LIGHT EMITTING DIODE (LED) ILLUMINANCE IN UNDERWATER ENVIRONMENT FOR MARINE AQUACULTURE

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DECLERATION

I hereby declare that this thesis, submitted to University Malaysia Sabah as partial fulfilment of the requirement for the degree of Bachelor of Mechanical Engineering, has not been submitted to any other university for a degree. I also certify that the work described herein is entirely my own, except for quotations and summaries of sources that have been duly acknowledged.

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ABSTRACT

Sustainable underwater lightings were developed to be use as a fish attractor for fisherman living in the coastal area within Malaysia and navigation aid for divers. The underwater lighting equipment consist of Light Emitting Diode (LED) module, wind generator, turbine blades and rechargeable lithium-ion battery. The underwater lighting will use wind power to generate electricity where then will be stored inside lithium-ion battery. For the LED module test, the illuminance of eight different colours of LED was studied which are white, green, blue, red, yellow, purple, cyan and deep sky blue. Based on the result obtained, the illuminance of all colours of LED will decrease as distance between LED and light meter increase when 5 V of voltage supplied to the LED. Deep sky blue colour of LED has the highest illuminance while red colour of LED has the lowest illuminance. As an example, when the distance between LED and light meter is 0.1 m, the illuminance of deep sky-blue LED is 812 lux while red colour of LED has illuminance of 52 lux. Next, the minimum voltage for all colours of LED to reach 20 lux of illuminance increase as distance between LED and light meter increase. Red colour of LED required the highest minimum voltage with a value of 3.67 V while both cyan and deep sky blue colour of LED required the lowest minimum voltage to reach 20 lux of illuminance with value of 2.36 V and 2.39 V respectively. For the validation part, the value of $H_{Submerged\ Theoretical}$ for 1 m length of floating station pipe with weight of 3.4 kg is 0.474 m while the value of $H_{Submerged\ Theoretical}$ obtained from buoyancy test is in the range of 0.438 m until 0.556 m. The average percentage errors obtained by comparing the value of submersion height is 7.80%. However, the complete prototype with 1 m of floating station with weight 3.4 kg was placed inside it is fast tilting and unstable. On the other hand, the complete prototype with 2 m of floating station and 8.75 kg weight placed inside the floating station can be stable as float in seawater. Based on the buoyancy test, the prototype became more stable as the average $H_{Submerged\ Experimental}$ increase. When the average $H_{Submerged\ Experimental}$ small which is 1.29 m the prototype fast tilting and unstable and become vertical and constantly stable as the average $H_{Submerged\ Experimental}$ increase to 1.5 m.

