# FIN PROPULSION

PHYSICS AND MATERIAL PROPERTIES

# INTRODUCTION

- What makes fins perform differently? (Carbon vs. plastic, soft vs. hard)
- Standardized performance specifications do not exist, manufacturers and vendors leave you guessing
- Fins are changed from one generation to the next by manufacturer experience
- Athlete feedback is a common development tool rather than computational fluid dynamic (CFD) modeling

# THINGS TO CONSIDER

- What is required to create propulsion at desired speed, and how fin propulsion works
- The efficiency of different materials, and why a material is efficient
- Can technique be adapted to the blade
- The diver's weight

# OSCILLATING FOIL PROPULSION

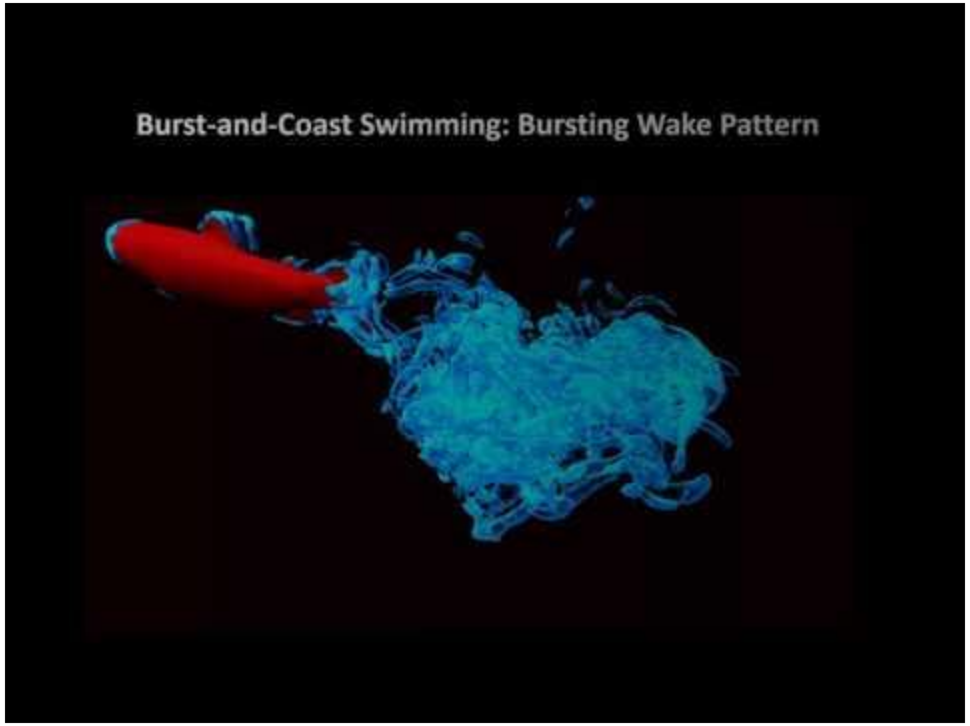
# OSCILLATING FOIL PROPULSION

- Also known as "flapping foil propulsion"
- Used by flying and swimming animals such as birds, fish, and butterflies
- Used by humans when swimming with a fin
- Biomechanical energy transfers force to fin blade creating an oscillating flexible foil
- The thrust produced is lift based like a wing compared to drag based like a kayak paddle pulled through the water
- It is used in industrial applications such as ship propulsion

# WHAT ABOUT FINS?

- Research papers have not been published on how freediving fins utilize oscillating foil propulsion
- The oscillating "foil" is the fin blade traveling up and down perpendicular to the direction of travel

# HIGH AND LOW PRESSURE AREAS




Model shows intermittent and consistent swimming techniques used, and the pressure regions along the body and caudal fin

