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Floating Buoy Technology for Research Purposes

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Abstract: *A buoy is a structure that is float on the sea surface used for the navigational, marine science, monitoring the meteorology and oceanography changes of the marine environment. This article presents a literature review on research and development of floating buoy technology for research purposes. The article starts with the historical background of various buoy technologies. Then, floating buoy working principles used for research are discussed. The reviewed according to the type of buoy technology for research purposes (tsunami buoy type, wave buoy type, weather buoy type, and profiling buoy type). This is followed by an overview of the buoy applications that have been undertaken by Malaysian research communities. The proposed concept design of buoy will be shown with the initial stability parameters analysis. To conclude, based on the research work undertaken thus far, what the researchers should expect as future work are suggested.*

Index Terms: *Buoy Technology; Tsunami Buoy; Wave Buoy; Weather Buoy Type; Profiling Buoy.*

I. INTRODUCTION

Buoys are commonly known as navigational aids floating bodies with shells of different shapes and sizes. Indicating a position in the sea is used to indicate dangerous area such as a shallow, rocky or sunken area or to indicate a transit route that must be followed [1]. Besides, buoy also used to specify the existence of obstacle for example reef and shallow sea [2]. The use of buoy for aids to shipping navigation has started since 1977s when Association of Lighthouse Authorities (IALA) endorsed 2 maritime buoyage systems cover 2 regions. (Region A; the rest of the world and Europe, Region B; America, Japan, Philippines, and Korea) [3].

Since then, throughout the world, great effort has been put especially on research and development activities focusing on the buoy technology use for research purposes to help researchers to collect and monitor oceanographic and meteorological data in the ocean and coastal area.

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There are five basic types of shape (Fig 1) in designing a buoy which popular shape that always been used for an existing design for buoy and beacons. Can type which is the

Cylindrical shaped, of buoy usually been used as a marker point for fishing and supply for some vessel. The nun buoy, also known as a conical shaped buoy, mostly use for the lateral mark. The spherical or globe-shaped buoy has literally been used as a mooring point for some small boat. The spar buoy has mostly been used as a tracking device which has its own antenna to transmit data to its own headquarters. Lastly, the pillar shape buoy that most popular buoy shape that has many types of function, some of them is mooring point, GPS device, lateral marking, and many more

The buoy also comes with the notation of different colors. The colors used for lateral marks in Region A are red, green, green with one red horizontal band and red with one green horizontal band. The colors used for lateral marks in Region B are green, red, red with one green horizontal band, and green with one red horizontal band.

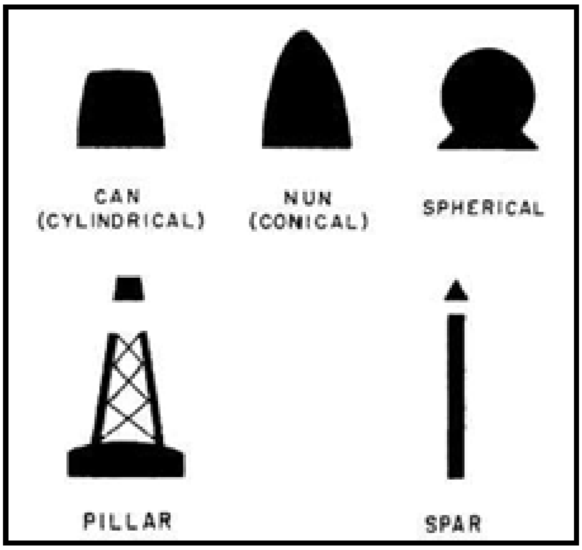


Fig. 1 Buoy basic shape [4]

The innovation using the current basic shape is following the aids in identification criteria for certain function. Identifying the buoy is based on the marking on the buoy, shape, color of the navigation aid, top mark, and lastly a special feature as example sound signal, whistle, horn, camera or many more. All these buoys actually can use the same identifying mark, but the design of the buoy play a big role that can load the base of the special feature on the floating and stability advantages that have on the shape of the buoy.

The use of green energy resource also takes advantage in the development of buoy technology. The solar power system to charge batteries can reduce the number of batteries replacement and cost.

In order to choose the battery to supply power to the buoy, there are some characteristics that need to take into consideration which is safety, cost, environmental effect, maintenance, energy capacity and working time.

