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Jelly Fish Swimming — Helicopter Flying Analogue

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SUMMARY Jelly fish swim by propelling a vortex ring jet - helicopters fly by propelling a helical vortex in air. The helical vortex can be approximated to a vortex ring jet. This paper examines the difficult way in which a helicopter generates vertical flow when compared with the very simple means used by jelly fish.

1 INTRODUCTION

Lighthill (1), Gray (2) and Webb (3) have discussed the swimming mechanics of animals and have separated the swimming motions into three major groups, namely viscous dominated (microscopic animals), inertial reaction (most vertebrates) and jet reaction (squid). In this paper it is intended to suggest a fourth mode of swimming for animals namely that jelly fish swim by firing vortex rings. Excluding the viscous dominated mode of movement in animals, there are obvious analogues existing between aircraft flight and swimming. Aircraft have three main modes in providing the motive force namely, propellers, jet and rotors. The rotor although is in some respects similar to the propeller, its role is fundamentally different. The rotor system on a helicopter provides directional control, lift, and motive force as its prime functions where as a conventional propeller only provides motive force.

Fish that swim via inertial reaction (by flapping a tail for instance) are similar in function to a propeller driven aircraft. The fins and tail fin on a fish provide the directional control in a similar fashion to the way in which the ailerons, the rudder and the elevators control the direction of aircraft. Squid swim by firing a jet - jet aircraft fly by firing a jet but both the jet aircraft and the squid have separate mechanisms for controlling their direction.

2 QUALITITIVE DESCRIPTION OF THE SWIMMING OF JELLY FISH

Gladfelter (4) describes the swimming motion of a particular species of jelly fish (there are thousands of different species) as a jet like motion. A considerable amount of confusion exists in the literature on when does a vortex ring become a starting jet. A vortex ring is an isolated blob of energy and momentum where as a jet is a flow which is being fed energy and momentum from its source. This distinction between vortex rings and jets has caused a considerable hurdle in Zoologistics understanding the swimming mechanics of jelly fish.

Figure 1 shows a schematic representation of jelly fish swimming. This motion can be described as follows:- the annular segmented muscle (similar to the sphcinter muscles) expands relatively slowly drawing fluid under the bell of the jelly fish, the muscle contracts rapidly to its zero strain position expelling a blob of fluid. This blob of fluid forms a vortex ring due to the momentum interchange between the stationary and moving fluid (this method of formation was described by Rogers (5) in 1858 and Batchelor (6) has reproduced photographs taken by Okabe and Inone showing the formation of a vortex ring). The period of beating of jelly fish is of the order of one second but the period does vary and is a function of size of the jelly fish and the species. If the wake of a jelly fish is examined far away from the point of generation a vortex ring jet would be seen.

It is interesting to note that jelly fish can control their direction of swimming by selectively contracting only a part of their segmented muscle causing the vortex ring to be fired along an axis other than the axis of symmetry of the jelly fish. Also jelly fish are carnivorous and they feed on small fish, fish larvae, and zoo plankton which are killed by a toxin located in their tentacles. As the vortex ring is fired out from the bell and down along the tentacles, the prey in the vortex will be flung out and may come in contact with the tentacles. Hence the swimming action increases the probability of jelly fish feeding. This mechanism shown in Figure 2 can readily be seen in the case of the box jelly fish (sea wasp or chironex fleckeri) and it is possible to use this feature to measure the velocity of advection of the vortex.

3 QUALITITIVE DESCRIPTION OF HELICOPTER ROTOR FLUID MECHANICS

A helicopter achieves its lift and motive force from rotating blades. Sullivan (7) along with many others considered the wake from a helicopter blade to be composed of two major vortical components. These components are a tip helical vortex and a helicoidal vortex. Experimentally it has been found that most of the vorticity generated by the rotor blades is contained in the helical vortex.

If the diameter (D) of the helical vortex is large, the vortical core diameter is small and the pitch of helix is small compared with helix diameter then the helical vortex may be represented by a vortex ring jet. This is the case for a helicopter rotor wake.

The complexity of the helicopter is due to the way in which the lift is achieved and manner in which the direction of the helicopter movement is controlled. The rotor blades have two separately varying pitches applied namely the cyclic and the collective pitchs.

4 COMPARISON BETWEEN JELLY FISH AND HELICOPTERS

The wakes from jelly fish and helicopters are similar in form namely a vortex ring jet with the major difference being the time scale of the motion. Jelly fish are a very simple planktonic animal, they do not have a brain, they swim by using one muscle system (in most animals at least two muscular systems are required for movement), the swimming motion is integrally related to food gathering and they can regulate their buoyancy rapidly to remain at one horizontal level, by changing their salt level. Helicopters are possibly one of the most complex type of aircraft known, they are difficult to fly, their operational cost is an order of magnitude higher than any other aircraft with the same load carrying ability, they have a very complex mechanism to generate their motive power, and they have the ability to hover expending large amounts of energy.

5 CONCLUSIONS

Jelly fish do swim in a similar manner to the way helicopters fly, but the functional design of a jelly fish is such that it can survive in a minimum energy situation where as helicopters fly using vast amounts of energy.

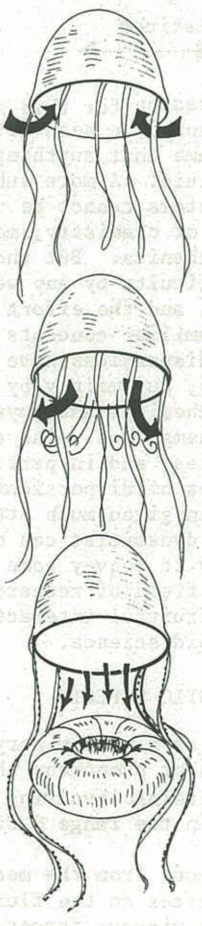

Figure 1 Schematic diagram of the vortex Ring Generation

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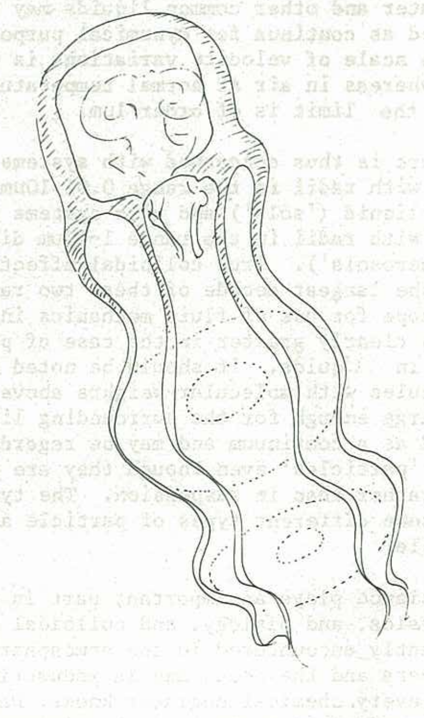

Figure 2 Schematic diagram of the Feeding Mechanism for Jellyfish