BIOMIMETIC PLANETARY ROBOTS FOR OCEAN EXPLORATION IN SPACE.

Mannam Naga Praveen Babu[1] and Krishnankutty. P[2], [1]Department of Ocean Engineering, Indian Institute of Technology Madras, Chennai - 600036, India. [1]E-mail: oe13d006@smail.iitm.ac.in, [2]Department of Ocean Engineering, Indian Institute of Technology Madras, Chennai - 600036, India. [2]E-mail: pkrishnankutty@iitm.ac.in

Introduction: Space exploration is the ongoing discovery and exploration of celestial bodies, planets and moons. The physical exploration of space is carried out by both human spaceflight and unmanned robotic probes (rovers). A rover is a planetary exploration vehicle designed to move acroos the celestial bodies or on surface of the planets. These rovers can be semi-autonomous or fully autonomous bodies. The main function of these rovers is to collect rock samplings, dust and images of the surface. The advantages of planetary rovers compared to stationary landers are they can make obeservations at a microscopic level and can conduct physical experimentations and they can examine more territory. However, the conventional rovers are subjected to limited powering aspects, obstacle avoidance, difficults to maneuver in highly rough terrains and unable to withstand in harsh environments. Naturally the diverse range of environmental conditions that could be encountered during exploration may not be suitable for existing rover systems. The plants and animal species evolved in nature, gives inspiration for designing and buildingof novel and high performance biomiemtic planetary rovers for land and liquid atmospheres on planets. Recently, scientific discoveries creates interest in exploring other planets' moons such as Saturn's Titan and Jupiter's Europa.

Conventional planetary rover designs are wheel operated on firm ground surfaces and proved successful in the exploration of Martian environment (eg: Mars). Hence, the conventional wheel type rovers are not suitable for liquid environments where operation would be in liquid atmospheres on jupiter's europa or within dense gaseous mediums. In order to explore liquid atmospheres in Jupiter's europa (the fourth largest moon on jupiter), the rover should have the ability to propel and manoeuvre effectively within liquid media and its design must reflect these operational requirements.

The current research is to design the planetary rover based on biological species that live in liquid environments on Earth e.g. aquatic mammals and fish. This would involve the development of a robotic system that was able to replicate the swimming aspects of fishes for liquid environments on plantes. This proposed research project will address the design and analysis of a biologically inspired or biomimetic rover concept, for example based on fish swimming, particularly carangiform modes (salmonid). Such robotic systems are highly robust and capable of generating thrust with caudal fin and auxilary (pectroral) fins. These fins increases the powering aspects of the vehicle in liquid environments and the elimiates the needs of rudder devices for maneuvering. Proposed case-studies will involve the exploration of the atmosphere of Europa and Titan.

Biomimetic Planetary Robot: The design considerations will include propulsion mechanisms, efficiencies and power requirements. These will be evaluated through numerical simulations that have been validated against previous studies involving biomimetic autonomous underwater vehicles. The bio-inspired planetary rover is shown in fig. 1. The forward (pectoral) fins have the freedom to oscillate in vertical and/or horizontal plane about the transverse axis and the aft (tail) fin has freedom to oscillate in the horizontal plane about the longitudinal axis. The pectoral fins provides instantaneous stopping ability to rover and helps in reducing the turning circle maneuvering parametes. The modes of operation of pectoral fins is shown in fig.2. The pectoral fins are operated by two servos for flapping motion and two rotational motors for rotation of fins shown in fig. 3. The caudal fin acts as main propulsor for the rover shown in fig. 4. The rover also consits of main controller box, wireless remote.

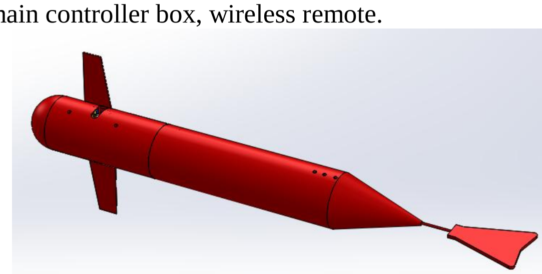

Fig. 1. Bio-inspired Planetary rover

Fig. 2. Pectoral fins in flapping and rotational mode.

