Design of a human powered bionic boat

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Guide : Prof. V.P.Bapat

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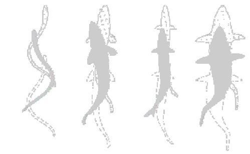

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Approval sheet

The project titled

“design of human powered boat on bionic action” by Abhijeet Kumar is approved for the partial fulfillment of the requirement for the degree of “Masters of Design”

Project Guide :

Chairperson :

Internal Examiner :

External Examiner :

Date :

Abstract

The project aimed at utilizing the propelling and maneuvering qualities of fishes to conceptualize a human powered boat. Similar projects have been studied deeply under the discipline on bionics, however what was needed was conceptualization of the principle into a feasible product, which was ultimately the aim of the project. Initial task was to come to terms with the existing studies in this area and underline guidelines which have to be followed . As I understood from the data on scale models and have been solely devoted to perfecting the motion of fish. Little effort has been made in putting the principle into a product form. In our effort to conceptualize a product , a scale model of the mechanism was made and experimented upon. Useful observations were taken from our experiments with the model, however given the constraint of time in this project; the data generated is mostly qualitative.

Although this project was with me for only a few months, it was undertaken under Prof. V.P. Bapat, IDC, who is an authority in the field of bionics, given his special interest in this area, the project is under development under his guidance.

Introduction

Question comes to mind as to why do we need to copy the motion of the fish to develop a propulsive mechanism?

Can a biological system made from muscle, bone, and skin legitimately guide the design of a man made system? There are a number of examples of this in the robotics community where a careful examination of the construction, dynamic behavior, and control of various biological systems led to the successful implementation of a five fingered anthropomorphic hand, a walking 6 legged insect, and a dynamic hopping kangaroo. Each of these implementations did not seek to exactly copy nature, but to distill what was fundamental to the behavior of the system and then implement that as best as was possible with available materials and technology. In effect the fundamental physics were preserved between biological model and man made system.

The intention of taking the project was based on the hunch that fish bionic action for propulsion in a human powered boat can be as efficient and effortless as fish swimming. Numerous projects have been carried out to make more efficient underwater vehicles on fish propulsion principle.

In our case, we have to realize that the vehicle is not fully underwater vehicle, only a part of it, the propelling mechanism is under the water which might have to drag the entire load above it along the water surface. So, experiments have to be carried out to see whether or not it is beneficial for our purpose.

Some of the existing human powered boats

Why they are popular ?

These boats uses the most common and simplified form of locomotion. Rotary motion of the pedal is transformed into rotary motion of the propeller. Refinements have been done over the ages and brought to a nice competitive product level. Variety of ranges are available for even common people.

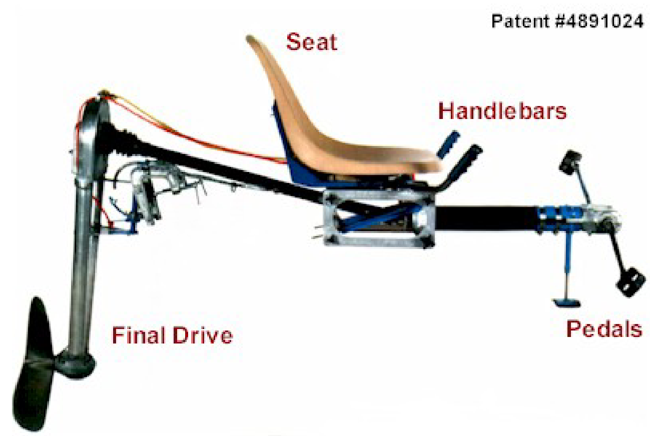
Fast and efficient ?

In most of cases the propeller is over the water surface which needs very less effort to give motion. The boat on the other hand gets a lift when attains certain speed, so the drag against water reduces drastically making the cruise enjoyable and fast.

Effortless ?

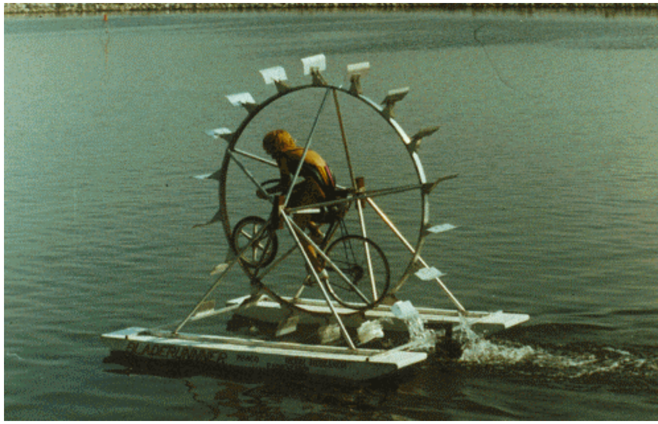
Rotary propeller displaces less water as compared to water displaced by an oar. Even if the propeller is bigger, research and continuous improvement have given lots of mechanical advantage to the user.

Some of the existing human powered boats (underwater propeller)



Less area of contact between the boat surface and water due to the lift it gets as it attains speed, so the propeller works more efficiently under the water.

some of the existing human powered boats (propeller above water surface)



Easier to rotate the propeller which is above the water level much faster than underwater and the drag reduces because no load is under the water.

