NATURE-INSPIRED INVENTIONS

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Flying Fish

Air–Water Hybrid Vehicle Concepts

Nature-Inspired Inventions

Volume 013 of 255

WealthSphere Labs

Flying Fish: Air–Water Hybrid Vehicle Concepts

Nature-Inspired Inventions, Volume 013

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About this book. This is an educational guide to biologically inspired engineering. The invention concepts in it are design ideas for study and experimentation, not tested or certified products. Worked numbers illustrate methods unless a source is named. Nothing here is engineering certification, legal advice on patents, or a substitute for qualified professional review of anything that will carry people, loads or risk.

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Introduction: A Fish That Leaves the Water

Over warm oceans, sailors have watched flying fish burst from the waves, spread wing-like fins and glide for tens of metres before dropping back into the sea. Some touch the surface, beat their tails rapidly against the water to accelerate, and take off again, extending their flight. They fly to escape predators below — dolphins, tuna, dorado — and they do it by crossing the boundary between two media that differ in density by a factor of about 800.

Vehicles that can operate in both water and air are a long-standing engineering goal. A drone that can dive to sample water, then fly home; a submarine that can launch an aircraft; a boat that skims the surface on a cushion of air; a sensor that crosses from sea to sky. Each faces the same problem the flying fish solves: designing one body that works in two very different fluids, and managing the violent transition between them.

This volume explains how flying fish fly, the physics of air–water transition and ground-effect flight, the history of hybrid vehicles, and how designers can approach air–water drones and craft.

How this book is organized

Chapters 1 and 2 cover flying fish behavior and anatomy. Chapter 3 explains the physics of two-media vehicles and ground effect. Chapter 4 surveys the history of hybrid vehicles. Chapters 5 to 7 cover translation, structures and control. Chapter 8 presents ten design concepts. Chapters 9 to 13 cover testing, failure modes, approval, a workbook and a case study.

Figures for real animals and vehicles are rounded and typical. Worked numbers are illustrations unless a source is named.

Chapter 1: How Flying Fish Fly

The flying fish family

Flying fish belong to the family Exocoetidae, with dozens of species in tropical and subtropical oceans. They range from around 15 to 45 centimetres long. Some species have two enlarged pectoral fins ("two-winged"); others also have enlarged pelvic fins ("four-winged").

The sequence of a flight

- **Underwater acceleration.** The fish swims rapidly toward the surface at a shallow angle.
- **Breaking the surface.** It leaves the water with its fins folded.
- **Taxiing.** With its body out of the water, it spreads its pectoral fins and beats the long lower lobe of its tail fin rapidly in the water, accelerating along the surface like a seaplane on its takeoff run.
- **Gliding.** Once fast enough, it lifts the tail clear and glides, often close to the surface.
- **Re-launch or re-entry.** Near the end of a glide, it may dip its tail back into the water and taxi again to extend the flight, or fold its fins and dive back in.

How far and how fast

Glides of tens of metres are common, and multiple re-launches can extend a single flight to hundreds of metres. Footage recorded by a Japanese television crew in 2008 showed a flying fish airborne for about 45 seconds, a widely reported example of an exceptionally long flight. Flight speeds are typically in the range of tens of kilometres per hour.

Why fly

Flying lets the fish escape predators that cannot follow it into the air. The predator loses track of the fish when it leaves the water, and the fish lands far away.

Chapter takeaways

- Flying fish accelerate underwater, taxi on the surface and glide.
- They extend flights by re-launching with tail beats.
- Flight is mainly an escape from underwater predators.

Chapter 2: Anatomy of a Two-Media Animal

Body shape

The flying fish body is streamlined and torpedo-shaped, suited to fast swimming. In air, the body is a fuselage, with the fins as wings.

Wing-like fins

The pectoral fins are greatly enlarged and supported by fin rays. When spread, they form wings with a reasonable aspect ratio and a cambered shape. When folded, they lie flat against the body, reducing drag underwater.

Tail

The lower lobe of the tail fin is longer than the upper lobe. This lets the fish keep beating the lower lobe in the water during taxiing while the rest of its body is airborne.

Wing performance

Research by Hyungmin Park and Haecheon Choi, published in the *Journal of Experimental Biology* in 2010, tested real flying fish specimens with spread fins in a wind tunnel. They found that the gliding performance was comparable to that of some birds, and that flying close to the water surface improved lift-to-drag ratio through ground effect.

Chapter takeaways

- A streamlined body serves as hull and fuselage.
- Folding fins work as wings in air and fold away in water.
- An asymmetric tail allows taxiing.
- Ground effect improves gliding near the surface.