It is a great decision to choose solar power system (photovoltaic power generation system) due to plentiful solar energy which can be collected easily [5]. The design of the solar power system is required to fulfill the demand of the load under the safety conditions and improving reliability.

Wireless Fidelity (Wi-Fi), Global System for Mobile Communications (GSM), Radio Frequency (RF) and Satellite are the types of communication lines used in communication unit of buoy that functioning to share the data of meteorological, acoustical data, oceanographic and Global System for Mobile Communications (GPS) data with all platform.

Through a review of academic journal pertaining to buoy technology, two areas of active research and development (R&D) can be identified:

1) The buoy stability assessment. Buoy stability assessment can be done by simulation and experimental study. The shape and weight of the buoy are the most important criteria for this assessment.

2) The buoy strength assessment. Using finite element analysis (FEA) the buoy body strength can be tested in static and dynamic conditions. Buoy material properties need to be decided to run this assessment.

To address all these areas is beyond the scope of this article. This article highlights on the buoy for specific function focus on research purpose only. The objective of this article is to provide a review paper of the researches done in this area. In this article, we discuss the buoy working principles of different types of buoy technology for research purposes. Then, we review buoy applications done by Malaysian researchers. The proposed concept design of buoy will be shown with the initial stability parameters analysis. Finally, what the researchers should expect as future work are suggested.

II. TYPES OF BUOYS FOR RESEARCH PURPOSES

Buoy for research purposes can be categorized into four main types [6]. They are:

- Tsunami buoy type,
- Wave buoy type,
- Weather buoy type and
- Profiling buoy type.

A tsunami buoy is a specialized buoy is deployed offshore to observe, record and measure ocean water pressure. The data will send to the control station will help the authorities to report an early tsunami detection and may issue a warning.

As shown in Fig. 2, the Tsunami buoy comprises the surface buoy and pressure sensor. The pressure sensor is anchored on the seafloor. It contains the pressure sensor, battery, processing unit, an acoustic transmitter, and modem. Then, the pressure sensor transmits the data from the seafloor to the surface buoy. The information will send via satellite to the control station.

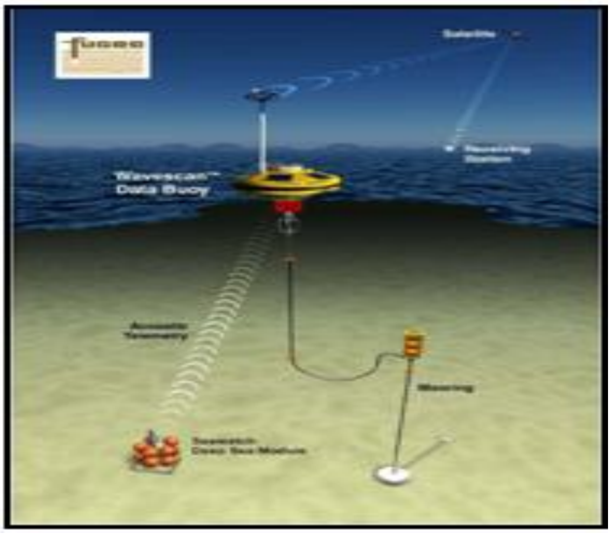
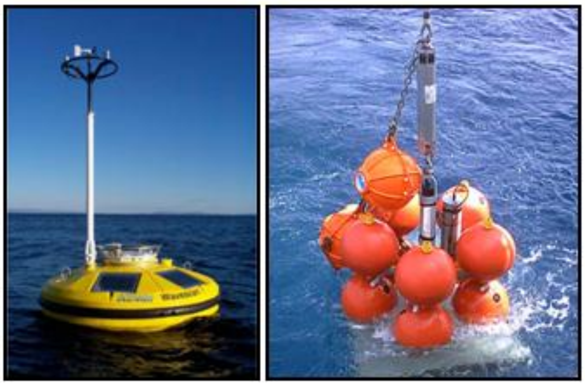


Fig. 2 Working Principles of Wavescan buoy

One of the Tsunami buoy type name as Wavescan designed by the company Furgo [7]. The hull is made from polyurethane foam-filled fiber-reinforced plastic. An anchor and deadweight are used to mooring the buoy to the seabed. The central cylinder part in the buoy is used to mount the energy storage batteries and data acquisition system (DAS) that are linked with pressure sensor call Sea watch Deep See Module (SDSM) As shown in Fig. 3, the actual surface buoy body and pressure sensor of Wavescan buoy.