Requirements for our design

- Mechanical advantage in transferring rotary motion of the pedal to achieve the type of motion required for bionic action

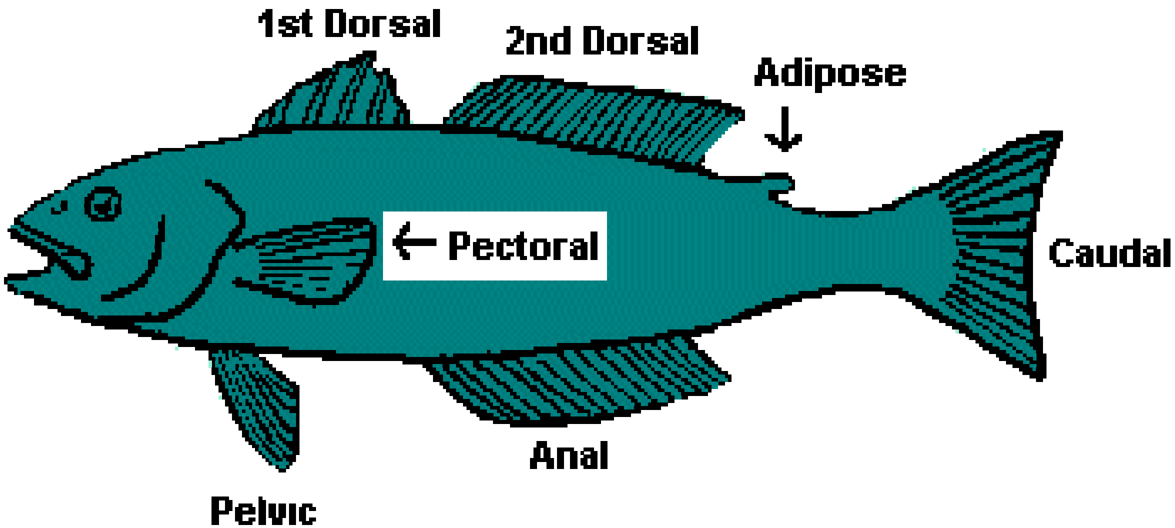
- Capturing the bionic action

- Hydrodynamic lift will decrease the effort required for propelling the boat against water surface

- Simplification of the mechanism as far as possible without loosing the action required

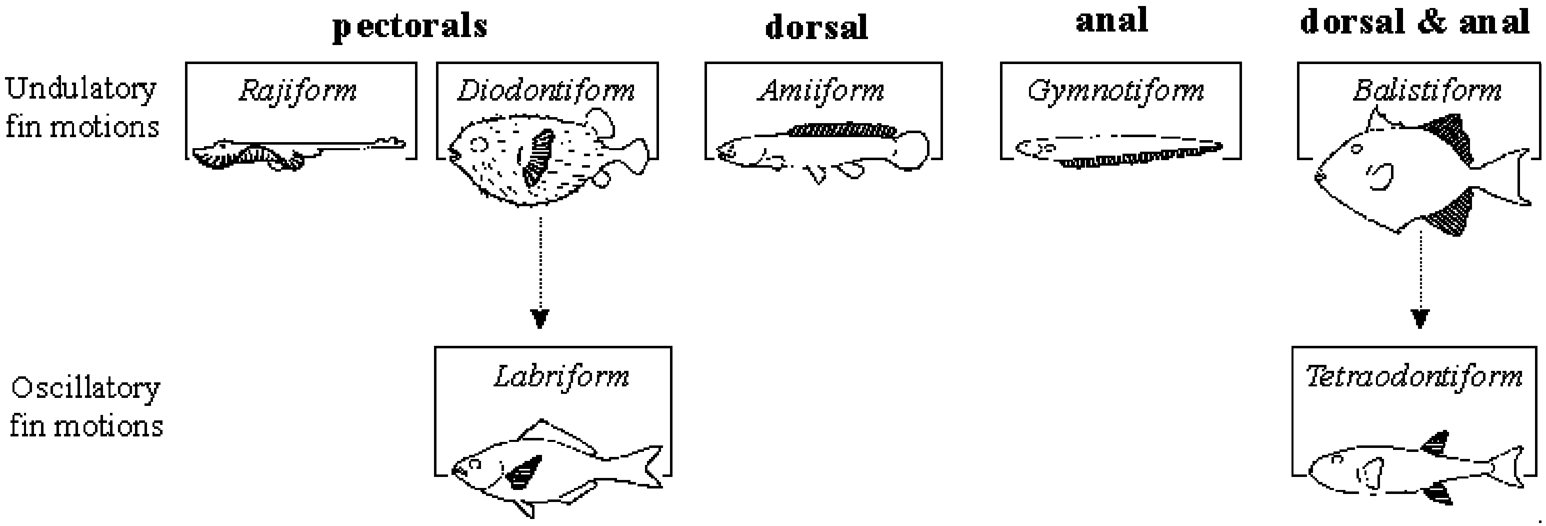
How fishes swim ?

Many living fish undulate or oscillate their body axes for swimming. They are usually categorized into four swimming types, depending on how much of the body stays more or less stable (figure below). Anguilliform, or eel-like swimmers undulate their entire body, whereas thunniform, or tuna-like swimmers move only the posterior part of their body, keeping the anterior part steady.



