SALT WATER IMMERSED PROPULSION ENGINE [SWIPE]

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Abstract: Global water resources available in the hydrosphere are distributed in many forms. About 99% of the total water available is bound in the form of ice (in the Polar Regions) or is salt water. Harnessing seawater to generate electricity is not a new concept. Research and developments have given us many methods for the same. However engines which run on sea or salt water are few, costly and extremely bulky. By the application of proper technology, salt water can be utilized as a fuel, to run engines using cheap and compact designs. Vehicles using the Sea Water Immersed Propulsion Engine (SWIPE) can enjoy numerous advantages, which have been discussed and might pave way for a feasible future underwater travel alternative. This study mainly focuses on the theoretical framework and design of an undersea engine, which runs on salty sea water, using it as a fuel. The properties of sea water are utilized to an advantage and its abundance makes it ideal for prolonged use underwater. Several functioning units, associated with the engine, have also been proposed. These units along with the engine itself, has been explained in theoretical detail.

Keywords: Engine, Immersed, Propulsion, Salt Water Engine, Sea Water Engine, Seawater Electrolysis, Swipe.

I. INTRODUCTION

This study is mainly focused on the theoretical design of an undersea engine which can be primarily used for under water search, rescue and retrieval or for exploration and enhancement of human knowledge. In recent times, submarines and other small exploration devices fulfill this role. However, they are usually driven by a fuel (diesel or nuclear). Diesel submarines are cheaper but require air to run its engines, and hence need to surface after a time span. Nuclear submarines solve that problem but are very hazardous and costly. Pollution has also been a major setback towards any development in this field [1].

Attempts to make a clean engine (working on the concept of electrolysis) have been made. One such concept has been introduced by the *US Navy* [2]. However, such engines proved to be bulky, costlier and difficult to maintain. It also had limited range and capabilities. There is a requirement of cleaner, smaller and faster underwater vehicles with new concepts of engines, which run independently under sea or ocean, without the need of any external factors like air, fossil or nuclear fuels (as in submarines). SWIPE does not require air or any conventional fuel, to run its engines. It utilizes the seawater to run and has no harmful emissions which can cause pollution. This engine will power smaller, faster and lighter, under water vehicles and hence, require lesser power too.

II. THEORY

About 70% of the earth's surface is covered with water. Ninety-seven percent of the water on the earth is salt water. Sea water is filled with salt and other minerals. Salinity of the ocean is very *Uniform*-it ranges between 34.7 and 34.9 parts per thousand. At the surface, however, salinity can vary from about 33 to 37 parts per thousand and averages about 35 parts per thousand. Low salinity (around 33 parts per thousand) is characteristic of the tropical ocean. Temperate areas typically have high evaporation rates and thus higher salinity levels in the surface ocean. The depth where salinity is transitional is called the *halocline* [3] and defined as a layer of the ocean where salinity is changing rapidly with depth. From fig 1, it is clear that the surface salinity is lower than the deep water salinity. The knowledge of salinity together with the differences in density and temperature, with depth [3] are keys to realizing the effectiveness of the SWIPE.

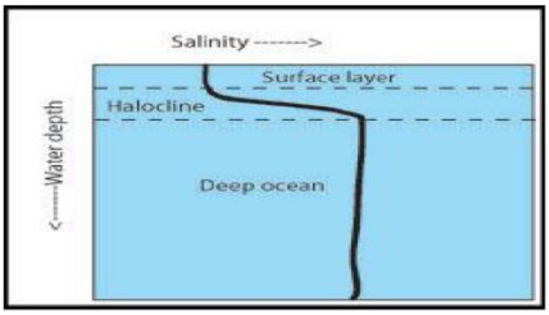


Fig 1: The Halocline Determines The Salinity Of The Ocean With Depth. It Changes Rapidly With Depth [3].

Sea water is a mixture of 96.5% pure water and 3.5% other materials, like salts, dissolved gases, organic substances, and undissolved particles. The dissolved ions conduct the electricity. Thus it is important to know the type of ions and measure of each of the dissolved substances in sea water. The conductivity of sea water depends on the number of dissolved ions per volume (i.e. salinity) and the mobility of the ions (i.e. temperature and pressure). Conductivity increases by the same amount, with a salinity increase of 0.01, a temperature increase of 0.01°C, and a depth (i.e. pressure) increase of 20 m. The main salt ions making up 99.9% are given in Table 1.