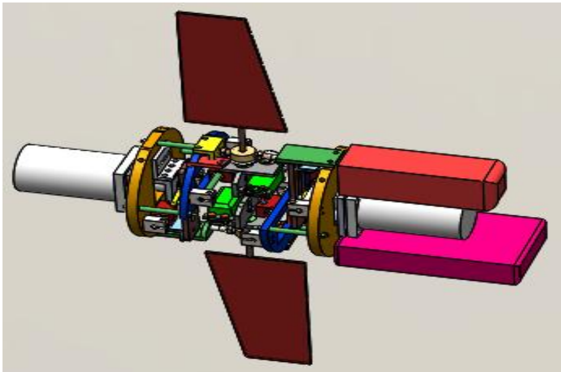

Fig. 3. Pectoral Fins with servo motors and batteries

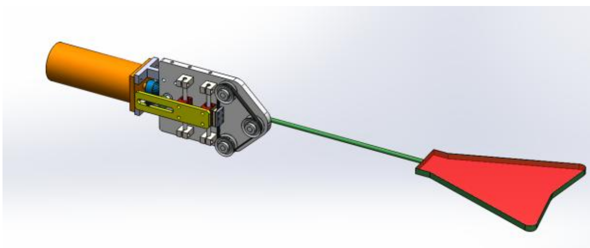

Fig. 4. Caudal fin propulsor for bio-inspired robot

Hydrodynamics of planetary robot: A lift-based propulsion theory is used to estimate the thrust generated by pectoral fins (used as auxiliary thrust device) and an empirical method is used to estimate the torque at the caudal fin. The fish body shape and fin geometrical parameters are also important with regard to the resistance and powering aspects. Numerical studies are conducted with the robotic fish to determine its resistance in bare hull and also for the case fitted with fins. This paper investigates the oscillating motion of caudal fin in yaw mode at different amplitude ratios. The caudal fin generates a reverse von karman vortex street (thrust producing wake) at strouhal number, 0.22. These mechanisms are presented and discussed in the proposed paper. The thrust force on pectoral fins and caudal fin was estimated using strain guage type force sensors in self propulsion mode with the help of towing carriage. These results are discussed in the present paper.

Fig. 5. Bio-inspired robot in testing stage.

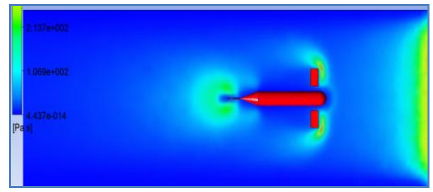

Fig. 6. Flow around the pectoral and caudal fins

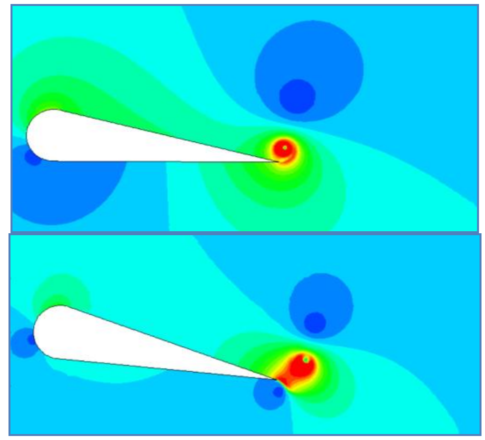

Fig. 7. Reverse von karman vortices around flapping caudal fin

Acknowlodgement: The authors would like to thank Dept. of Ocean Enginnering, Inidan Institute od technology Madras, Chennai, India for suporting this project.

Bibilography:

[1] Anderson J, Streitlien K, Barrett D, Triantafyllou M. Oscillating foils of high propulsive efficiency. Fluid Mechanics 1998;360:41–72.

[2] Taylor GK, Nudds RL, Thomas ALR. Flying and swimming animals cruise at a Strouhal number tuned for high power efficiency. Nature 2003;425:707.

[3] Read DA, Hover F, Triantafyllou M. Forces on oscillating foils for propulsion and maneuvering. Journal of Fluids and Structures 2003;17:163–83.