ABSTRAK

Pencahayaan bawah air yang lestari dikembangkan sebagai tarikan ikan bagi nelayan yang tinggal di kawasan pantai dalam Malaysia dan bantuan navigasi untuk penyelam. Peralatan lampu bawah air terdiri daripada modul Light Emitting Diod (LED), penjana angin, bilah turbin dan bateri litium-ion yang boleh dicas semula. Pencahayaan bawah air ini akan menggunakan tenaga angin untuk menjana tenaga elektrik yang mana akan di simpan di dalam bateri litium-ion. Bagi ujian modul LED, kecerahan lapan warna LED berbeza telah dikaji iaitu putih, hijau, biru, merah, kuning, ungu, cyan dan biru langit dalam. Berdasarkan keputusan yang diperoleh, pencahayaan semua warna LED akan berkurangan apabila jarak antara LED dan meter cahaya meningkat apabila voltan 5 V dibekalkan kepada LED. LED dengan warna biru langit dalam mempunyai pencahayaan tertinggi manakala LED berwarna merah mempunyai pencahayaan paling rendah. Sebagai contoh, apabila jarak antara LED dan meter cahaya ialah 0.1 m, pencahayaan LED biru langit dalam ialah 812 lux manakala LED berwarna merah mempunyai pencahayaan 52 lux. Seterusnya, voltan minimum untuk semua warna LED untuk mencapai 20 lux pencahayaan meningkat apabila jarak antara LED dan meter cahaya meningkat. LED berwarna merah memerlukan voltan minimum tertinggi dengan nilai 3.67 V manakala kedua-dua warna cyan dan biru langit dalam LED memerlukan voltan minimum terendah untuk mencapai 20 lux pencahayaan dengan nilai 2.36 V dan 2.39 V masing-masing. Bagi bahagian pengesahan, nilai teori Hsubmerged bagi panjang paip stesen terapung 1m dengan berat 3.4 kg ialah 0.474 m manakala nilai $H_{Submerged\ Experimental}$ yang diperolehi daripada ujian daya apungan adalah dalam julat 0.438 m hingga 0.556m. Purata peratusan kesilapan yang diperoleh dengan membandingkan nilai Hsubmerged ialah 7.80%. Walau bagaimanapun, prototaip lengkap dengan 1 m stesen terapung dengan berat 3.4 kg diletakkan di dalamnya adalah tidak stabil. Sebaliknya, prototaip lengkap dengan 2m stesen terapung dan berat 8.75 kg diletakkan di dalam stesen terapung boleh terapung dengan stabil di atas air laut. Berdasarkan ujian daya apungan, prototaip menjadi lebih stabil apabila purata Hsubmerged meningkat. Apabila purata Hsubmerged kecil dengan panjang 1.29 m, prototaip menjadi condong dengan cepat dan tidak stabil. Manakala prototaip menjadi tegak dan sentiasa dalam keadaan stabil apabila purata $H_{Submerged\ Experimental}$ meningkat kepada 1.5m.

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LIST OF ABBREVIATIONS

CFD	-	Computational fluid dynamics
FBD	-	Free Body Diagram
FOWT	-	Floating offshore wind turbine
LED	-	Light Emitting Diode

LIST OF SYMBOLS

λ	-	Wavelength
D	-	Diameter
D_o	-	Outer diameter
D_i	-	Inner diameter
A	-	Area
ρ	-	Density
ρ_{water}	-	Density of water
t	-	Thickness
L_o	-	Outer length
L_i	-	Inner length
$L_{concrete}$	-	Length of concrete
m	-	Mass
m_{cap}	-	Mass of cap
$m_{end\ cap}$	-	Mass of end cap
$m_{UPVC\ Pipe}$	-	Mass of UPVC pipe
$m_{concrete}$	-	Mass of concrete
$m_{1m\ floatig\ station}$	-	Mass of 1 m floating station
m_{weight}	-	Mass of weight used
V	-	Volume of water displace
I_0	-	Moment of inertia of water line area

F_B	-	Buoyancy force
W	-	Weight
G	-	Center of gravity
M	-	Metacenter
C	-	Center of buoyancy
$\overline{GM}$	-	Metacentric height
$\overline{CG}$	-	Distance from center of buoyancy to center of gravity
$H_{Submerged\ Theoretical}$	-	Theoretical value of submersion height
$H_{Submerged\ Experimental}$	-	Experimental value of submersion height
$H_{Unsubmerged\ Experimental}$	-	Experimental value of unsubmerged height

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CHAPTER 1

INTRODUCTION

1.1 Overview

According to Loomis (2020), underwater lights are lights that able to be installed underthe surface of water. There are many types of underwater light such as xenon, mercuryvapor, metal-halide, halogen bulbs and light emitting diode (LED). The most popular lighting in marine lighting market is LED lights. The LED has shorter wavelength that able to penetrates deeper into the seawater and lot of marine organism or marine life are sensitive to the LED light (Davies et al., 2020).

The LED lights are more energy efficient and durable as well as reliable compared to other marine lightings (Your Guide to LED Underwater Lighting, 2021). In order to make the LED light waterproof and can be installed 5m underwater, the protection effect of the LED lights should reach IP69 and more. The LED lights consist of many different colours such as white, blue, red, green, yellow and more. The colour choices will be differ based on the application of the LED light (Haynes, 2021).

