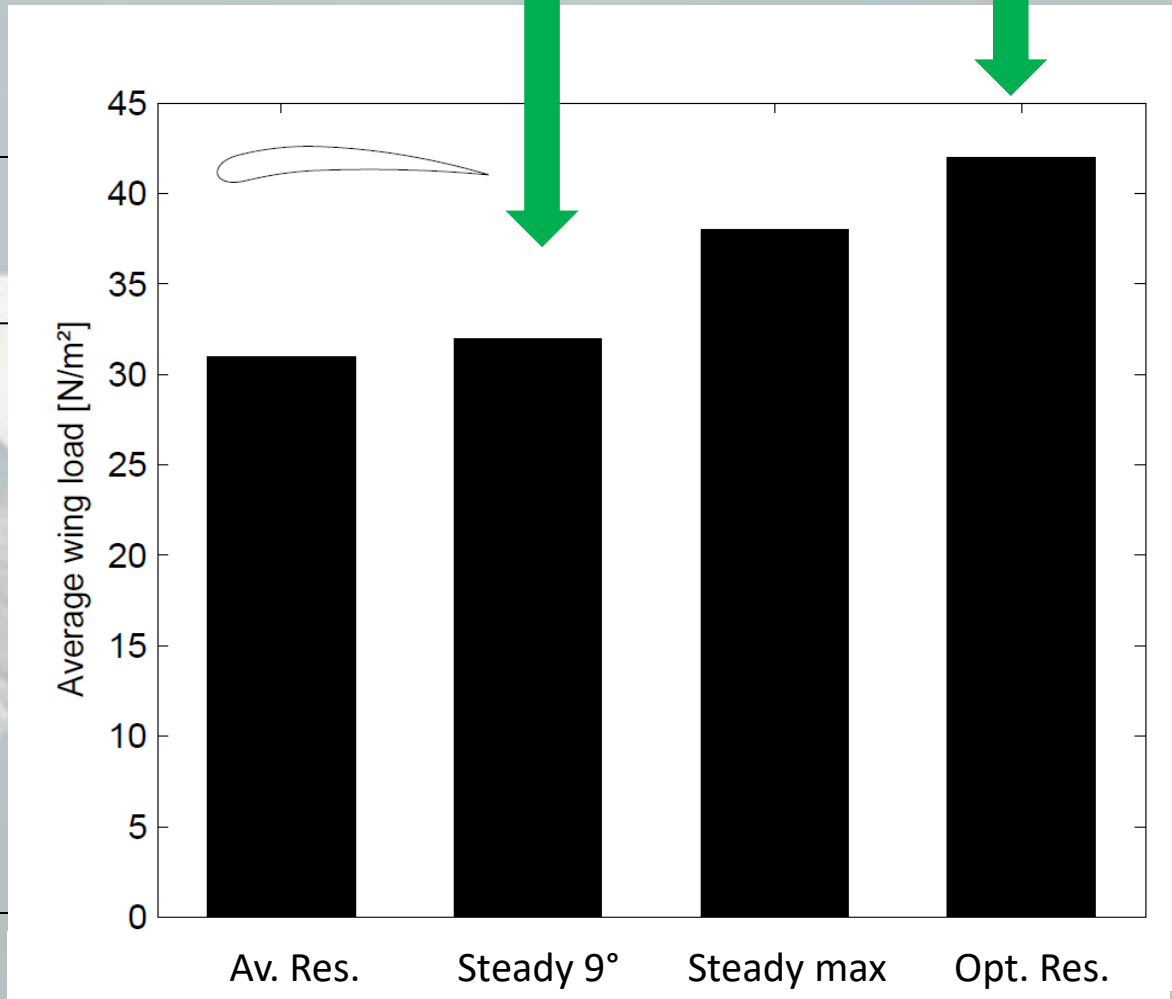
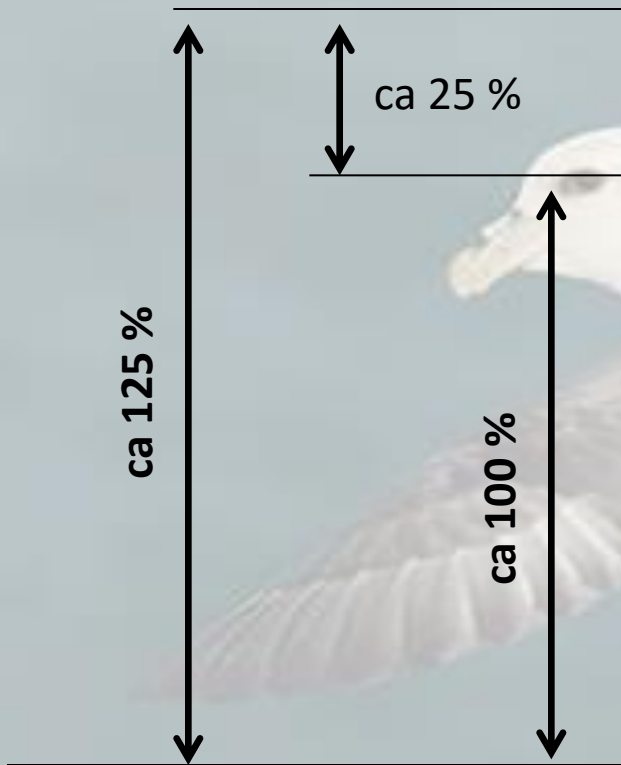
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RESULTS (netto aerodynamic krachten):