The buoy diameter is 2.8m and weight is 300kg. The main systems of this buoy are to continuously measure the ocean water pressure. Its pressure sensors have a pulse output where can measure sea pressure every 15 seconds. It is used to collect long time series data sets that are used to predict the weather, cyclone detecting, and climate modeling [8].



(a) (b)

Fig. 3 (a) Wavescan buoy and (b) SDSM

An ocean motions pattern is the most valuable data needed to see the influence of the wave height. One of the techniques used to observe wave is using the wave buoy. The wave buoy types itself a primary converter of the wave profile. It comprises the buoy body integrated with accelerometer, sensor, and compass.

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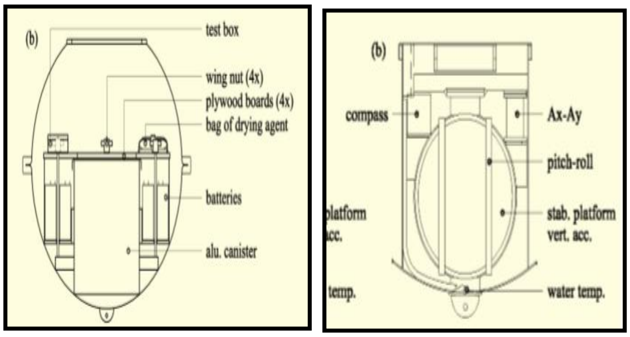
As shown in Fig. 4, the wave buoy that mostly recognized in the world.
Both buoys use the same buoy shape which is spherical and stainless steel as a material for the body.

(a) (b)

Fig. 4 (a) Waverider Mk III buoy and (b) TRIAXYS buoy

The diameter and weight of Waverider from RS Aqua Ltd come with two types which are 0.7m (105kg) and 0.9m (225kg). The wave buoy working as an accelerometer that place inside aluminum canister (Fig. 5) and the sensors can measure the heave, pitch, and roll of the ocean waves. The buoy also equips with a bank of dry cell batteries that convert the data reading from an accelerometer into a radio signal sent back to the received station. The compass to determine directional wave data [9].



(a) (b)

Fig. 5 Mk III buoy (a) internal components and (b) inside an aluminum canister

TRIAXYS buoy from AXYS Technologies Inc is 1.1m in diameter with 230kg weight. This buoy has three accelerometers to measure acceleration X, Y and Z-axis; the rate sensors to measure ocean swell in roll, pitch and yaw axis and compass to measure sensor heading. Other main components for TRIAXYS buoy are shown in Fig 6.

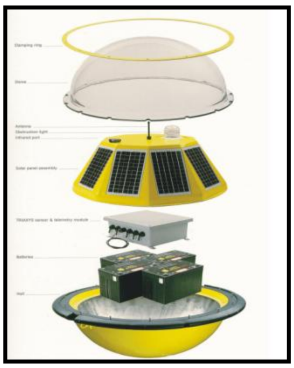
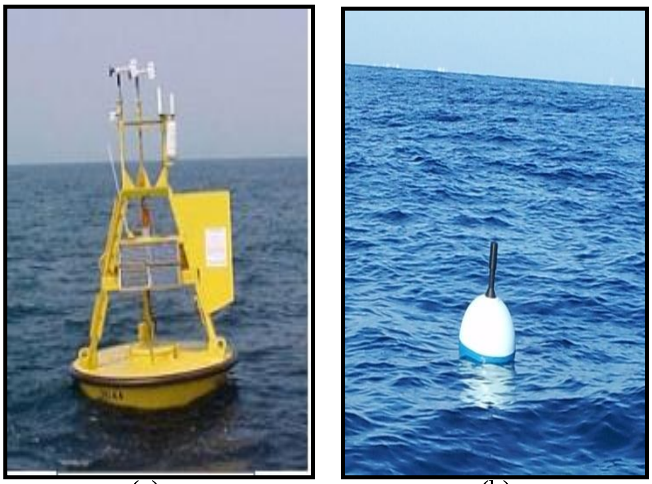


Fig. 6 Components of TRIAXYS buoy

The weather buoy is generally referred to as the marine environmental buoy or Coastal Weather Buoy (CWB). This buoy act as weather stations which can measure water, air, and barometric temperature, wave height and period, wind speed and direction. The development of marine environmental buoy has been started by the National Oceanic and Atmospheric Administration (NOAA) National Data Buoy Center (NDBC). There are two common weather buoy types which are called mooring or drift buoy as shown in Fig. 7.