The LED light start to be introduced in 1907 and in 1960s, the LED light start tobe use as indicator lamp. The design of the LED light then being develop and improve until the range of application of LED become wider. The LED light start to be use in underwater application in 2000s and nowadays it is become the most popular underwater lights. Nowadays, for depth of 6000m, the standard LED lights able to provide about 3.4 lumens of light per dollar compared to halogen light which only able to provide 2.3 lumens per dollar (Chew, 2011).

There are many benefits of underwater lights, such as for fishing, ambience andsafety (Your Guide to LED Underwater Lighting, 2021). LED lights able to attract marinelife such as fish, crab and prawn. Some application of artificial light to attract marine lifedone by fisheries such for squid-jigging and net. Artificial light such as LED lights also can be used to prevent bycatch. According to Sakamoto, et al. (2017), bycatch is a situation where unintentionally caught marine life or species. Example for bycatch animalsuch as dolphins, turtles, whales, and sharks. These are low population species. Not onlyfish, but other animal such as turtles also get attract to light. According to John Wang, as mentioned by Sakamoto, et al. (2017), a turtle also attracted to light when placed ina dark tank. Differently to specific light characteristic such as intensity, wavelength, colour, flickering and polarization. The respond of the species such as showing attraction., no response or repulsion. Therefore, by using LED light, the fishing operationcan be improved (A. C. Utne-Palm et al., 2018).

According to (Gietler, n.d.), different colour disappear at different depth underwater. This is because, water absorbs different wavelength of light to different degrees. The water will absorb red then orange and yellow accordingly because water will first absorb a light that has a longest wavelength with the lowest energy. The colour red, orange, yellow and green will disappear with depth underwater of 15ft, 25ft, 35ft until 45ft and 70ft until 75ft respectively.

The term light always being related to the term of illuminance and luminance. According to (Phillips, 2020), luminance is the amount of light that being emitted and reflected from a surface. The term of luminance can also indicate brightness. A colour luminance can be measured by using spectrophotometer. The International System of Unit (SI Unit) for luminance is candela per meter square (cd/m^2). On the other hand, illuminance is the amount of light falls upon a surface area. This indicates the total of light that the object receives. The illuminance can be measured by using light meter andthe SI unit for illuminance is lumen per meter square or lux.

1.2 Problem Statement

According to Loomis (2020), fish eyes can capture blue wavelength at 425nm until 490nm at near UV wavelength in 320nm until 380nm due to colour receptor in their eyes. Shrimp also has both wavelengths in their colour vision as well as green receptor at 530nm. Phytoplankton are microscopic marine algae that that require sunlight to growand live. So, phytoplankton get attracted to underwater LED light at night. This is because, at night, there is no sun light, so phytoplankton swarm LED light as a food source. Since phytoplankton is a food source for other aquatic life, they will be followingphytoplankton. This will create an underwater fish feeder. LED light can provide high lumen output at lower electrical cost. Different LED light will release different lumen outputs as measure of their power. The white, green, aqua, red and blue LED light will release 180, 130, 110, 90 and 50 lumens per LED respectively. Hight intensity of LED light can increase visibility of light and increase the lumen output. Higher lumen outputwill attract more phytoplankton and aquatic life. Fish will get attract to LED light with a colour of green, aqua, white, blue and red accordingly.

According to Barki et al. (2021) as mentioned in a study conducted by Lee (n.d.),guppies were most attracted to white LED light and least attracted to red light. Based on her study, Rasbora fish get attracted to green, red, and white LED light but not to blue LED light. This is because, Rasbora can differentiate wavelengths, and only react to mixed, intermediate or long wavelengths, but not to short wavelengths. Different species of fish may have different preference of colour and attract to different colour. Based on study conducted by Sakamoto, et al. (2017), blue light with wavelength of 465nm attracted most fish, while red light with wavelength of 633nm attract the least number of fish. According to Marchesan et. al. (2005) and Ryer and Olla (2000) as mentioned in the study, several studies have shown that the reaction of fish towards light varies depending on its species according to the intensity and wavelength of the light. According to Kroger (2013) as mentioned by Nguyen (2019), most of squid and cuttlefish are colour blind. The Japanese squid will get attracted to blue, green and whitelight but not red light. On the other hand, crab will move toward blue light and white light but not affected by the red and green light. Crab also will move away from purplelight. The colour vision of a species are depends on the structure of the eye.