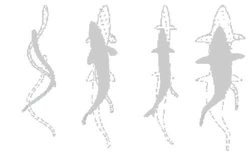
Median/Paired Fin Propulsion

The following diagram depicts the specific swimming modes identified within MPF propulsion, based on the (extended) classification scheme proposed originally by Breder in 1926. Distinction is made based on the fins used and the type of motions performed.



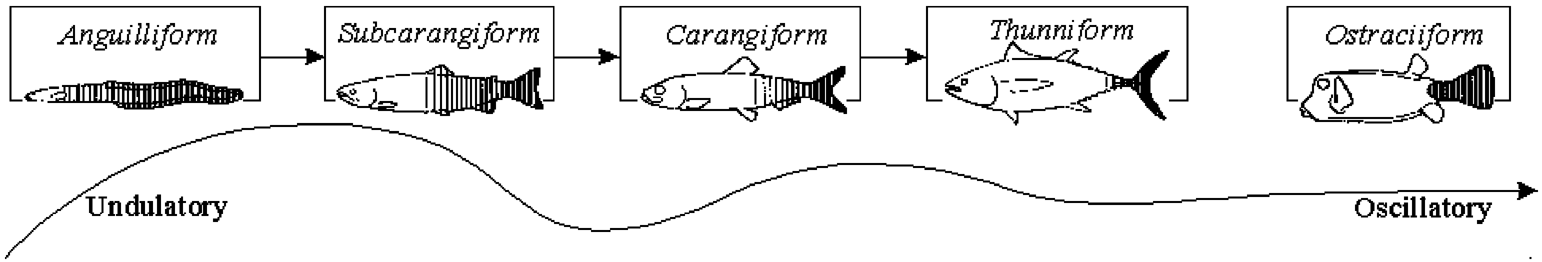
MPF Undulations

Undulating fins are routinely used by many fish as auxiliary propulsions, as well as for maneuvering and stabilization. They can also provide adequate thrust to be used as the sole means of locomotion, at generally low speeds. The fins of tallest fish consist of the fin-rays, that have varying span and stiffness, and a flexible membrane connecting them together. In median fins a set of muscles (usually six) for each fin-ray provide the later with two degrees-of-freedom movement capability, while it has been suggested that certain fish can actively bend the rays of their median fins. Paired fins have an even more complex muscular system, enabling movements such as rotations of individual fin-rays.



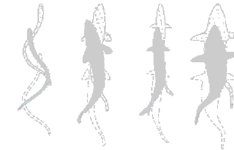
Body/Caudal Fin Propulsion

The following diagram depicts the specific swimming modes identified within BCF propulsion, based on the (extended) classification scheme proposed originally by Breder in 1926.



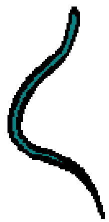
BCF Undulations

In undulatory BCF modes the propulsive wave traverses the fish body in a direction opposite to the overall movement, and at a speed greater than the overall swimming speed. The four undulatory BCF locomotion modes identified in the above figure reflect changes mainly in the amplitude envelope of the propulsive wave, but also in the way thrust is generated. In anguilliform, subcarangiform and carangiform modes an *added-mass* method is used whereas thunniform swimmers rely on a *vorticity* method for propulsion.



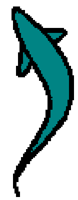
Types of movements

Anguilliform



The way most eels and many other fishes, such as brotula, gunnels, oarfish, and nurse sharks move. In addition, the sea snakes of Australia's seas swim this way. In streams, **eels** and **lampreys** use anguilliform movement. The fish moves the entire body against the water in a snake-like fashion. This method of swimming is surprisingly efficient. Electric eels do not swim this way, but instead hold their bodies very still and undulate only their fins to swim. This is because of the electrical fields that they generate.

Subcarangiform

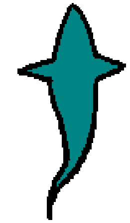


This movement category includes **salmon**, **trout**, **catfish**, **minnows**, and cod. These fishes undulate most of their bodies, but leave their heads fairly still and concentrate most of the movement in the last two-thirds of their bodies. .

Carangiform

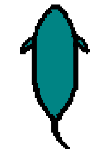
These fishes include drums, jacks, and snappers, and are very fast swimmers. In streams, **bass**, **crappie** and **sunfish** use carangiform movement. The forward parts of their bodies are not capable of undulation. They throw their bodies into a shallow wave that increases in amplitude as it moves backward toward the tail, which snaps like a whip. As you can see, this leaves the head almost still. The *caudal peduncles* (the part of the tail just before the caudal fin) are narrow and the tails are often forked, leading to more efficient movement.

Thunniform



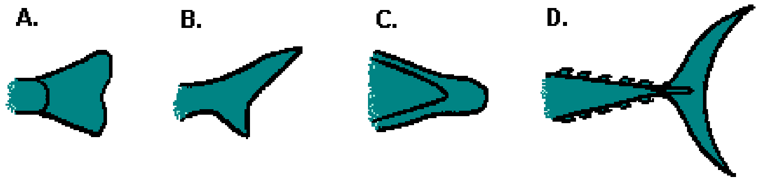
This term is sometimes used to describe the extremely fast and efficient movements of fishes like tuna, billfish, and lamnid sharks. These fishes have very narrow caudal peduncles and large caudal fins that are *lunate* (look like the sliver of a waxing moon). Their tails are reinforced by keels, for strength and stability. This movement type can also be seen in whales and **dolphins** (mammals), and was used by the extinct ichthyosaurs (reptiles).