Table 1: The chemical ions in sea water [4]

Chemical ion	Valency	Concentration ppm, mg/kg	Part of salinity %	Molecular weight	Mmol / kg
Chloride Cl	-1	19345	55.03	35.453	546
Sodium Na	+1	10752	30.59	22.990	468
Sulfate SO_4	-2	2701	7.68	96.062	28.1
Magnesium Mg	+2	1295	3.68	24.305	53.3
Calcium Ca	+2	416	1.18	40.078	10.4
Potassium K	+1	390	1.11	39.098	9.97
Bicarbonate HCO_3	-1	145	0.41	61.016	2.34
Bromide Br	-1	66	0.19	79.904	0.83
Borate BO_3	-3	27	0.08	58.808	0.46
Strontium Sr	+2	13	0.04	87.620	0.091
Fluoride F	-1	1	0.003	18.998	0.068

Table 2 shows the electrical conductivity of seawater (among others). At a depth of 4000m, the bottom water (0°C, salinity 35g/kg) has conductivity 6% greater than the surface water. The mean conductivity of the oceans is around 3.27 S/m to 5 S/m. This makes the range of depth fairly good for the SWIPE to function, since it primarily functions on the effectiveness to convert seawater to electricity.

Table 2: Electrical conductivity of sea water at atmospheric pressure [5]

	Salinity (g/l)	Temperature (°C)	Ambient Pressure (Pa)	Density (kg/m^3)	Conductivity (S/m)	Gap Resistance (mΩ)
Unsalted Water	N/A	20	1.01×10^5	998.21	N/A	210
Salted Water	100	20	1.01×10^5	1074.05	14.29	950
Sea Water (Average)	35	20	1.01×10^5	1024.75	4.79	2835
Deep Sea (500 m)	35	10	5×10^6	1029.32	3.81	3564
Deep Sea (1000 m)	35	5	1×10^7	1032.38	3.35	4056

III. THEORETICAL ANALYSIS

The proposed engine design of SWIPE is compact and incorporates the design of an underwater diesel submarine but is smaller. The engine uses ions present in the sea water to generate electricity in two ways – through its skin layer and electrolysis. A new concept of battery design and efficient generation techniques ensure that an adequate supply of electricity is present. The major parts of the SWIPE are the Battery, Special Electrolysis Chamber, Control Unit, Electric Motors and the Propeller System. Associated units which lie outside the engine but are interlinked to it are the External Graphene Layer, Separate Storage Tanks, Regulator, Fuel Cell Unit, Breathing System and Lighting and other utilities unit.

By providing energy from a battery, water (H_2O) can be dissociated into the diatomic molecules of hydrogen (H_2) and oxygen (O_2). However, the seas and oceans predominantly contain salt water including other ions. The electrolysis of brine (saltwater), industrially done by the *Chloralkali Process* [6], is only half the electrolysis of water since the chloride ions are oxidized to chlorine rather than water being oxidized to oxygen. The presence of deposited manganese-molybdenum oxide anodes, with high selectivity, is used for evolving oxygen in the electrolysis of seawater [7]. The oxygen evolved, finds its use in helping human beings to breathe in an environment underwater. Further, hydrogen and oxygen is recombined to generate back electricity through fuel cells [8]. The H_2-O_2 fuel cells are developing with time and becoming more efficient. The use of fuel cells not only ensures added generation of electricity but also causes no pollution. Newer technologies like generating electricity from sea water with the help of graphene have also been incorporated [9].