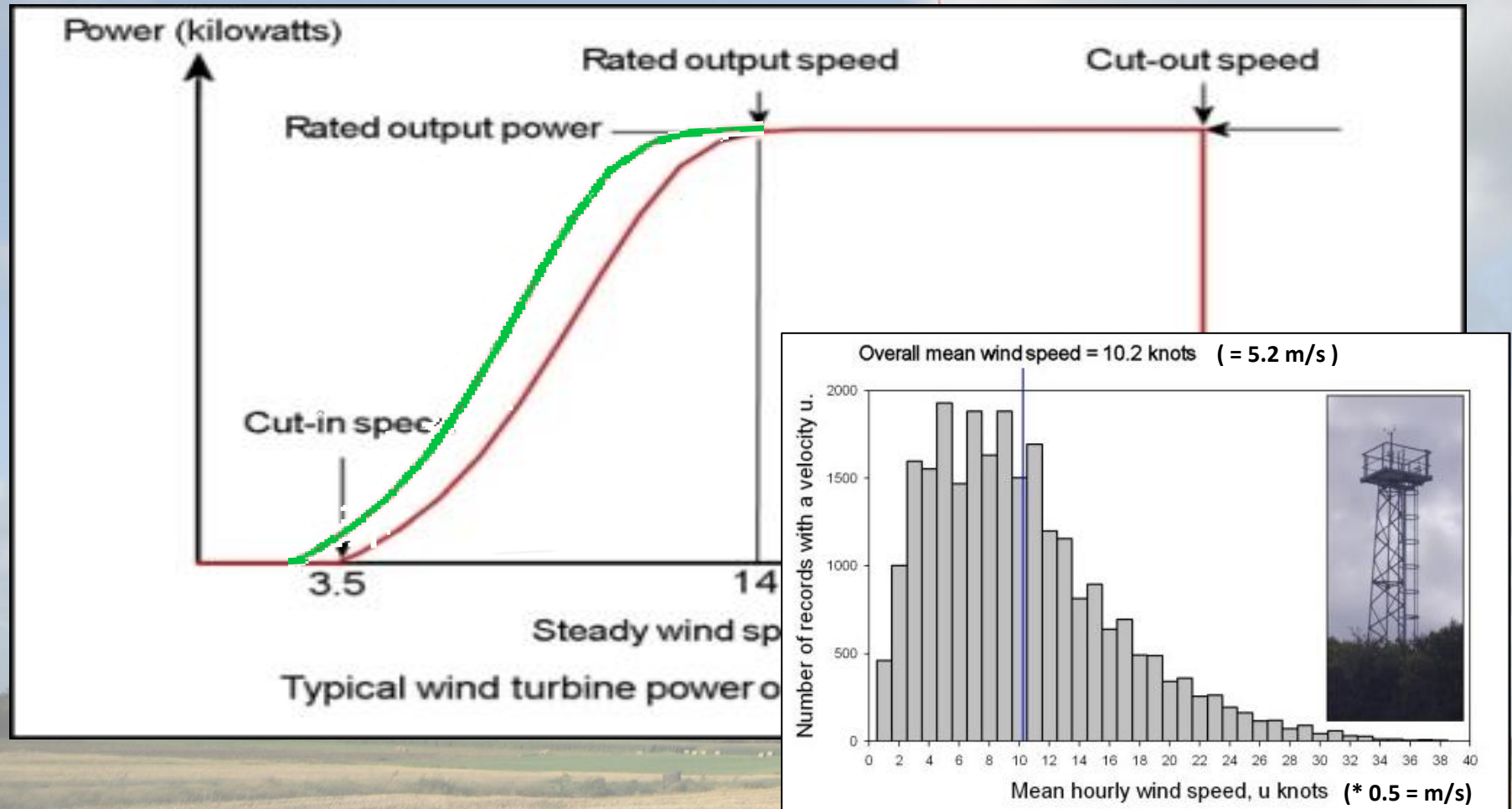
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Hoe werkt dit uit in de Praktijk ??? (oftewel... Maakt dit echt een verschil ??):



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CONCLUSIES:

- 1 = albatros/stormvogel aerodynamica levert hogere aerodynamische krachten dan statische profielen (...NB: patent toegekend !!...)
 - 2 = potentiële toename aerod. Krachten = 20 - 25 %
potentiële toename vermogen = 20 - 25 % (?)
 - 3 = Winst vooral bij vaak voorkomende (lage) windsnelheden
- } = **VEEL-BELOVEND!!**

HUIDIG/TOEKOMSTIG ONDERZOEK:

- *Kosten van weerstandstoenames door loslatingen -> kan de winst verlagen...*
- *Meer onderzoek naar optimalisatie parameters*
- *Technische implementatie bij werkelijke wind turbine systemen (eerst op schaal)*



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... van turbines naar propellers ...



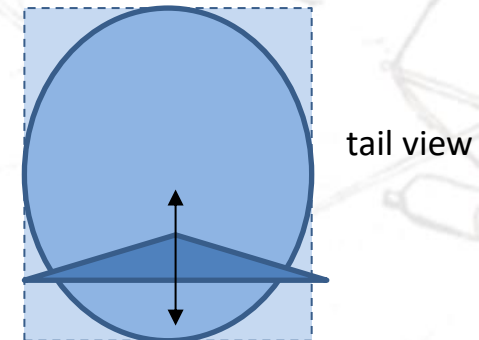
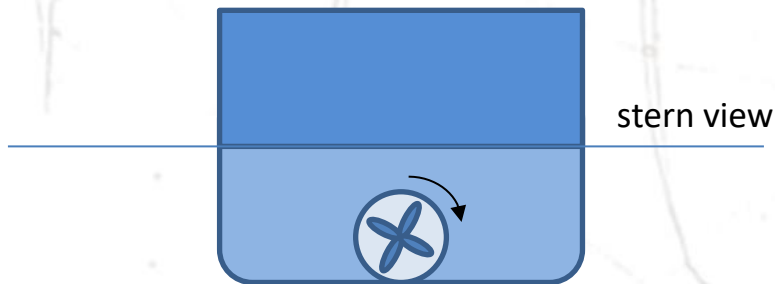
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2) Biomimetisch optimaliseren van scheeps-voortstuwing...