Ostraciiform



Many fishes are hampered by a boxy or globular shape. Trunkfish's, cowfishes, and boxfish's have too much armoring to be able to flex their bodies. These fishes scull their tails like oars.

Caudal fin shape:



A. The *homocercal* (homo-SUR-kul) tail is a modern development. It is symmetrical. It includes truncate, square, slightly forked, and deeply forked types. It is by far the most common caudal fin shape, shared by most fishes.

B. The *heterocercal* tail is an ancient form, possessed by only a few primitive fishes, such as sharks, sturgeon, and paddlefish. It was a necessary tail shape when fishes had no swim bladders and were heavy in the front; if the fish tried to use a symmetrical tail, it would have plunged toward the bottom. Instead, it developed a tail with a deliberately downward-driving design and supplemented it with horizontal, plane-like pectoral fins that transformed that downward force into a horizontal, forward-driving force. Genius!

C. This tail has a *non-differentiated* caudal fin. This may be found on eels of all sorts, as well as lampreys.

D. The *lunate* tail is a tail that the tuna and mackerel have refined to an engineer's delight. This tail provides powerful forward force, with very little turbulence.

Selection of swimming mode

eel

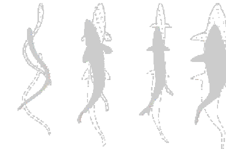
Green moray

For my study, I have selected **anguilliform mode of locomotion.**

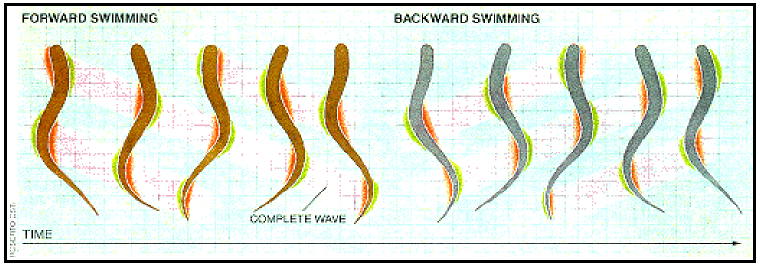
Anguilliform mode

Anguilliform is a purely undulatory mode of swimming, in which most or all of the body participates. The side-to-side amplitude of the wave is relatively large along the whole body, and it increases toward the tail.The body is long and thin, while the caudal fin is typically small and rounded, often missing altogether. The inclusion of at least one wavelength of the propulsive wave along the body, means that lateral forces are adequately cancelled out, minimizing any tendencies for the body to yaw. Typical examples of this common locomotion mode are the eel and the lamprey. The Green Moray also has well a developed dorsal fin (see image) which results in further compression of the body.

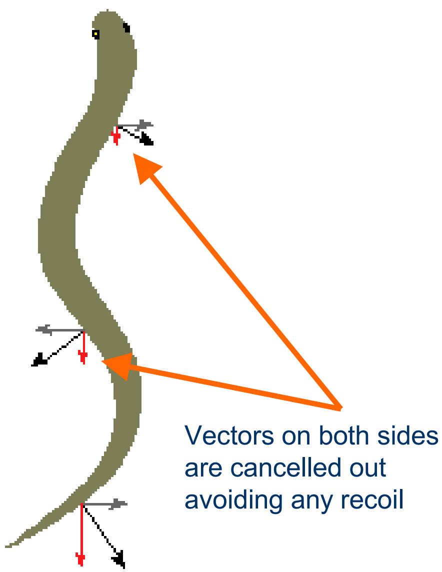
This increases swimming efficiency in the same way that a flattened oar is more efficient for rowing than a rounded pole. The morays use anguilliform swimming to great effect when they dart forward out of a crevice to seize prey (invertebrates and fishes), and they can swim nearly as well backward, which is handy for entering into the shelter of a crevice or hole to avoid predators.

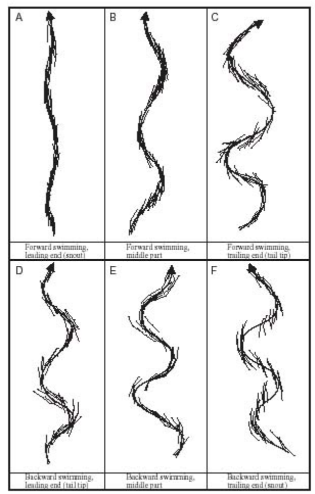


Advantages of anguilliform mode of locomotion



Forward swimming **backward swimming**





•Capability of swimming **backward** and **forward** by **altering** the **propagation direction** of the propulsive wave (tail is stiffer)

•Long and slender fish like an **eel** will migrate an obvious **sine wave** from head to tail that **exerts vector forces** on water on either sides (the **whole body** participates)

•Good for unsteady swimming actions like **rapid turns** and **quick starts** that are characterized by high **acceleration.**