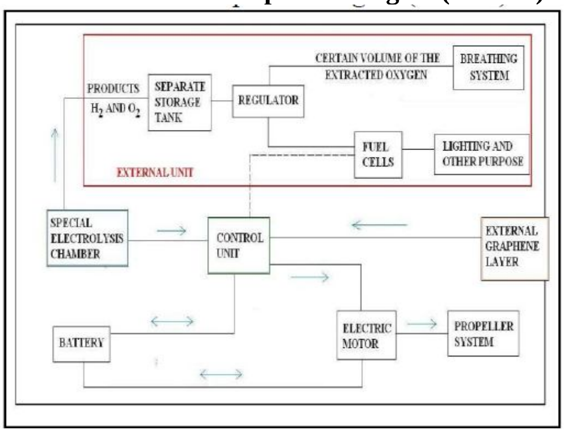
3.1. Design

The main process flow diagram of SWIPE is shown in Fig 2. It consists of the following parts.

- Special Electrolysis Chamber (SEC)
- Battery
- Control Unit (CU)
- Electric Motors (EM)
- Propeller System
- External Graphene Layer
- External Unit

The Separate Storage Tanks, Regulator, Fuel Cell Unit and other systems are not a part of the main engine but must be a part of it. Hence it is labeled as the External Unit (Fig 2).

Fig 2: The main process flow diagram of Salt Water Immersed Propulsion Engine (SWIPE)

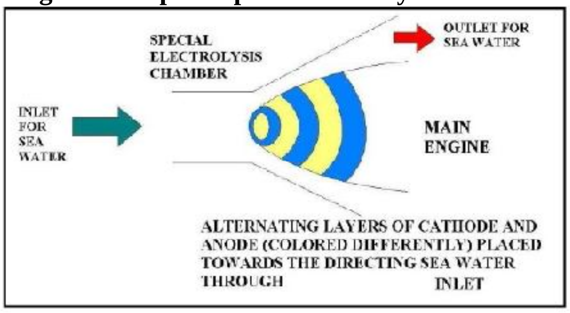


The SWIPE must be rigid, compact and lightweight. Aluminium and fiber glass composite are the choice materials for its construction. The design of SWIPE is that it includes all the units from power generation to propulsion. Thus a single such SWIPE can be attached to any exploration vehicle, where it can function independently. This is a huge benefit which other engines cannot provide. The theoretical design and function of each part of SWIPE is explained in detail.

3.1.1 Special Electrolysis Chamber (SEC)

This device is located at the front part of the engine and is in direct contact with the seawater. It consists of an electrolysis chamber, as shown in Fig 3, with MnO_2-type manganese–molybdenum oxide electrodes. These electrodes have extremely high oxygen evolution efficiency in chloride-containing solutions. They are prepared by anodic deposition on IrO_2-coated titanium substrates [10]. It utilizes the fact that the equilibrium potential of oxygen evolution is lower than that of chlorine evolution. This seawater electrolysis technique evolves oxygen required for breathing inside the vessel, eliminating the need to surface or provide an external supply of oxygen. Surface activation of the MnO_2 electrodes is required for oxygen generation from electrolysis of seawater [11].

Fig 3: Concept of Special Electrolysis Chamber



The electricity generated from the SEC is sent to the Control Unit, from where it is either directed to the battery unit for storage or directly to the electric motor for propulsion. A continuous supply of sea water through the chamber (inlet and outlet) ensures continuous electrolysis and supply of electric charge or current.

3.1.2 Battery

The battery chamber consists of a number of strategically placed units of battery on the main engine. Although, the vehicle attached to the engine must contain an array of batteries for power, the main engine must have ample units of battery attached. It must be ‘strategically placed’ to avoid consumption of extra space or make the engine bulky. The batteries will be connected to the CU on one side providing it current for storage. On the other side, it will be directly connected to the motor which propels the engine (Fig 2). The CU will regulate the amount of current it requires. These batteries will also provide backup power to all units, which will be again regulated via the CU. The double headed arrow between the battery and EM (Fig 2) means that current can be supplied from the battery during use as well as returned to the battery for storage, when not required.