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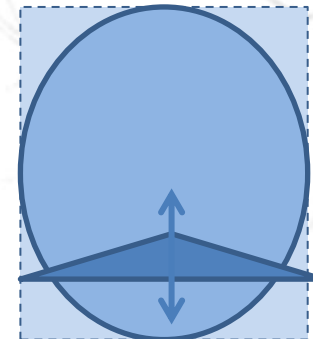
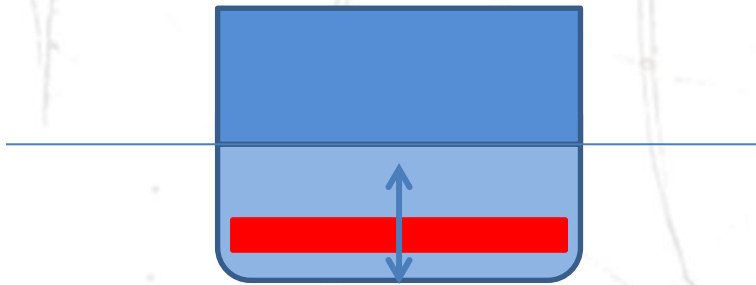
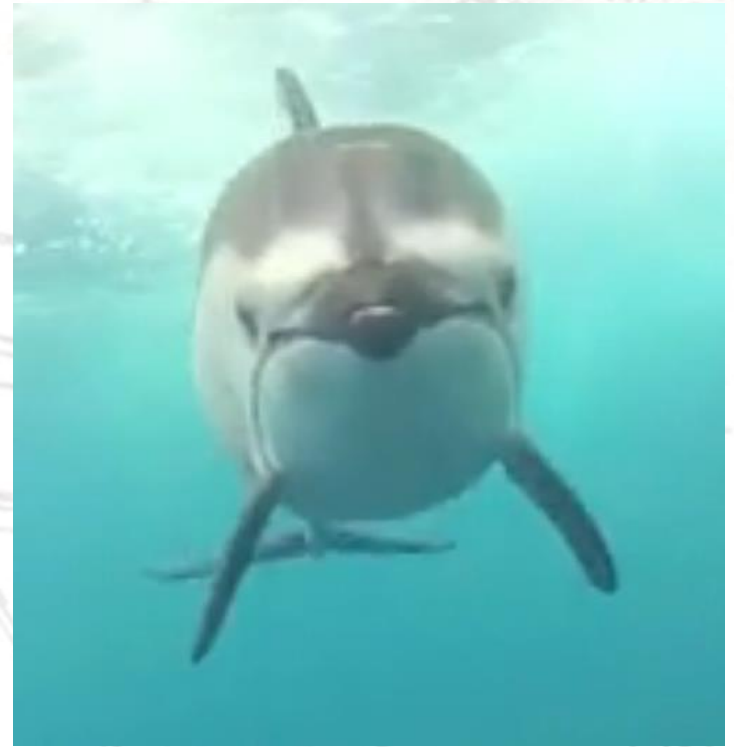
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$F = m a = m (du/dt) = d(mu)/dt$	Schip	Dolfijn
Stuwkracht: $F = \frac{1}{2} \rho u_w^2 A C_T$	Kleine A Hoge u_w	grote A lage u_w
Vermogen cons. : $P = \frac{1}{2} \rho u_w^3 A C_T$	Hoge P	lage P
Froude eff. : $\eta_F = \frac{2 u_s}{u_s + u_w}$	0.2-0.4	0.8-0.9



