DESIGN AND DEVELOPMENT OF AUTONOMOUS BIOMIMETIC BLACKTIP SHARK

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FACULTY OF ENGINEERING
UNIVERSITI MALAYSIA SABAH
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DECLARATION

I hereby declare that the material in this thesis is my own except for quotations, excerpt, equations, summaries and references, which have been duly acknowledged.

1 April 2016

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ABSTRACT

The aim of this project is to design a biomimetic swimming device using a single actuator with a compliance body for locomotion in a liquid environment with basic autonomous manoeuvrability. The biological Blacktip shark is being utilized as the reference model. The working concept of the biomimetic robotic fish is based on a single non-uniform cantilever beam in fluid environment. The kinematic model and kinetic model approach has been utilized to develop the theoretical model by trajectory approximation theory and beam theory for estimating the robotic fish swimming performance. The theoretical model has shown to be comparatively close in estimating the measured result particularly in the prototype design parameter. The experimental result found that the prototype optimum tail beat frequency is 2 Hz at optimum actuation amplitude of 80 deg has been achieved for the prototype design parameters. The prototype is also able to be controlled manually for performing basic manoeuvrability (swim forward, yaw left and yaw right). A basic autonomous detect and avoid of obstacles in underwater environment with basic manoeuvrability have also been developed.

ABSTRACK

REKABENTUK DAN PEMBANGUNAN BIOMIMETIC IKAN YU BLACKTIP AUTOMASI

Matlamat projek ini adalah untuk mereka bentuk peranti biomimetic dengan pergerakan tunggal dan mekanisme yang flexible untuk bergerak di persekitaran bendalir dangan pergerakan automasi yang asas. Ikan Yu jenis Blacktip digunakan sebagai model rujukan. Konsep perekaan ikan robot biomimetic ini adalah berdasarkan pemahaman rusuk julur dalam bentuk yang tidak seragam di dalam persekitaran cecair. Model kinematik dan model kinetic digunaken untuk mendapatkan model teori daripada teori penghampiran trajektori dan teori rusuk. Teori model dapat menganggarkan keputusan daripada eksperimen terutamanya pada parameter rekabentuk prototaip. Daripada keputusan eksperimen didapati bahawa frekuensi optimum pergerakan ekor ialah 2 Hz dan pergerakan amplitud optimum ialah 80 darjah adalah parameter reka bentuk prototaip. Prototaip boleh dikawal secara manual untuk melaksanakan pergerakan asas (berenang ke depan, kiri dan kanan). Prototiap telah dihasilkan dan boleh mengesan dan mengelak halangan dengan pergerakan asas secara automasi di persekitaran air.

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LIST OF ABBREVIATIONS

3D	-	Three dimensional
ABS	-	Acrylonitrile Butadiene Styrene
ADAMS	-	Automated Dynamic Analysis of Mechanical System
BCF	-	Body and/or caudal fin
CRT	-	Compliant Robotic Tuna
CAD	-	Computer Aided Design
DOF	-	Degree Of Freedom
FDM	-	Fused Deposition Modelling
IR	-	Infrared
MIT	-	Massachusetts Institute of Technology
PLA	-	Polylactic Asid
PZT	-	Piezo Ceramic
RTV	-	Room Temperature Vulcanization
SMA	-	Smart-Memory Alloy
USB	-	Universal Serial Bus
TX	-	Transmit
RX	-	Receive
RF	-	Radio Frequency
PCB	-	Printed Circuit Board
U.K	-	United Kingdom
U.S	-	United State
VCUUV	-	Vorticity Control Unmanned Undersea Vehicle
UC	-	University of California

UE	-	University of Essex
BUAA	-	BEIHANG University
HIT	-	Harbin Institute of Technology
TU	-	Tallinn University of Technology
FILOSE	-	Robotic Fish Locomotion and SEnsing
NMRM	-	National Maritime Research Institute
MHI	-	Mitsubishi Heavy Industries
OU	-	Osaka University
DSP	-	Digital Signal Processor
MEI	-	Motion Engineering Inc.
PVC	-	Epoxy Polyvinyl Cloride
Li-ion	-	Lithium-ion
CAB	-	Computer Aided Manufacturing

LIST OF NOTATION

A	-	Cross-sectional area [m^2]
A_{ref}	-	Reference frontal area [m^2]
A_{tail}	-	Tail actuation amplitude [m]
a	-	length along the body [m]
C	-	Speed of body wave [Dimensionless]
C_1 and C_2	-	Constant relation with boundary condition [Dimensionless]
C_d	-	Drag coefficient [Dimensionless]
c_1	-	Linear wave amplitude envelop [m]
c_2	-	Quadratic wave amplitude envelop [m]
E	-	Young's modulus [N/m^2]
ε	-	Strain [Dimensionless]
f	-	Actuation frequency [Hz]
f_{fluid}	-	Fluid resistance force [N]
G	-	Green's Function [Dimensionless]
H	-	Amplitude displacement [m]
h	-	Lateral displacement [m]
h_{tail}	-	Body travelling wave [m]
I	-	Moment of inertia [m^4]
K	-	Body wave number [Dimensionless]
k	-	Material response [Dimensionless]
L	-	Body length [m]

ℓ_{body}	-	Body span length [m]
$\ell_{excited}$	-	Distance of moment point [m]
ℓ_{head}	-	Head length [m]
ℓ_{tail}	-	Tail length [m]
M	-	Moment [Nm]
M_o	-	Initial moment [Nm]
$M_{bending}$	-	Overall bending moment [Nm]
$M_{viscous}$	-	Bending moment [Nm]
m	-	Added mass per unit length [Kg/m]
η	-	Viscosity [N.s/m^2]
ρ	-	Material density [kg/m^3]
ρ_{fluid}	-	Fluid density [kg/m^3]
Q_1 and Q_1	-	Constant relation with material response [Dimensionless]
R	-	Tail radius of curvature [m]
R_i	-	Top view geometry constant value [m]
r_1	-	Side view geometry constant value [m]
St	-	Strouhal number [Dimensionless]
T_{cycle}	-	Wave cycle period [s]
t	-	Time domain [s]
U	-	Forward swimming speed [m/s]
u	-	Unit step function (Dimensionless)
w	-	Lateral velocity [m/s]
ω	-	Body wave frequency [Hz]