•Amplitude near the **caudal fin** is more than the amplitude near the **head**

•**Streamlined flow,** less turbulence caused to water

Limitations of anguilliform mode of locomotion

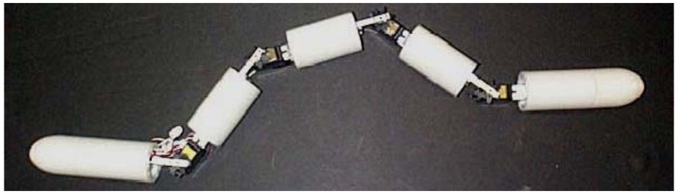
•**Not for high speed and cruising**

•**Whole body involved (more drag)**

•**Inefficient braking (slows down)**

Biomechanics project done on eel

Stage 1. Mechanical linkages to simulate the eel motion



Stage 2. linkages integrated together with each link having the cross section of an eel fish

Stage 3. Materials used to simulate exact feel of the movement

Stage 4. Tested on swimming pool covered with synthetic rubber skin.

Stage 5. Sculpted to an eel and tested under water with other fishes.

Cross section of a snake and an eel

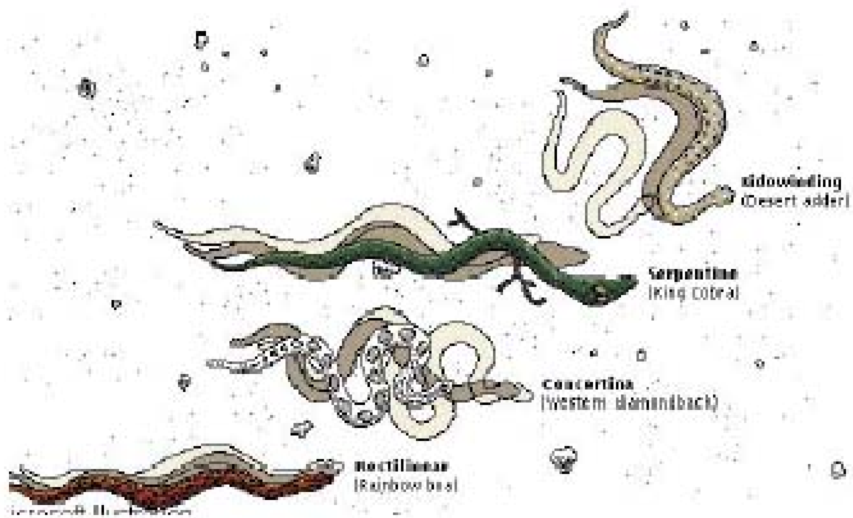
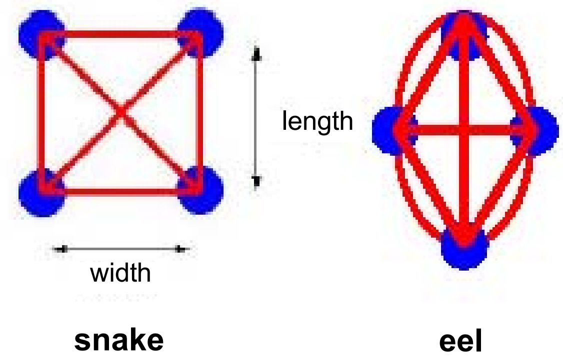
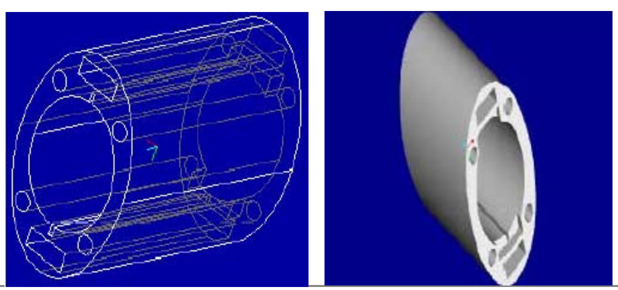


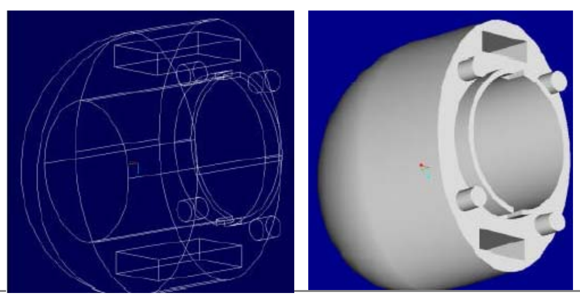
Figure 8.
Characterization of a snake cross-section (left) and an eel cross-section (right). Note lateral