The brightness of the LED light will also affect the attraction of marine life. According to article "How LED lights can help with night fishing or squid fishing" (2019),a super bright light will scare some fish away while squid are fond to super bright light.Blue and bright green LED light will be ideal to attract squid. Based on the study conducted by Nguyen (2019), anchovy preferred the underwater illuminance of 0.03 luxuntil 6.00 lux (Inoue, 1972) and the optimal underwater illuminance for mitre squid is

between 1.5 lux until 22.5 lux (Ibrahim and Hajisamae, 1999). This information shows that, different species of marine life will prefer different underwater illuminance.Therefore, the problem statement of this study is how to design a good underwater LED. LED in a buoyant in the market has been design for specific application or purpose and cause to limits the targeted species and the power also need to be brought by human. This cause fish not schooling. Therefore, the project will design LED in floating station that can be powered by wind turbine where it will be use to attract fish.

1.3 Research Objectives

The objective of this project are:

i. To develop the underwater light floating station with proper length and weight of concrete inside the floating station to make sure the underwater LED light can partially be submerged on a sea water.
ii. To measure the illuminance of underwater LED light in a dark and underwater environment.

1.4 Scope of Works

The scope of works is as below:

i. Wind turbine will power the underwater LED light by using USB power supply.
ii. Sustainable where it can be use repeatedly and did not release chemical compound.
iii. Not suitable for a major application or big scale of project since the underwater LED light is small size.
iv. Cannot be use in bad or extreme weather.
v. This study only covers the underwater LED with floating buoyant not include battery and wind turbine.

1.5 General Research Methodology

Figure 1.1 shows the flow chart of the project research methadolohy.