# VORTICES

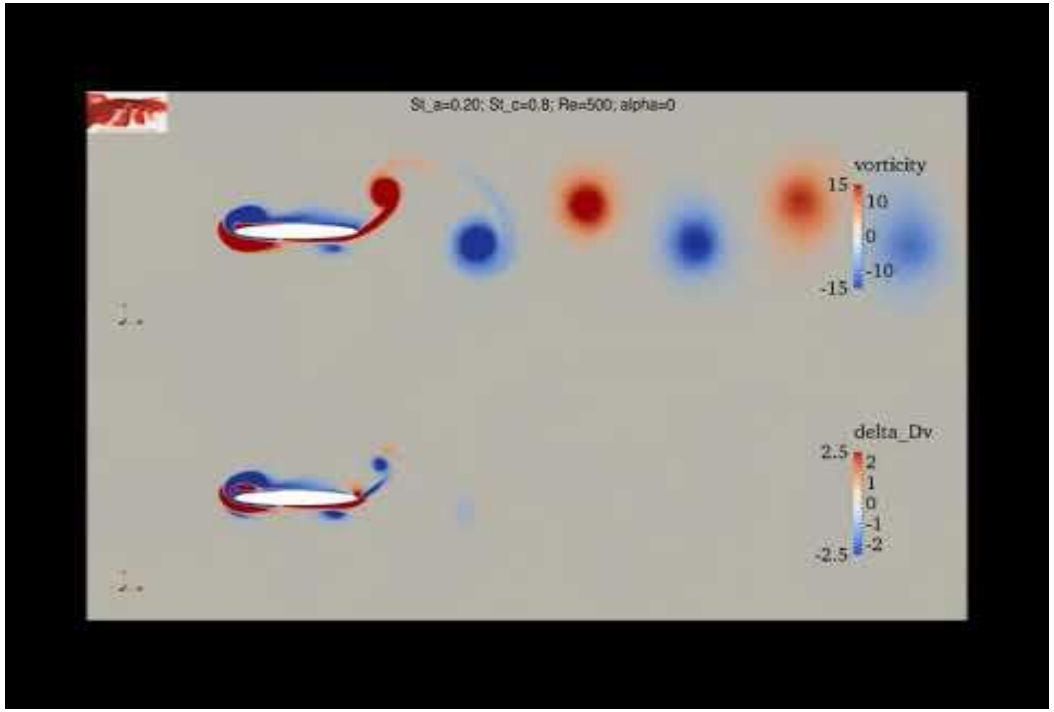
- A vortex is a whirling mass of fluid
- When induced on an oscillating fin blade, opposing vortices exist
- Vortices rotate opposite directions on each side of the foil
- Generated by high and low pressure regions of the oscillation
- Vortices are "shed" intermittently off the trailing edge of fin
- Vortices shed simultaneously of trailing edge will cause drag

# VORTEX MANIPULATION

Vortices can be seen from the origin
To the point that it disconnects from the foil.

On a flexible foil such as a long freedive fin, the vortice must be manipulated by proper technique until it is released from the trailing edge

For example, a pause at the end of the backstroke before continuing the forward stroke will interupt the flow of the vortex on the opposite side and cause interference at the point of shedding



# CAUSES OF INEFFICIENT VORTEX SHEDDING

- Bicycle kicking does not create or shed vortices efficiently from both sides of blade
- Even medium stiffness blades will be too stiff to oscillate with good technique for many divers. Evidence will be bicycle kicking and too much side swaying of the fins paired with ankle fatigue
- Kicking frequency not the same on the forward and back stroke stalling the blade

# EFFICIENCY FACTORS TO CONSIDER

# EFFICIENCY FACTORS

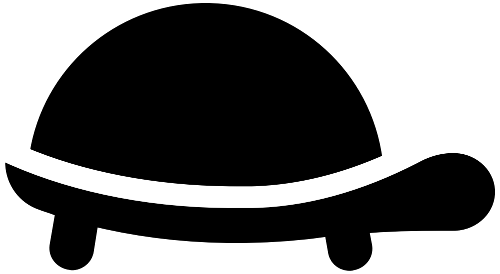
- The divers weight relative to fin stiffness
- The diver's drag which disrupts the smooth flow of water to and across the fins
- Plastic deformation of the fin material
- Diver's minimum leg strength (not maximum)
- Diver's decreasing energy (02 depletion during dive, caloric depletion during long session, possible dehydration)

# DIVER'S WEIGHT

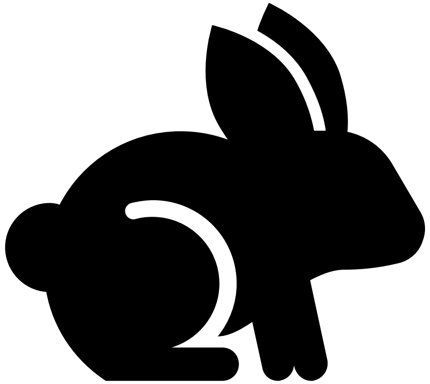
- Weight is the primary factor when choosing the appropriate stiffness
- The weight should be the diver plus whatever equipment or extra weight will be pushed during the intended use of the fins
- Common misunderstanding for new freedivers leads them into fins too stiff whereas they should have been developing good technique and using soft fins.
- Manufacturers should be consulted for personal stiffness selection and not spearfishing message boards
- A surplus of leg strength is not justification for purchasing a stiffer blade

# DRAG

- Technique that reduces drag will add efficiency greater than minor differences between fins
- Streamlined and narrow flutter will shed vortices efficiently
- Streamlined and narrow flutter provides smoother water flow back towards the fins
- Streamlined and narrow flutter presents less surface area as a brake to oncoming water