Mooring buoy basically used a discus shape body with a 3-12m diameter. The designs vary based on the operational need at each station location. The buoy body typically constructed with aluminum or ionomer foam. The buoy working principles are by obtaining and encode the data from all the sensors and transmits to the shore communication center using High Frequency (HF) radio. Drifting buoy use spherical design ranges 0.3-0.4m in diameter. This buoy is attached with the tether and sea anchored called drogue. Total weight of drift buoy and drogue are roughly 23kg. The buoy is made from ABS plastic. It has equipped with the thermistor to measure sea surface temperature, salinity sensor, anemometer, and a wind vane to measure wind speed and wind direction and barometer to measure sea-level barometric pressure. A typical weather buoy is equipped with various oceanographic and meteorological sensors such as anemometers, air temperature sensor, water temperature sensor, barometer, salinity sensor, and humidity sensor [10].



(a) (b)

Fig. 7 (a) NOAA mooring buoy and (b) NOAA drifter buoy

The profiling buoy generally functions to monitor the water quality of the coastal waters, lakes and fish farms. It also can collect and measure of oceanographic and meteorological parameters. This buoy can do profiling to the depth of water range 75-150m. As shown in Fig. 8, the buoy contains a control unit, an embedded web server, a GSM/GPRS/EDGE or satellite router, a winch inside the buoy, a short-range radio for communication with a sensor unit, solar panels, and battery pack.

The collected data is transmitted to the control unit, and the users can get real-time data on a webpage accessible on the internet [11].

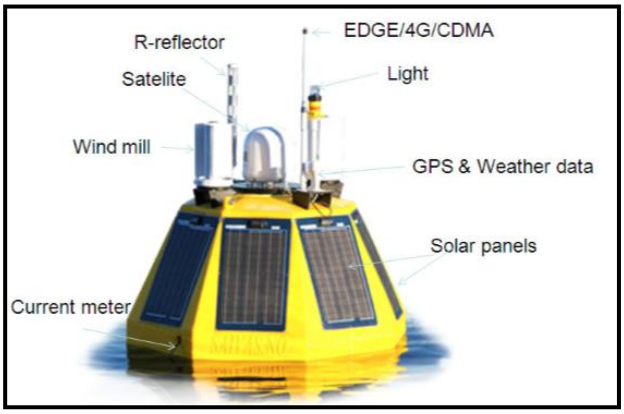


Fig. 8 APB5 profiling buoy

III. REVIEW ON BUOY APPLICATIONS IN MALAYSIA

In this part, an overview of the buoy applications that have been undertaken by other research communities in Malaysia will be briefly discussed by the authors based on the review from the type of buoys technology for research purposes.

GPS Buoy

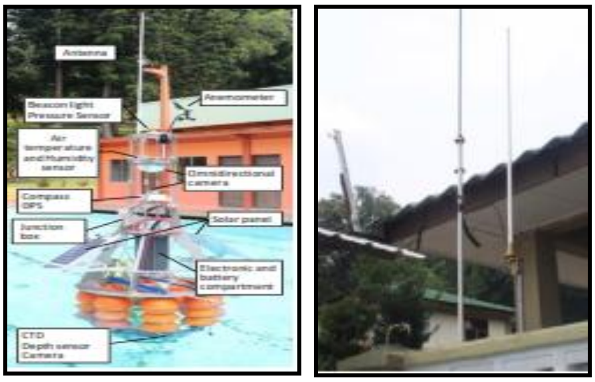
Wave buoy is fabricated to a different type of applications. For example, Global Positioning Buoy (GPS) buoy is one of the buoys equips with many components and sensors. Fig. 9 shows the GPS buoy made by metal with its control station. The buoy GPS antenna is mounted on the buoy body to measure the surface of the ocean. It can record the different wave motions patterns. The field study has been carried out and GPS receiver can collect high precision data even buoy is moving by the ocean wave or current [12].

(a) (b)

Fig. 9 (a) GPS buoy and (b) control station

MIOOS Buoy

Intelligent buoy by Malaysian researches is a buoy integrated the audio and surveillance system on Malaysian Integrated Ocean Observation System (MIOOS) buoy. It can transfer data wirelessly to the ground station. All the data a safely safe in cloud system. The buoy also integrates with multiple sensors for collecting oceanography and meteorology data. For collecting image data, two cameras are attached to this buoy. Fig. 10 shows the MIOOS buoy made by marine-grade aluminum and ground station [13].



