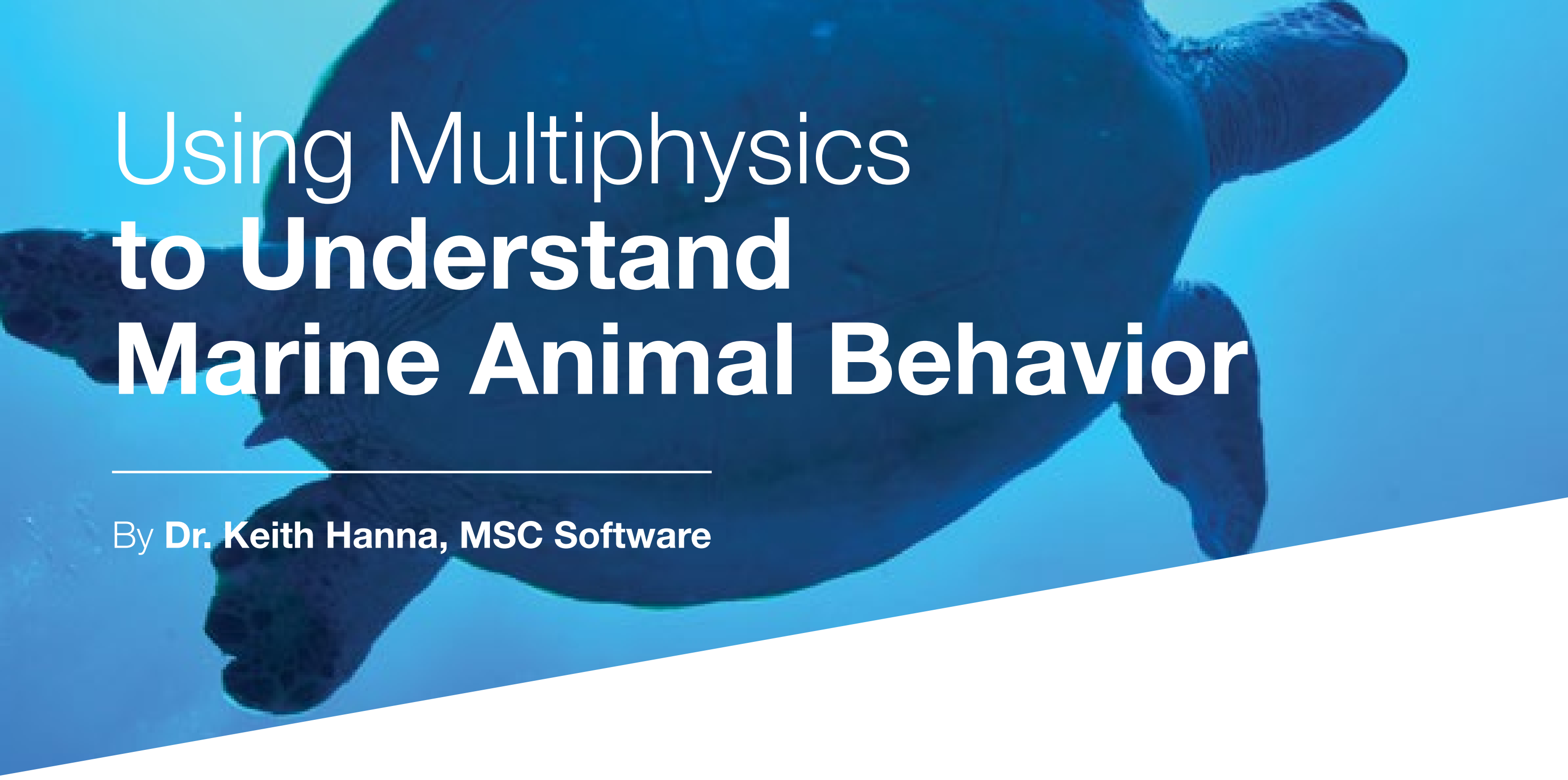


Using Multiphysics to Understand Marine Animal Behavior

By **Dr. Keith Hanna, MSC Software**

Professor Tsutomu Takagi from Kindai University (Laboratory of Fisheries Production System, Department of Fisheries, Faculty of Agriculture)

Dr Michel Azoulay, Sr. Technical Consultant, Maine Marine Composites, LLC Portland, ME, USA

Knowledge of our ocean depths and how marine organisms adapt to life under water is still developing in terms of what we know of the underlying science. Two recent studies by MSC Software users, Kindai University in Japan, and Maine Marine Composites LLC in the USA, have helped to throw some interesting light on the true nature of the lives and struggles of bluefin tuna and leatherback turtles respectively.