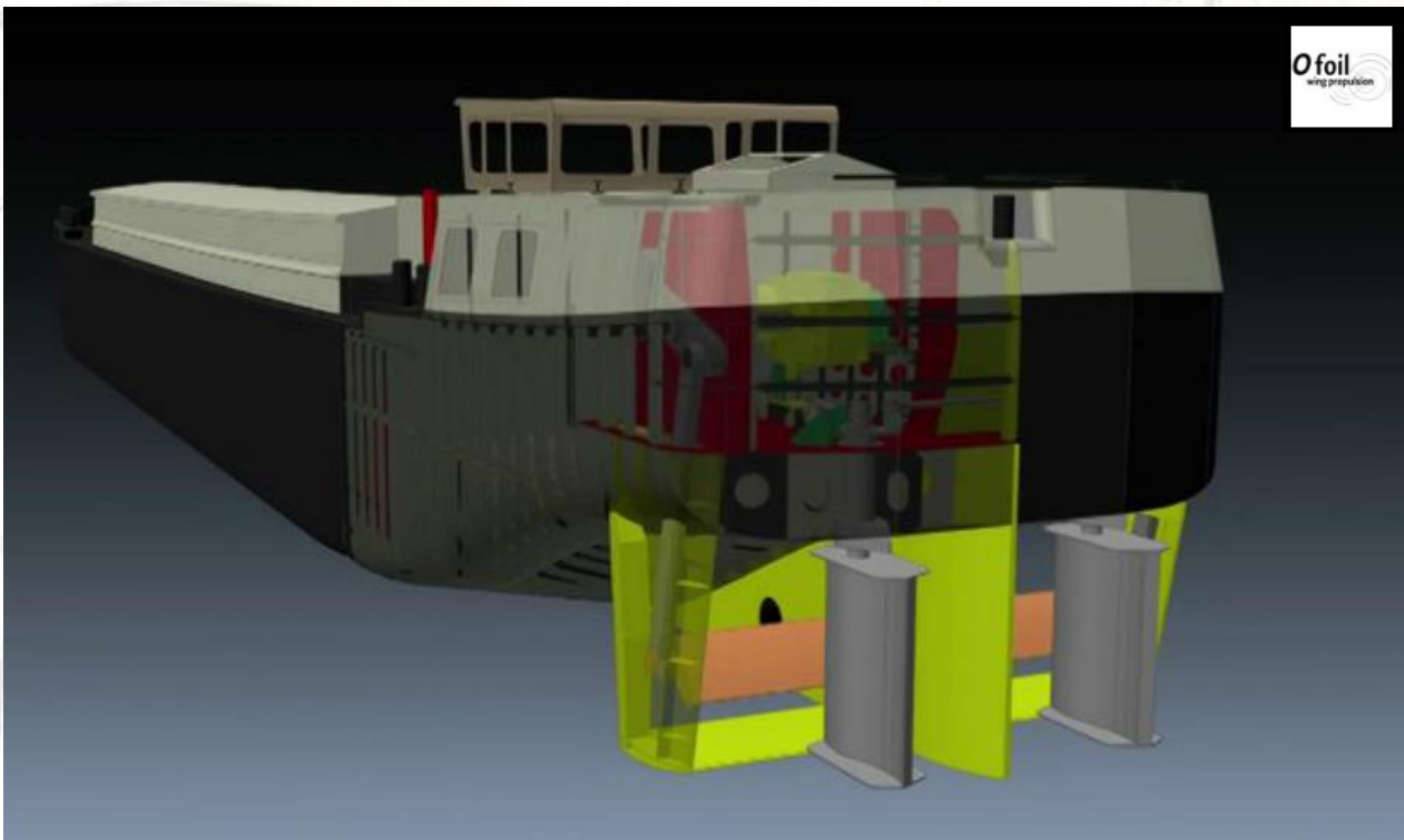


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Prachtige Biomimetica...

... maar...

Wat voor Vleugelprofiel zou zo'n systeem moeten hebben ??

Wat is eigenlijk het vleugelprofiel van een walvis-staart ??

- We gaan een stukje terug in de tijd -



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Noordse Vinvis

Dood aangespoeld bij Rotterdam

Onvolwassen vrouwtje

Lengte ≈ 9 m

Gewicht ≈ 10.000 kg

Zou worden versneden om het skelet er uit te halen... Die nu tentoongesteld is in Leiden (Naturalis) ...



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... De walvis wordt naar een bereikbare plek getransporteerd...



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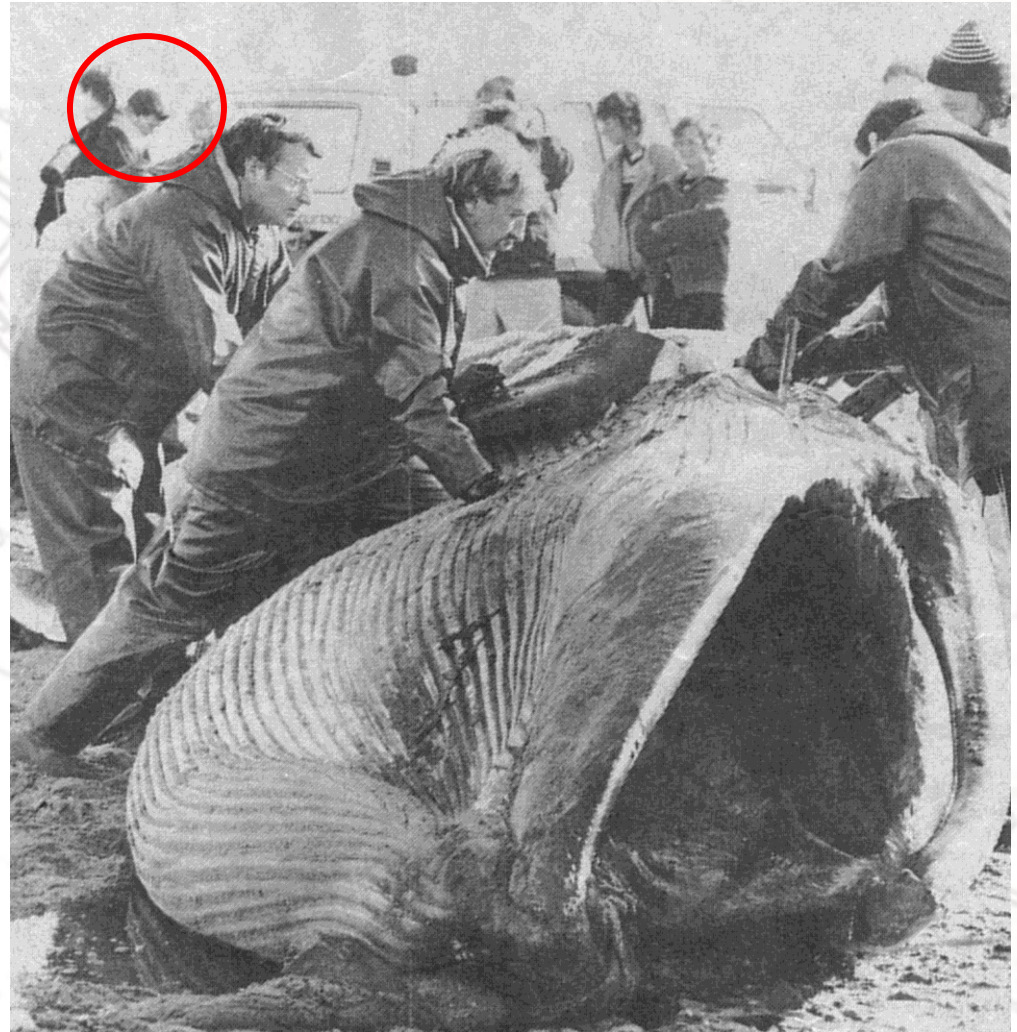
Een 'eager young scientist'
vd Universiteit Groningen
wilde de staartvin hebben ...

... Om die anatomisch te bestude-
ren om de functionele morfologie
van walviszwemmen te kunnen
begrijpen ...

De staart was ca 1 m breed...
... zeiden ze ...

Paste wel in de kofferbak...
... zeiden ze ...

Het pakte wat anders uit ...