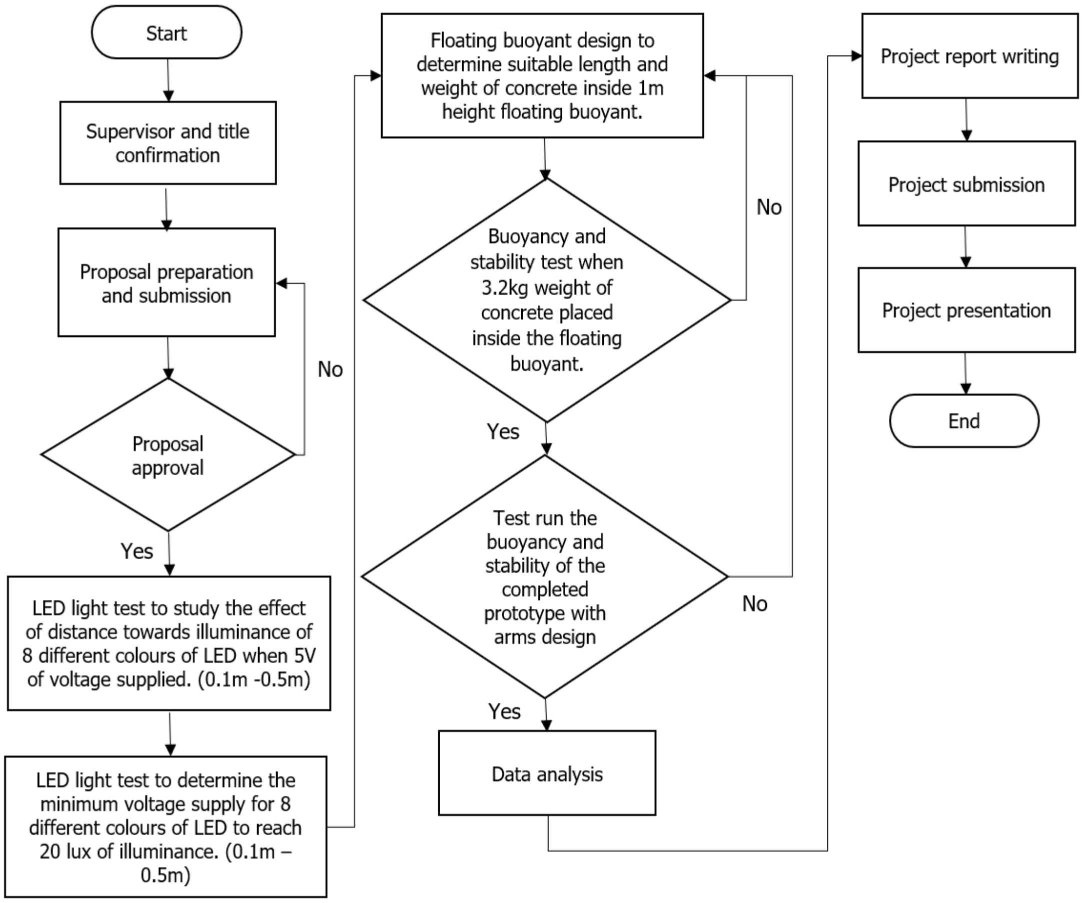

Figure 1.1: The Flowchart of The Project Research Methodology

1.6 Research Expected Outcomes

The research is expected to have the following outcome:

i. Able design the underwater light floating station with proper length and weight of concrete inside the floating station so that the buoyancy force and body weight will be balance when the underwater light partially submerged on the sea water.
ii. Able to explain the relationship between illuminance of LED light with the distance of the LED light and the light meter.
iii. Able to explain the relationship between illuminance of LED light with the voltage supply to the LED light.
iv. Able to test run the buoyancy and stability of the underwater lightprototype.

1.7 Research Contributions

The research contribution of this project is as follow:

i. Success in constructing an underwater LED lighting that is low cost for marine life application.
ii. The underwater LED lighting can be construct easily to with different LED light illuminance to attract different species of marine life.
iii. The LED light for the underwater lighting can be change easily according to the desire brightness to attract different species of marine life focusing to fish.
iv. The LED light for the underwater lighting can be change easily according to the desire colour to attract different species of marine life focusing to fish.

1.8 Research Commercialisation

The research commercialization of the project is as follow:

i. Suitable for most of the people as the underwater LED lighting can be construct and operate easily.
ii. Low maintenance and construction cost.
iii. Sustainable design since the underwater LED light can be used repeatedly and did not release any chemical compound.

1.9 Research Gantt Chart

Table 1.1: Gantt Chart for Semester 1-2021/2022

No.	Item	Week													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.	First project briefing														
2.	Confirmation of supervisor and research title														
3.	Project proposal writing														
4.	Project proposal submission														
5.	Brainstorm ideas														
6.	Introduction														
7.	Literature review														
8.	Methodology														
9.	Project I report writing														
10.	Finding the suitable length for the underwater LED light														
11.	LED light test andprototype construction														
12.	Project I report submission														
13.	Preparation for presentation														
14.	Presentation of Project I														

Table 1.2: Gantt Chart for Semester 2-2021/2022

No.	Item	Week													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.	Testing and experiment	■	■	■	■	■	■	■	■	■	■	■	■		
2.	Data analysis		■	■	■	■	■	■	■	■	■	■	■		
3.	Draft writing				■	■	■	■	■	■	■	■	■		
4.	Draft submission										■	■			
5.	Draft correction										■	■	■		
6.	Final draft submission											■	■		
7.	Preparation for presentation												■	■	■
8.	Presentation of Project II														■
9.	Thesis correction														■
10.	Submission of final thesis														■