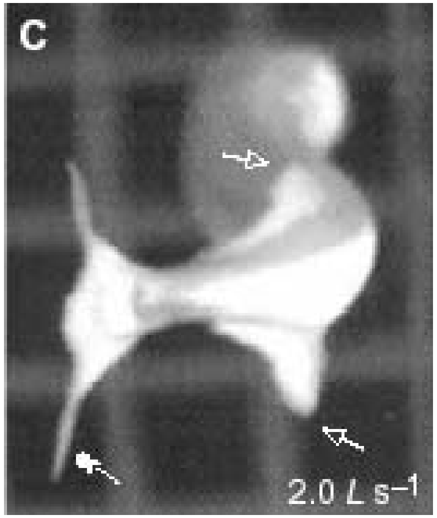
3-D MODEL OF MIDDLE LINKS



3-D MODEL OF END LINKS



Propulsion in anguilliform



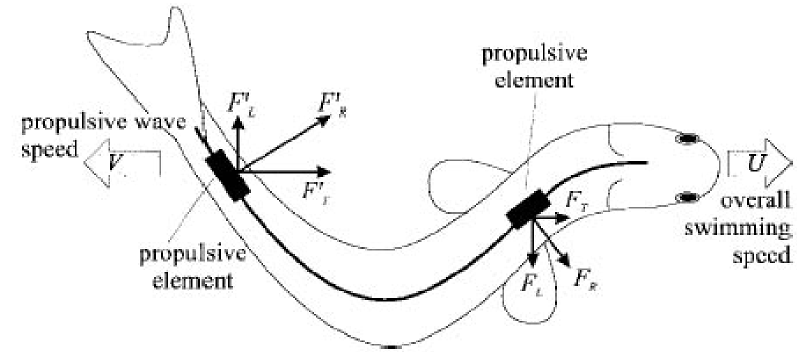


Fig. 6. Thrust generation by the added-mass method in BCF propulsion.

Swimming efficiency

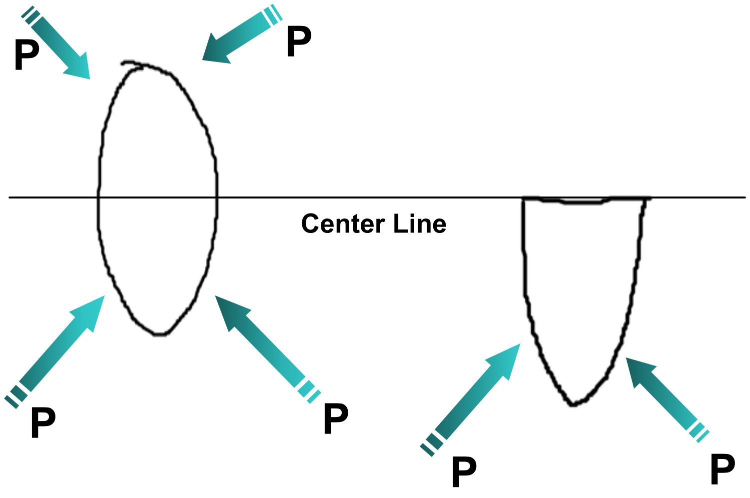
U/V

U = overall swimming speed

V = wave propagation speed

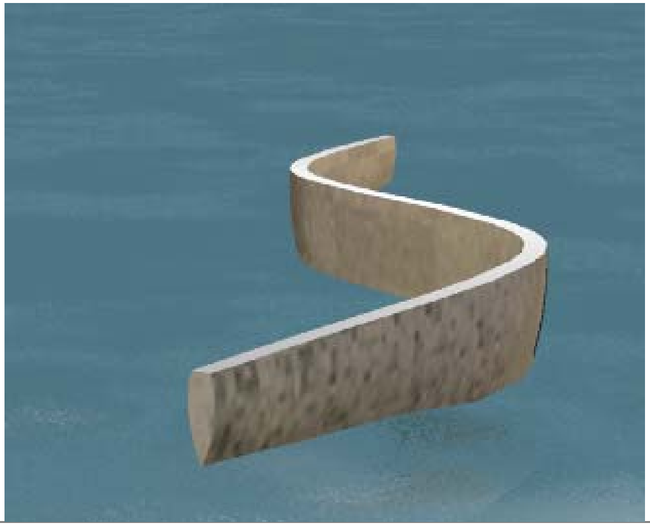
'V' is normally greater than 'U'