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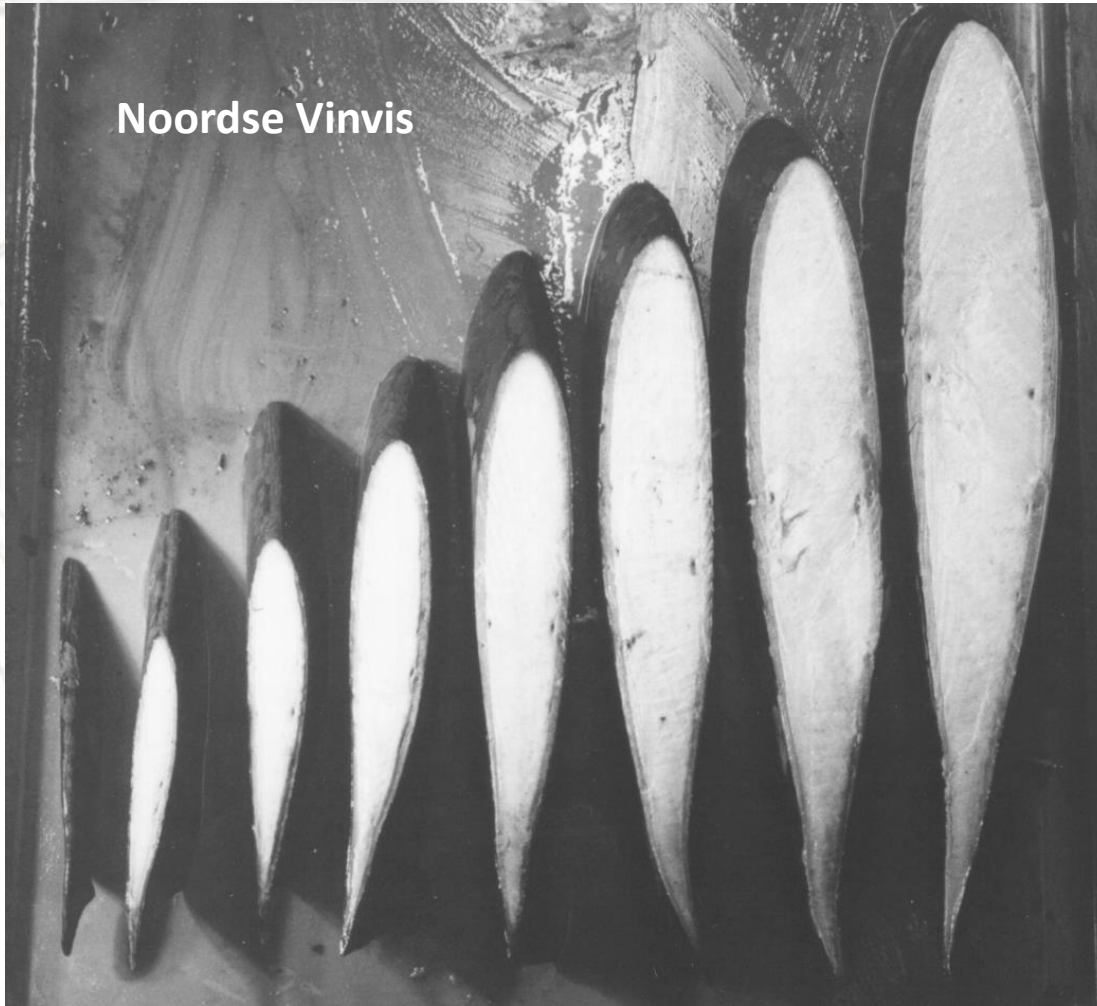
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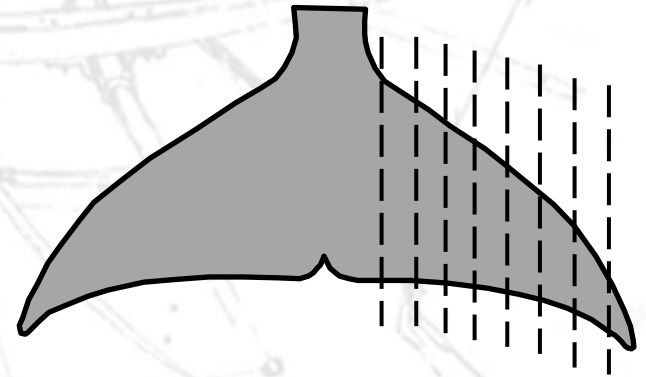
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Noordse Vinvis



Helft vd staart werd in plakken gesneden:



=>

Is dit de 'ideale' vorm voor een scheeps-propulsie-systeem??