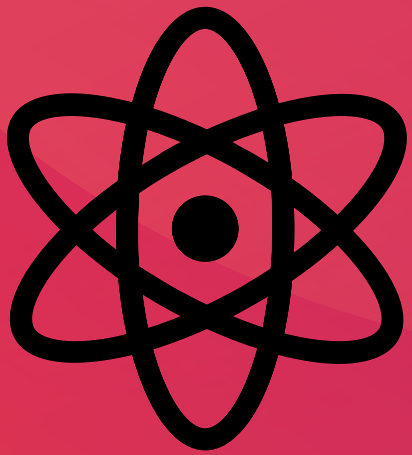


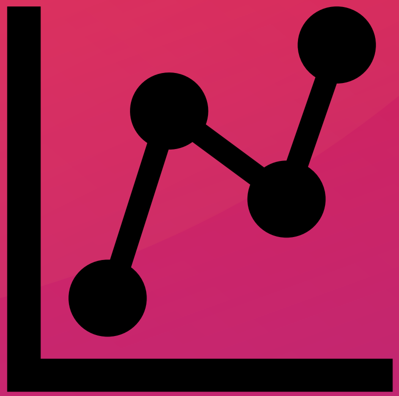
# SPEED



- Slow acceleration is most efficient
- A fin's speed cannot be compared from one diver to another due to differences in technique, input power, and body weight
- For efficient freediving, the primary factor is whether the blade and diver achieve the minimum desired travel speed

# MATERIAL PROPERTIES





# YOUNG'S MODULUS

Is a mechanical property that measures the stiffness of a material

Explains the properties of elastic and plastic deformation

Elastic and plastic deformation are important concepts in understanding why certain fin materials absorb more energy than others in a kick cycle

# STRENGTH AND STIFFNESS

Strength is the ability of a material to resist a force and relates to the point of failure

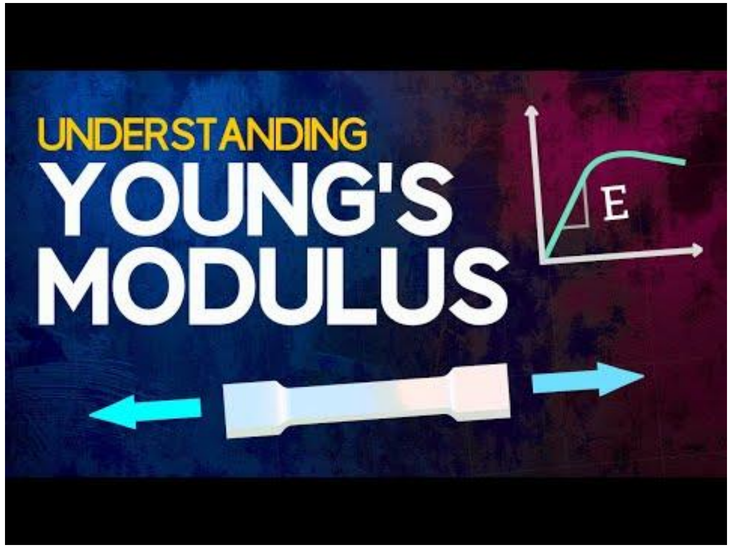
Stiffness is the ability of a material to resist a force within its elastic region

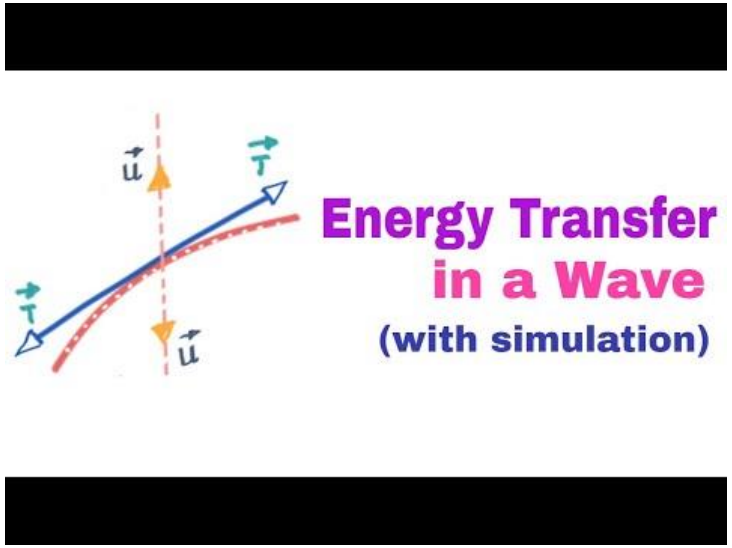
# ELASTIC DEFORMATION

A material bends and returns to its original position without any permanent deformation