Technical details



Eel's cross section

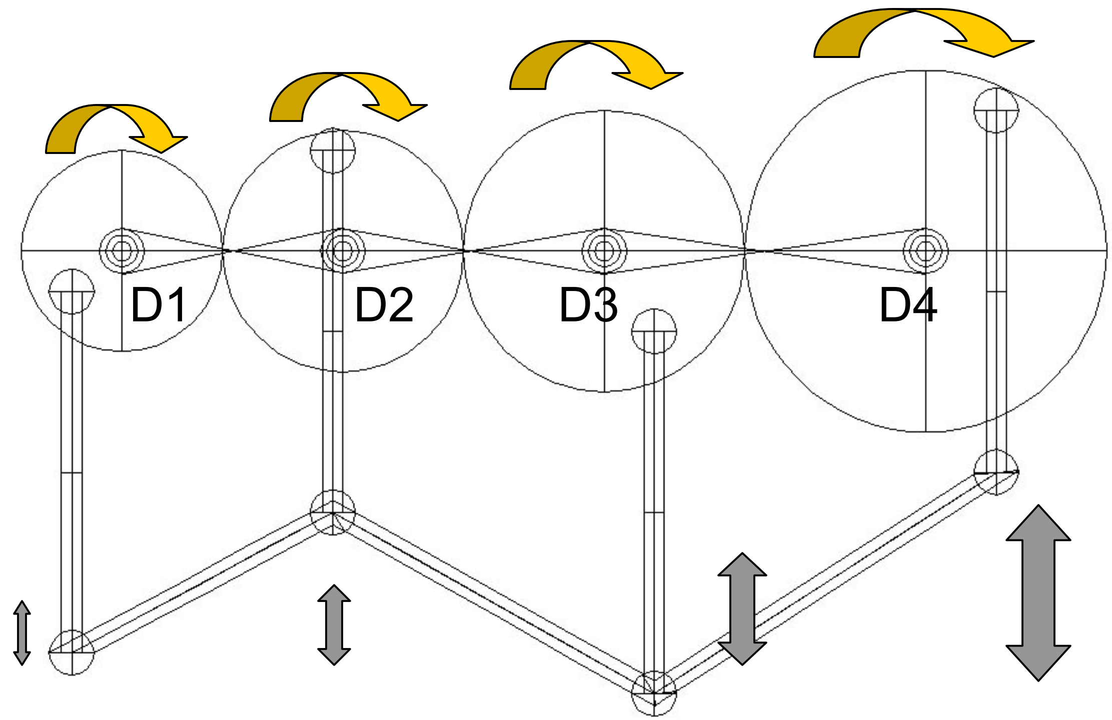
Ideal cross section for our design



Pressure exerted on both sides of the center line of the Elliptical cross section of an eel which cancels out the forces and allows it to maneuver itself up and down as well as in all direction.

It will be beneficial for us if we can have some kind of hydrodynamic lift that might decrease the drag of the boat against the water surface and makes the boat lighter. So, chopping of the upper portion of the ellipse as shown in the figure would be helpful for us where the pressure will be exerted on the bottom side only while generating the sinusoidal wave in the trunk. The resultant of the forces will be acting upward giving the desired lift to the boat.

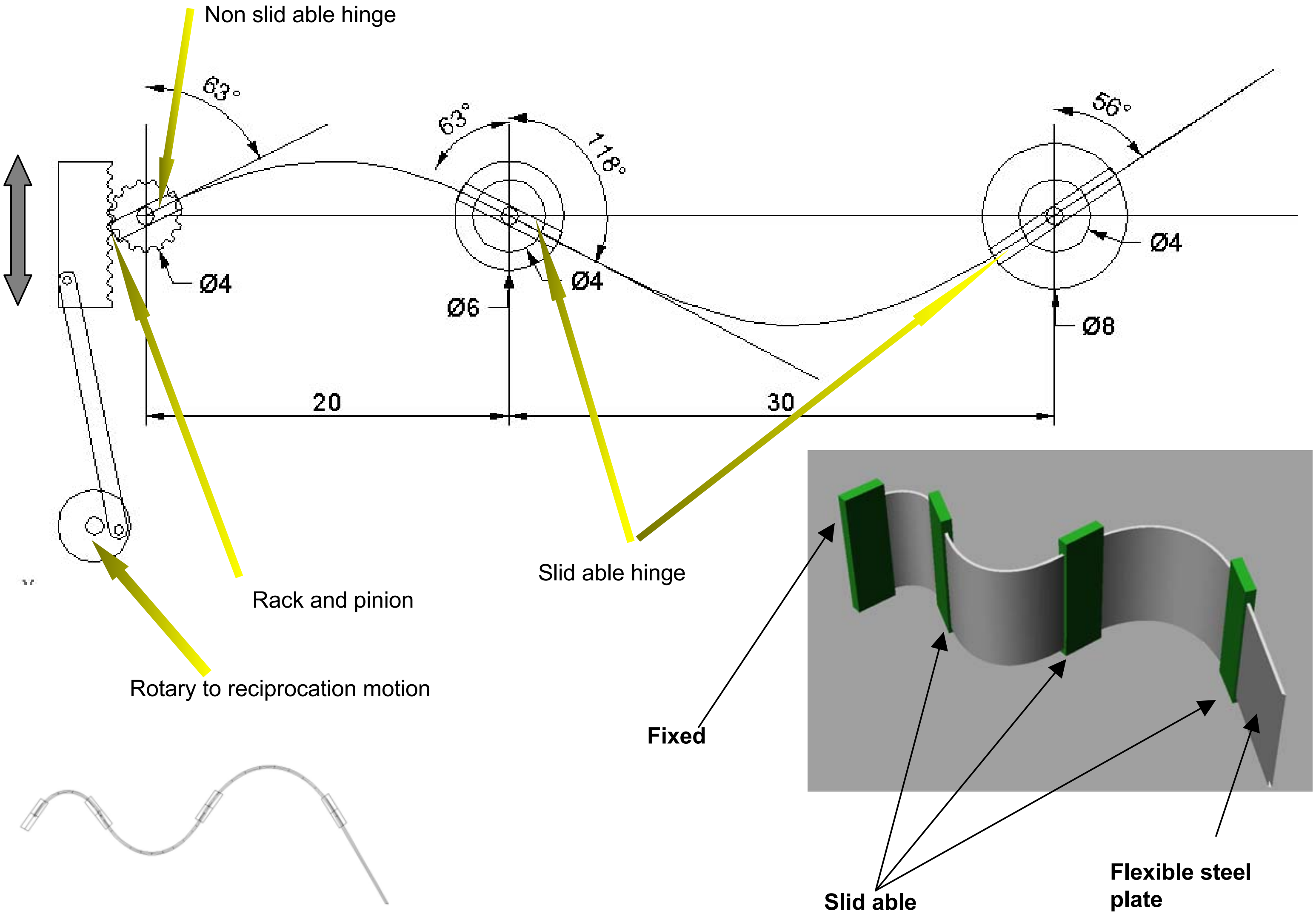
Initial concept for creating undulations