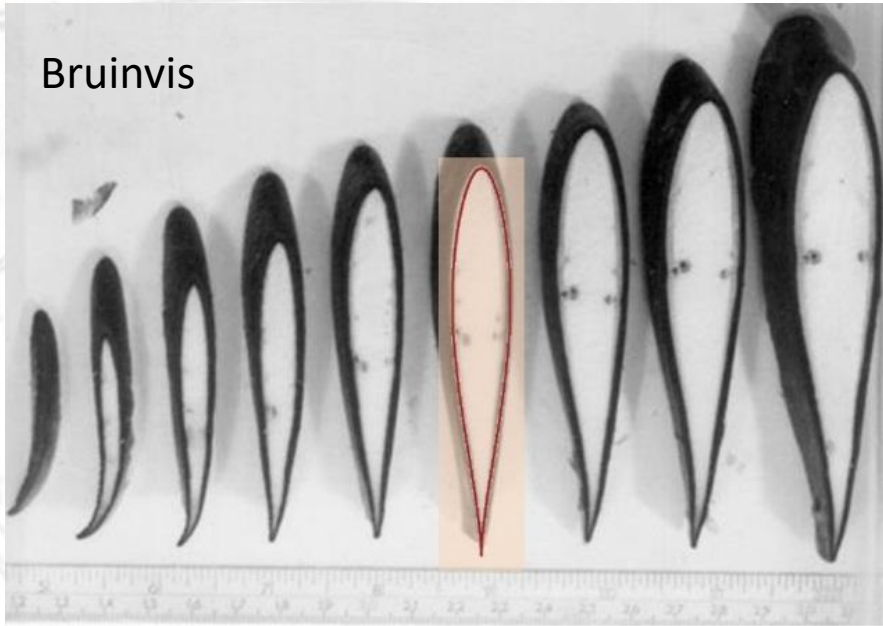
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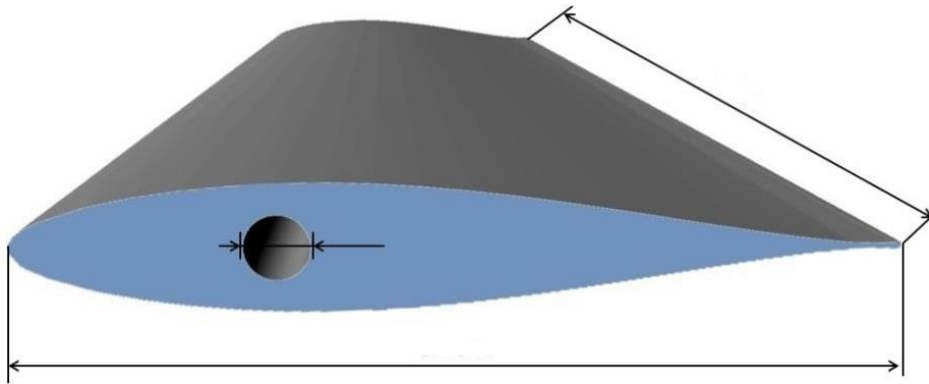
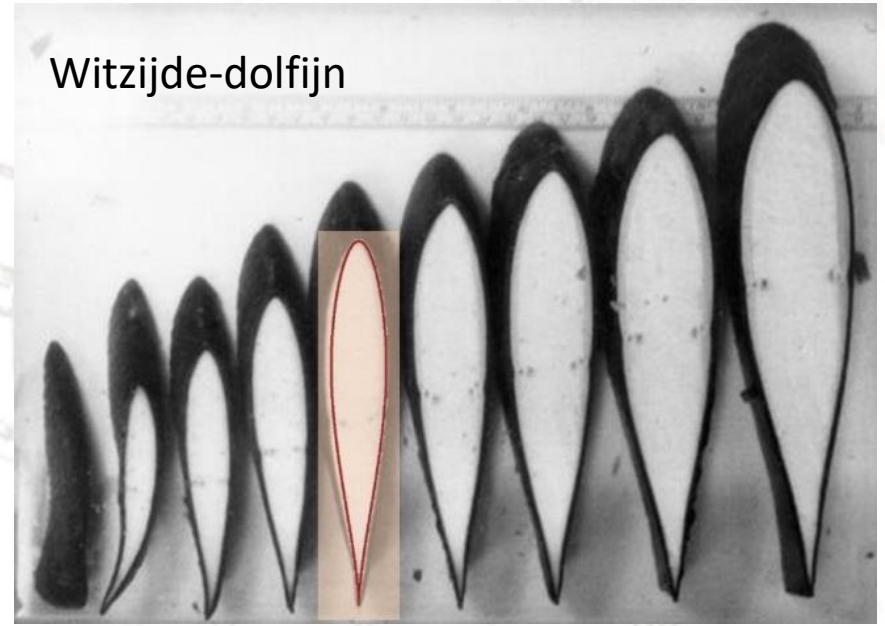
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Bruinvis