A change in shape from low stress that is easily recoverable after the stress is removed

In freediving fins this is often decribed by the "snap" of a blade returning to its original position




# ELASTIC DEFORMATION

- The range from the unflexed position of the fin to the point that it no longer returns to its original shape, or is relatively sluggish to return in the case of polymer and rubberized materials
- Unlike metal and plastic materials, fiberglass and carbon fiber do not have a plastic deformation region, but are more similar to ceramics and glass. If flexed beyond their elastic limit they will simultaneously reach their strength limit and fail

# PLASTIC DEFORMATION

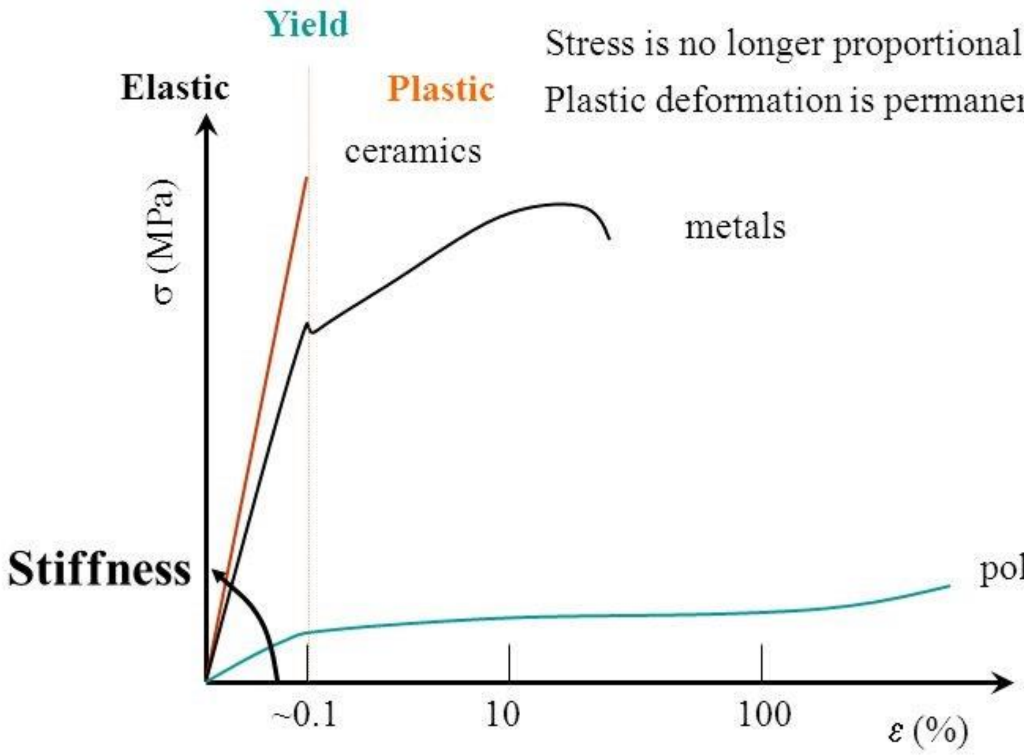
- A permanent distortion in a material that causes it to elongate, buckle, bend or twist
- The region of stress following the limit of elastic deformation
- The point of flex in a polymer or rubberized fin blade at which it does not return to is normal position. This changes at different temperatures.

# PLASTIC DEFORMATION

## Plastic Region

Stress is no longer proportional to strain

Plastic deformation is permanent, non-recoverable



# HOOKE'S LAW

- A part of hook's law states that the force to elastically restore a material to its original position is equal to the force that was required for deformation
- Due to this, we can say that the amount of energy lost each kick cycle is equal to that range of deformation that does not return, for example when a plastic or rubberized fin is flexed so far that it becomes sluggish relative to the kick cycle speed. The lost energy is cumulative throughout the dive.
- Except any stiffness added by the tendons of a rubber foot pocket, the fiberglass and carbon fin blades do not experience molecular (plastic) deformation like polymers when stretched, so any energy absorbed by the fiberglass/carbon fiber is comparably negligible.
- No fin material will give you an extra boost unlike what some product reviews may say when referring the "snap".

# SUMMARY

| | |
|---|---|
| Understanding | Understanding the basic mechanics of fin propulsion and vortex distribution will enable you to recognize how good technique should look at the fin |
| Knowing | Knowing the factors that interfere with the fin's efficiency will enable you to make corrections to optimize efficiency |
| Deeper | Deeper understanding of the physics of deformation and elasticity will make you better informed when comparing the performance of different fin materials |