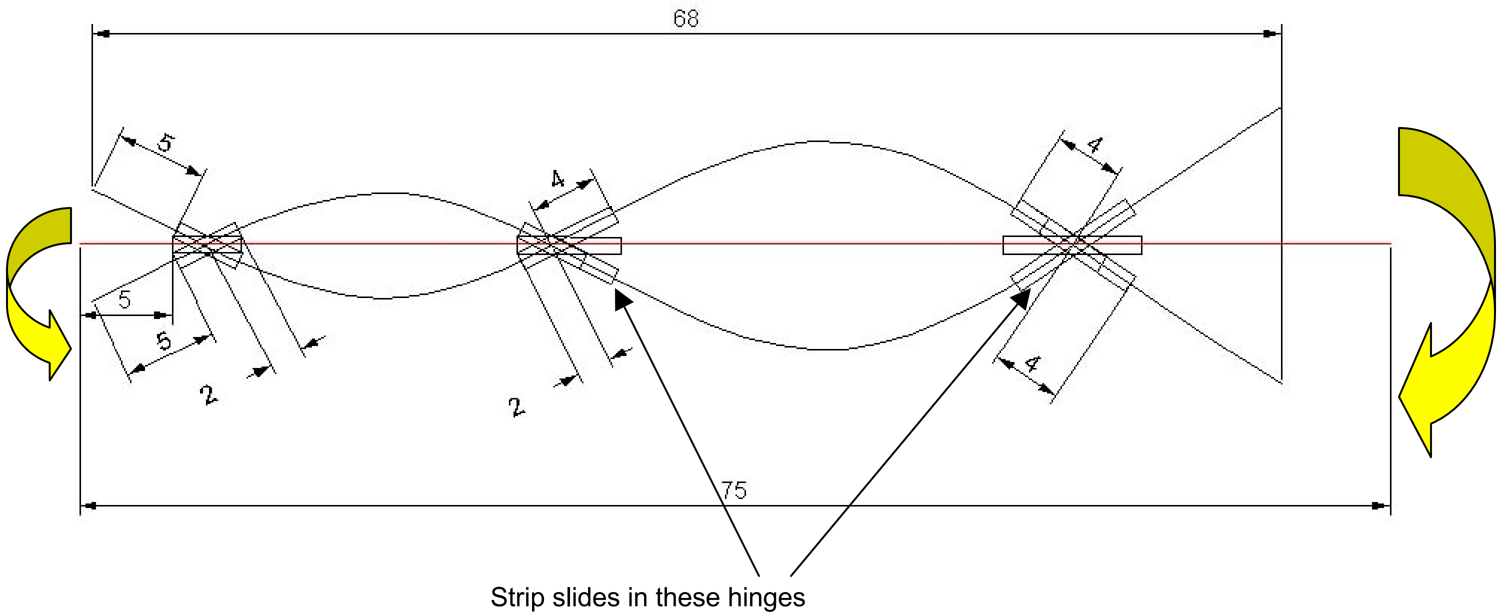
RPM is same for all the wheels
D1, D2, D3, D4 gives different amplitude

Failed to capture the movement when analyzed critically

Mechanism to be developed for the boat



Analyses

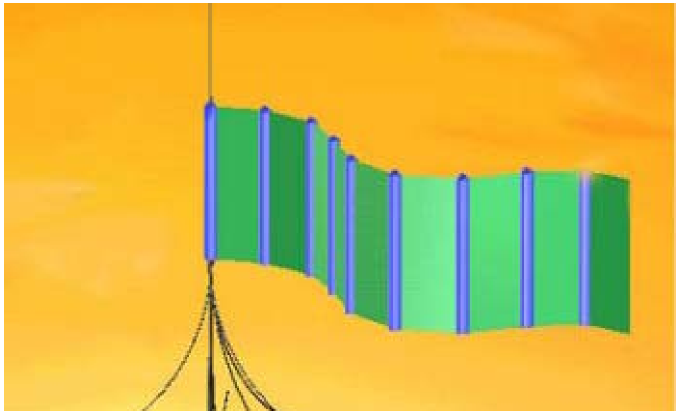


The mechanism

The idea is to give a sinusoidal movement to the flexible strip whose amplitude increases as it progress towards the posterior side. The head side is attached to a reciprocating mechanism which will create the undulations as the slid able links are provided and strip can slide along it. The slid able hinges have different lengths so as to produce different amplitude.

Failed, as it could not produce progressive sinusoidal wave. Though the stationary sinusoidal wave was created which would propel the boat with very less speed and that is due to increasing amplitude and not due to transfer of the energy.

Rectification



In the previous mechanism, the intermediate nodes are fixed, though the stripe which will actually produce the undulations was free to slide along the nodes. But the movement of the wave was not progressive as we know that for progressive wave, at any point the wave should have a crest and a trough, which was absent.

The stripe should be flexible and each element as shown in the figure should be free to oscillate from one extreme to another so as to create a complete progressive sinusoidal wave. One end should be fixed to some reciprocating mechanism which will reciprocate at certain speed and create the wave as done with a ribbon by a gymnast.

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