CFD Uncovers the True Nature of Bluefin Tunas, the ‘Diamonds of the Sea’

Pacific Bluefin Tunas (*thunnus orientalis*) are beautiful large fish known as “the diamonds of the sea” and their nature is to swim freely in the ocean. This makes close examination of their behaviors difficult which is why little of their biological characteristics has truly been explored. Professor Tsutomu Takagi from Kindai University, Faculty of Agriculture, has been applying CFD fluid analysis using scFLOW from MSC Software to reveal the mysterious nature of these animals.

Bluefin tunas are the most prized fish from the tuna family by fishermen and chefs. In 2002, Kindai University even succeeded in farm-raising this special fish and named the breed ‘Kindai tuna’ which attracted wide public attention for the species. Professor Takagi then started to take an interest in this beautiful creature after noting that biological data for bluefin tunas in the wild have not yet been fully collected. He decided to use the fluid analysis software scFLOW to investigate the true nature and unknown swimming characteristics of fish in general, but with a particular focus on the bluefin tuna.

Tunas are large, carnivorous fish that inhabit the open seas. They are a *perciform* fish, under the *scombroidei* suborder, in the *scombridae* fish family. Their biological classification is actually the same as mackerel and swordfish. Besides bluefin tunas, eight other species of tuna exist, including the familiar yellowfin tunas and bigeye tunas. Bluefin tunas are the largest in the group: they can weigh 400kg (882lb) and be up to 3m (10ft) long. They are known as the 'diamonds of the sea' and they account for only 2% of the entire tuna catch worldwide, but are traded in the fish markets of the world at the highest rates. Professor Takagi and his team decided to use fluid analysis software to investigate bluefin tunas' swimming capabilities to understand this fascinating fish better.

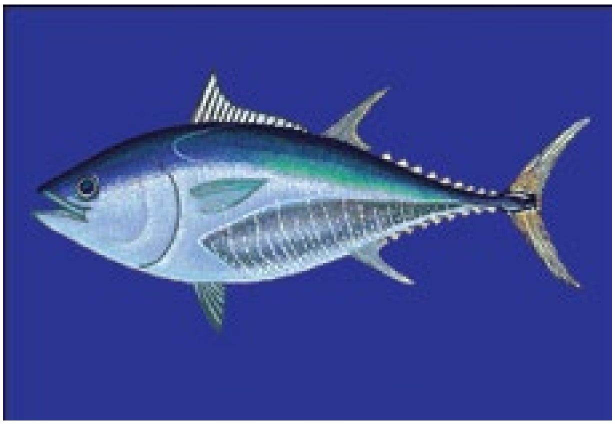
Tunas can swim very fast reaching speeds of nearly 90km/h (56mph) although slower ones, such as the yellowfin tuna, swim at 75km/h (47mph). As a comparison, Indo-Pacific sailfishes, which are known to be the fastest marine creature, can swim at a phenomenal 108km/h (68mph). In terms of the body length speed per second, yellowfin tunas are at 20BL/s (BodyLengths/s) and the Indo-Pacific sailfishes are at 15BL/s, which indicates that tunas are one of the fastest, medium sized fish species in the world.

Considering their speed and ability to swim long distances, the fluid drag force on a tuna's body was thought to be small. But an unanswered question was: how can a tuna's drag force be measured or calculated? To test a live tuna in an underwater environment, Professor Takagi would need a tank that was large enough for the fish to swim. Such a tank would also need the capability to change the fluid velocity and attaching a resistance board to the fish would also be needed. Convinced that the results would be inaccurate, even if the research team did manage to conduct such a test, Professor Takagi explored the application of computational fluid analysis tools. Professor Takagi created a virtual model of a tuna by scanning a real fish using a 3D scanner. It sounds easy, but modeling the fish was a demanding task. It required preparing a frozen tuna (to prevent decay) and painting the frozen fish white to minimize diffuse reflections of the laser beam used (see figure 1).

Using CFD, Professor Takagi calculated the drag on a gliding 34-cm (1.1-feet) long tuna to be 5gf (0.355pdl). This is the same drag as a 5-mm (0.2-inch) diameter, 15-cm (a half-foot) long cylinder. For a 100-cm tuna, the drag was 400gf (28.4pdl). This is equal to the drag of a 30-mm (1.2-inch) diameter, 15-cm (a half-foot) long cylinder. These CFD results demonstrated that the tuna's drag is relatively low regardless of the body size.