Witzijsde-dolfijn



NACA 63-015 or 63-018

Optimaal voor hoge Re
Grote range aanstroomhoek



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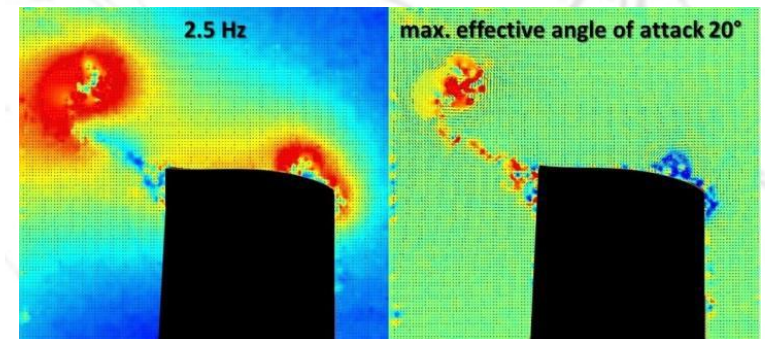
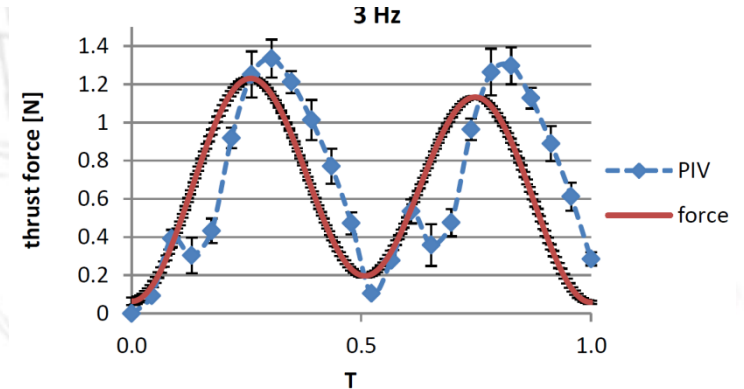
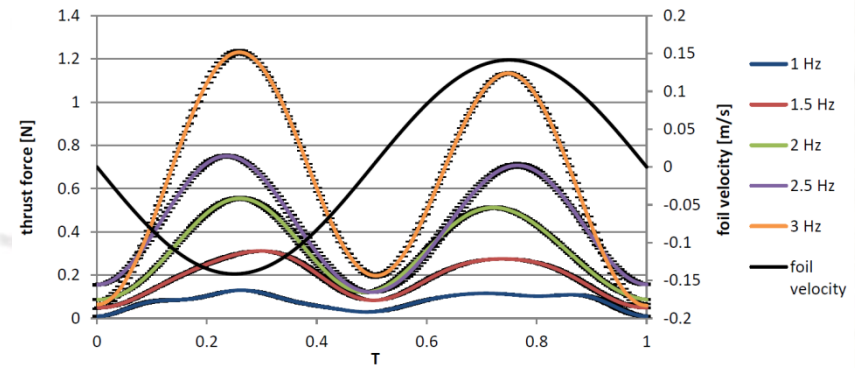
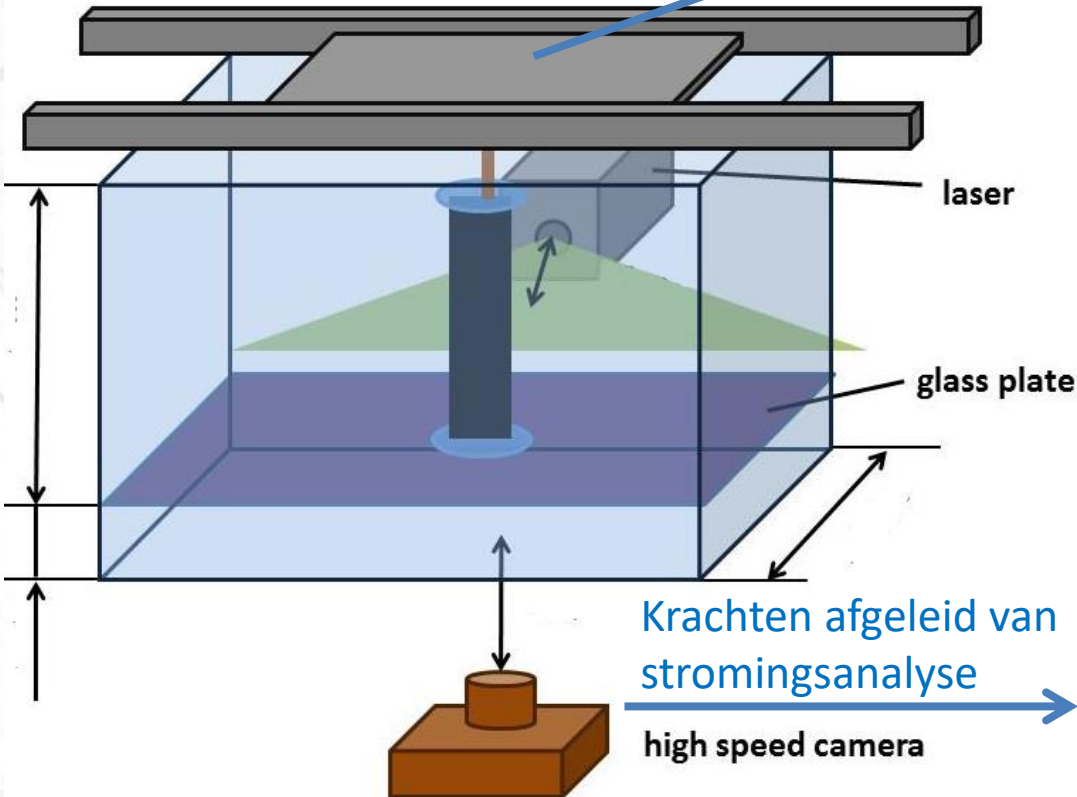
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Testen van een undulerend profiel:

directe meting krachten



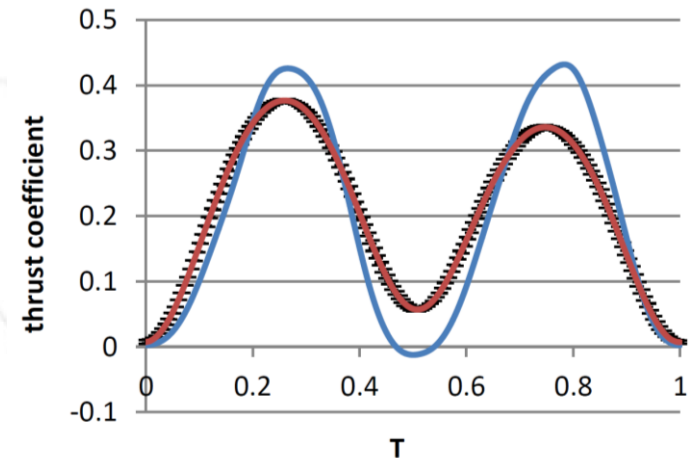
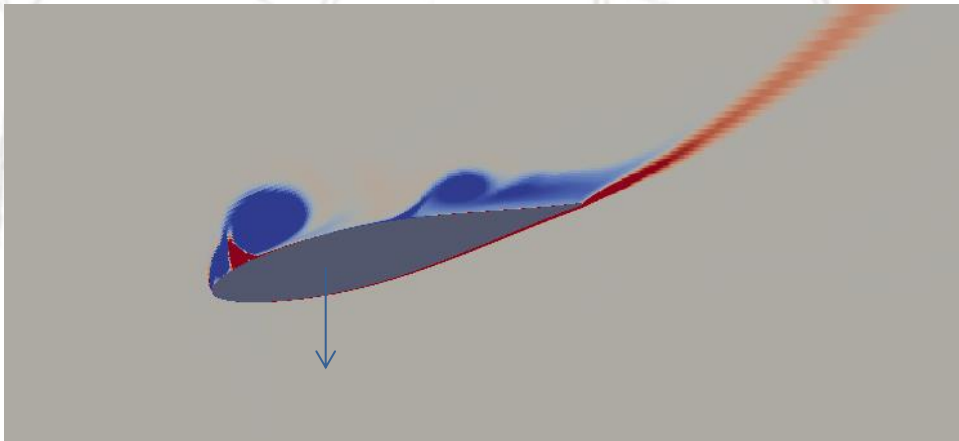
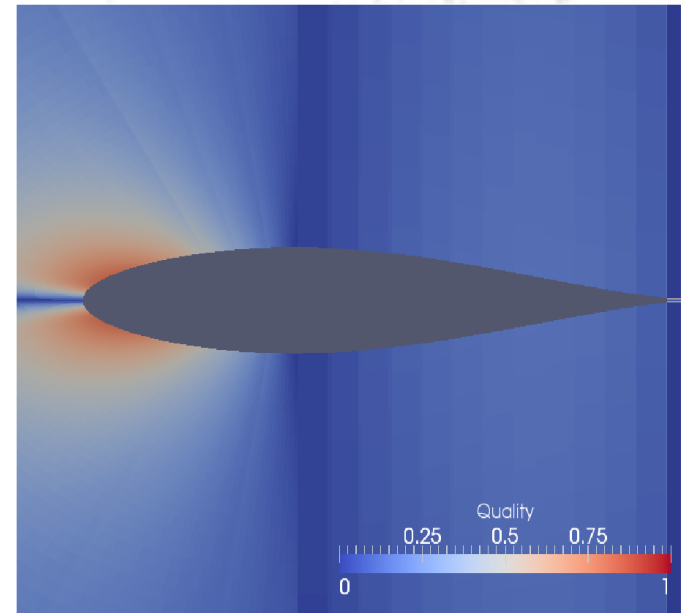
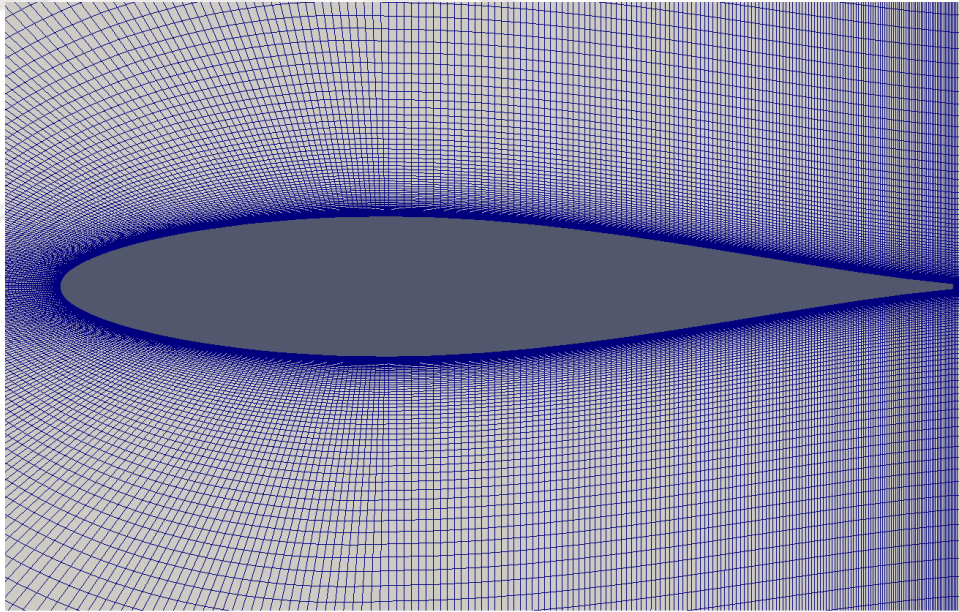
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Computational Fluid Dynamics Simulations (UASBremen) => goede match met exp. data