(a) (b)

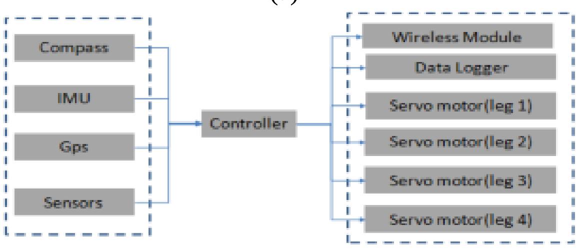
Fig. 10 (a) MIOOS buoy and (b) ground station

Drifting Buoy

The buoy is developed based on water strider that can be operated on the water surface. This buoy uses a waterproof plastic container as the main body, the legs by aluminum, polystyrene foam and high-density polyethylene attached at buoy legs for easy buoy to float. The drifting buoy design provides a cost-effective solution compared to the two buoys as a review before. Even have 2 kg of weight and the dimension of 39.5cm length and 27 cm breadth but the drifter buoy (Fig. 11) can be described as below [14]:

- Can steer freely and on the water subsurface.
- Equip with sensors, GPS, controller, wireless equipment, data logger and four servo motors at legs.
- The wireless module connected to the communication systems between the drifter and ground station.

(a)



(b)

Fig. 11 (a) Drifting buoy and (b) system overview

Heave Buoy

This type focusing on heave buoy (Fig. 12) wave energy converter (WEC). Using shape cylinder, this buoy is functioned to generate energy from the ocean wave. This wave energy can produce electric resources to the buoy. The analysis has been done and the results show the heave buoy give a good heave result with regards to the wave force. The researcher shows the viability of wave energy converter can be integrated on the buoy as a secondary source after battery [15, 16].

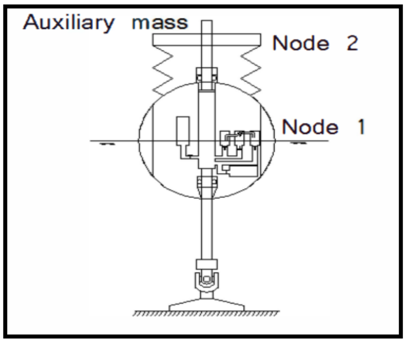


Fig. 12 Heave buoy with auxiliary mass

IV. BUOY CONCEPT DESIGN

Based on the buoy technologies that have been discussed, the initiative to further research on buoy is needed. As we can see, the buoy design such as Wave scan form Furgo has large diameter compared to other buoy design. Thus, the new concept buoy design is proposed by researcher with acceptable diameter to deployed at the Malaysian coastal area as shown in Fig.13.

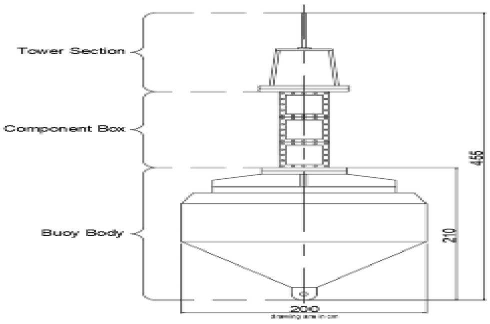


Fig. 13 New Buoy Concept Design

The design shape that will be used is a diamond shape. The V-shaped bottom will make it more stable same as the ship hull design. The improvement in stability has been done by focusing on the metacentric point, center of gravity, center of buoyancy and the heeling or trimming. Because of the design shape is more likely like a cone, it makes the design have zero heeling and trimming and easier the calculating method because it does not need to consider the trimming or heeling. The performance of the design absolutely perfect because the design itself does not glide on the water.

V. RESULT AND ANALYSIS

Maxsurf Bentley software is used for initial stability analysis. Before that, there are step needs to be done in Maxsurf Modeler (Fig.14) before it can be transferred to the Maxsurf Stability, the steps are, need to determine the frame of reference of the model. It includes the drawing waterlines, the reference point and the zero point (Fig. 15).