Professor Takagi conducted a CFD simulation that accounted for the movement of the tail (figure 2) using the moving body capability in scFLOW. He created a smooth virtual representation of a moving tuna by recording a video of a real tuna and approximated the real world motion of each point on the body with periodic functions. This enabled him to investigate the motion of the bluefin tunas further, such as identifying its tail thrust and analyzing the outward movement of its pectoral fins, which effectively function as wings underwater.

The pectoral fin is essential for the swimming ability of tunas, as it generates the lifting force. Although tunas possess swim bladders inside their bodies, the bladders do not fully sustain the upward force needed to keep them buoyant. This is one of the reasons why tunas must keep swimming constantly. They use a similar mechanism underwater as airplanes use to produce lift in air. Professor Takagi's CFD simulations clearly showed that substantial lift can be generated



Bluefin tuna (source: Wikipedia.org)

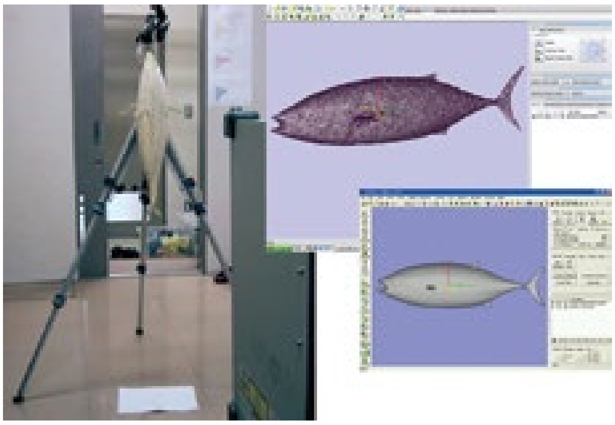


Figure 1: A frozen tuna being scanned on a 3D scanner in Prof Takagi's laboratory with resultant geometry and surface mesh representation

by moving the tuna's pectoral fins outward. In addition, tunas can streamline their bodies to minimize drag by tucking their pectoral fins into the indentions on the sides of their bodies. The *caudal peduncles* are the bumps attached to the root of the tunas' tails and they also function as minuscule wings.

"For the larger migratory fish such as the Indo-Pacific sailfishes, two layers of caudal peduncles are attached to its body just like a biplane. It's fascinating that the reasons and purposes behind the designs of living organisms become evident when I look at it from the fluid-analysis perspective," comments Professor Takagi.

MSC Adams Helps Save Tangled Leatherback Turtles

Do you like to go fishing in your spare time? Many of us do … but the consequences for marine animals other than the fish that we want to catch may be harmful.

You've probably never even thought about turtles when going on a boat outing in certain locations around the world, but mooring lines and aquaculture gear can affect them to the extent of killing them because they get caught up in the line and can't escape. Fishermen like to increase their fishing efficiency using synthetic materials, which unfortunately leads to turtles getting entangled in mooring lines and cables more and more. Lately, this phenomenon has been happening more frequently, yet little is known about how this occurs. Moreover, it is difficult to measure and (reference 2) nearly 4,500 turtles a year are estimated to be part of 'bycatch' as they get entangled with mooring lines. The burning question for MMC was: with the scant information researchers have about entanglement, what can they do to remedy this problem and help the turtles with simulation software?

Without proper measurement, simulating a reality we're unfamiliar with, that is, humans are rarely there the moment turtles get entangled, but engineering simulation software is a great alternative to help us to understand the physics of what is going on. As researchers, MMC turned to MSC Adams, the world's leading multibody dynamics software, to help understand what might be happening in this situation and therefore find a solution. They used Adams to develop a computer simulation model of a turtle swimming and then its entanglement behavior with a floating mooring line. It accurately mimicked the behavior of adult leatherback sea turtles (*Dermochelys coriacea*) using this approach (reference 3-4). Through the successful reproduction