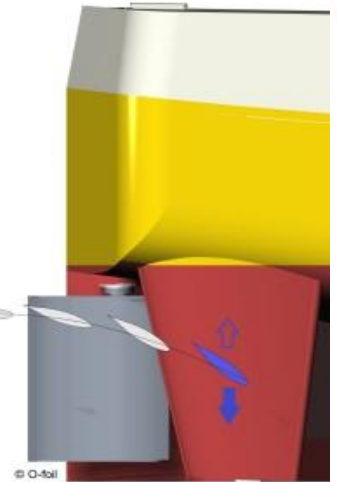
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Wat is de potentiële WINST... ?



Geïnstalleerd motorvermogen = 30 - 50 % lager dan voorheen...

Brandstof besparing tot ca 35 % ...

Motor-gedrag schip & snelheid = vergelijkbaar met voorheen (*zelfs achteruit*) ...



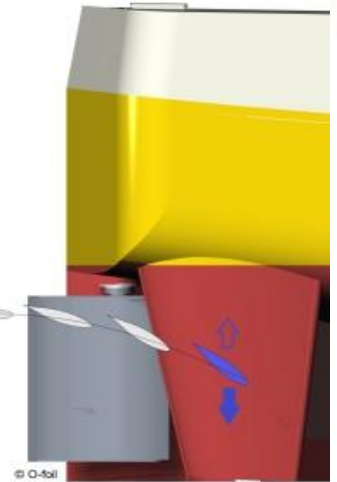
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Wat nog te DOEN... ?



Profiel kan verder worden geoptimaliseerd ... (63-018 nog niet toegepast)

Bewegingspatroon verder geoptimaliseren... (Amplitude, Keerpunten, Frequentie)

Instabiele stromingseffecten kunnen krachten verhogen... (nog te doen)



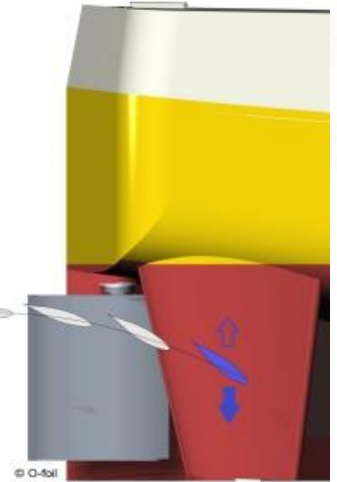
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Onze volgende STAP... ?



NIEUW Project onderweg voor meer onderzoek:

RUG -> Optimaliseren profiel, bewegingspatroon, met/zonder scheepsromp & bodem

TU-Enschede -> Additionele CFD-simulations: efficiëntie, schip, romp & bodem

MARIN Wageningen -> Schal model testing in maritieme test faciliteit



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DANK VOOR UW AANDACHT ...

VRAGEN ??

Copyright by Nature

BIOMIMETICA

=

**INNOVATIEVE
OPLOSSINGEN**

uit de
BIOLOGIE
voor de
PROBLEMEN
van de
TOEKOMST

Eize J. Stamhuis

Instituut voor Energie & Duurzaamheid - Universiteit van Groningen



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