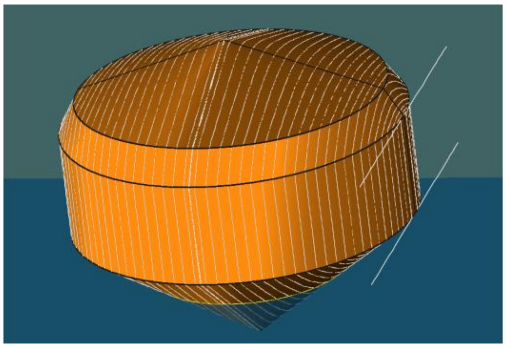


Fig. 14 Buoy model by Maxsurf Modeller

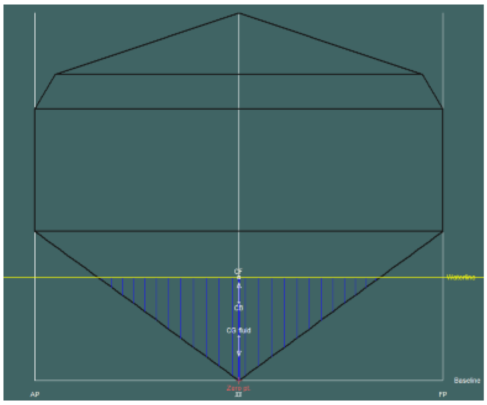


Fig. 15 The draft of the buoy model

From this analysis, the draft captured is 0.425m (yellow line) from the buoy keel. The freeboard allowance is still high thus allow researchers to put more loads inside buoy body such as a system that can be used for research purposes. The mooring weight also can be added if buoy still not fully submerged. Then, the buoy model is run in a specific water condition to determine the condition of the design versus the water roughness condition. The maximum wave height for Malaysia coastal is 6m, the analysis has been run and the graphic result is shown in Fig. 16.

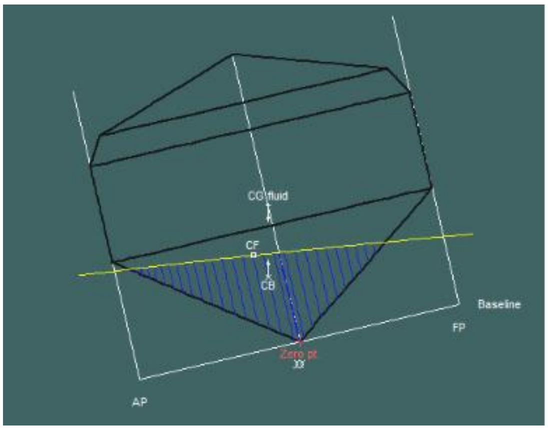


Fig. 16 The buoy model tested at 6m wave height

The stability result of the design model design can be divided into some categories which are the height of metacentric point, which defines the height of a point where being a center toward the heeling angle. Moreover, the estimated weight of the design and the material used is also been identified using fiberglass as the base materials.

From the analysis, the weight is estimated as 256.5kg which is the buoyed weight in lightweight conditions without interior loads and mooring. The metacentric, GM height value captured is 0.643m from the center of gravity, KG. The heeling activity will never challenge the small metacentric height rather than high metacentric height. High metacentric height may get a stiff position, but the heeling angle will automatically be greater than a small metacentric height. Finally, the other initial stability parameters calculated based on Maxsurf Bentley as shown in Table I.

Table. 1 Buoy model stability parameters

Stability Parameters	Buoy Model
Centre of Gravity, KG	0.365m
Centre of Buoyancy, KB	0.378m
Distance from KB to Metacenter, BM	0.63m
Maximum Heeling Angle, θ	60°

VI. CONCLUSION

The objective of this study is to review on research and development of floating buoy technology for research purposes. At present, the buoy for research in Malaysia is focused on ocean wave observation system and analyzing oceanographic and meteorological data. The researcher has proposed a new buoy concept design to fit the above purposes. The future study can be focused on these two important aspects. First is strength analysis of buoy. The advantage of 3D design to simulate before developing the prototype can reduce construction time. The Finite Element Analysis (FEA) and Computational Fluid Dynamic (CFD) can simulate the buoy model to make sure final prototype can be successful develop. Next, the components system (sensors, communication network, data logger and camera) integrated to the buoy need to be identified at an early stage of buoy development for specific functions will reduce the costs. The step-by-step development will help in finalizing the functions of the buoy for research purposes. In the end, the initial stability parameters data provided by researchers can be used as a benchmark for further research.

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