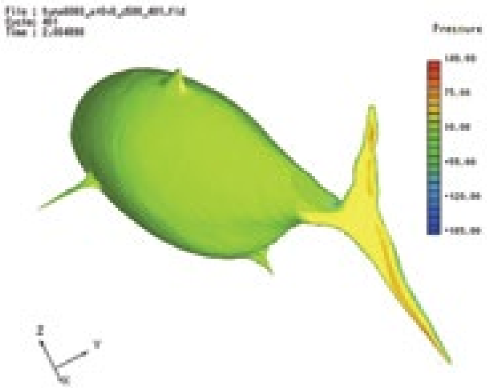
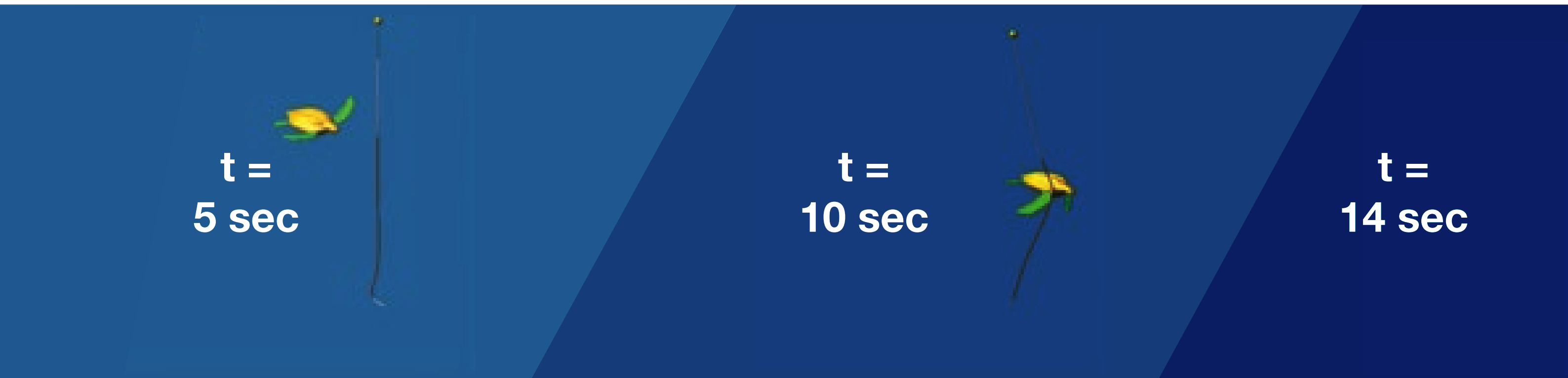


Figure 2: scFLOW CFD analysis prediction of body surface pressure on a bluefin tuna with the tail in motion

Leatherback Turtle (source: Wikipedia.org)



of the turtle and its movements the MMC team was able to drastically increase the bending stiffness of the mooring in hopes of preventing future entanglement. Ultimately, the Adams computer model led to recommendations for an advanced mooring line which will reduce the number of entanglement cases. The result MMC hope will be many fewer turtles getting stuck and more of these beautiful creatures being saved for posterity. A tool like MSC Adams can therefore assist designers of advanced mooring and fishing line technology to reduce the number of leatherback turtle entanglement events (see reference 5 for the full story).

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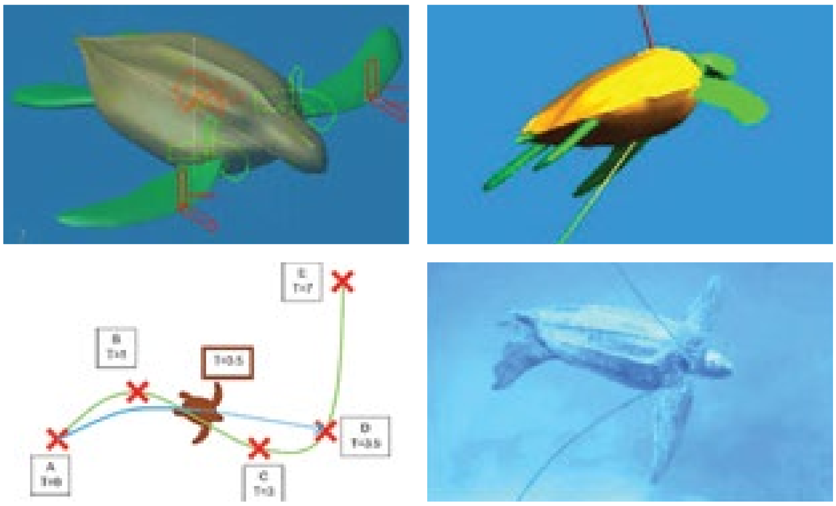

Figure 3: MSC Adams MBD model of a Leatherback Turtle, an entanglement event timeline with a mooring line, the predicted entanglement end point after entanglement and a typical photo of an actual turtle after entanglement

Figure 4: MSC Adams MBD analysis of a Leatherback Turtle entanglement motion over 19 seconds with a floating mooring line