3.1.3 Control Unit (CU)

This is the brain of the SWIPE. It is connected to all the units of the engine, directly or otherwise (Fig 2). It controls all the features and also provides information to the user directly. It has two main sources for current – the SEC and the External Graphene Layer. The current is regulated between the Electric Motor for propulsion and the Battery for storage. Another source for current for the CU is the Hydrogen fuel cells [12], located in the External Unit. The Main Engine comprises of the CU, the EM and the Propeller System. In Fig 2, the double headed arrows indicate that current can be provided and also extracted from the battery unit when required. The main function of the CU is to regulate current and control all the engine features. It must contain specific current sensors in all connected units. The CU is an intelligent unit which assists the engine to use power when required e.g. movement at a certain depth. It must have pressure sensors, temperature sensors, SONAR (both horizontal and vertically placed), flow measurement devices, current sensors and armed with features present in modern submarines [13]. It must be compact and lightweight. Since it controls the whole engine, it might get heated up. Flowing seawater over the CU, connected to the engine can be a simple solution. Sea water serves as the natural engine coolant.

3.1.4 Electric Motors (EM)

The motor under discussion is a DC Motor [14]. These are fundamentally generators and motors coupled into one unit and works in the same fashion [15]. It is being called motors here to understand that it is something which powers the propeller and causes motion. It is connected to the CU, which supplies it current for its working. It is also connected to the Battery unit to provide it continuous current to run. Its function is to drive the propeller system and also act as a generator.

3.1.5 Propeller System

This is the main system which propels the engine (Fig 2). It is situated at the very end of the engine and is fundamentally a large fan that transmits power by converting rotational motion into thrust [16]. One SWIPE contains one propeller attached. So, to increase the propeller for an undersea vehicle would mean to add more SWIPEs. The design of propeller can vary according to requirement of the engine.

3.1.6 External Graphene Layer

The External Graphene Layer is a thin layer of graphene over the surfaces of the engine exposed to sea water. This external layer of graphene might also be added to a vehicle to which SWIPE is attached thus making it 'external'. It essentially generates electricity from sea water [17]. It has been added to the SWIPE because the seawater flowing through the engine, from inlet to outlet (Fig 3) can be used to generate electricity, however small, for powering certain displays or sensors on the SWIPE. It is directly connected to the CU and may power it.

3.1.7 External Unit

The External Unit (Fig 2) consists of all the units which are not present in the interior of SWIPE but without which the SWIPE cannot function. It contains Separate Storage Tanks to store the generated Oxygen and Hydrogen separately. The O_2 is used for breathing purposes and in fuel cells and the H_2 is the main constituent for hydrogen fuel cells. The O_2 is sent to the Breathing System and the H_2 in the fuel cell unit, in regulated amounts via the Regulator. The function of the regulator is to control the amount of gas sent from the Storage tanks to the Breathing System and the Fuel Cells. The Fuel Cells are typically hydrogen fuel cells and function in the typical manner [12]. These cells are connected to the Lighting and external circuit system and powers it. It is also connected to the CU to provide any excess amount of current from the cells.

The External Graphene Layer encompasses the external unit and the internal surfaces of the engine in contact with seawater. This may also be present in the vehicle attached to the SWIPE making it an internal as well as external feature.

CONCLUSION

Deep ocean water contains more salt than at lower depth. Abundance of salt water is extremely important to run SWIPE. The SWIPE can thus, theoretically, function at any depth. The engine uses salt water to generate electricity and drive a motor for propulsion, but does not emit any harmful by-products or damage its ecosystem in any way. SWIPE uses the ions, already present in the ocean salt water, to generate electricity run a propeller system at the rear end of the engine. The gases emitted after the chemical reaction in the batteries are beneficial for the sustenance of human life inside the vehicle, to which the engine will be fitted, or charge the fuel cells.

There are many benefits of the SWIPE: -

- It is a completely independent engine, compact, lightweight and clean
- It uses seawater as a fuel making it free from other forms of energy for power
- It does not cause any pollution and is ideal for deep sea or ocean use
- SWIPE can be designed in many ways, according to requirements.
- Prolonged underwater use, without the need to surface, is its key feature
- Serves as a smaller, cheaper, faster and feasible alternate to undersea exploration and rescue operations

Although this is the theoretical concept, the SWIPE is a feasible model. The amount of current generated must be sufficient to run the engine completely and is subject to future research. The design, specific working conditions keeping in mind the physical properties of sea water [18] and cost of manufacturing of the SWIPE are all aspects where future research can be carried out.

Submarines are usually diesel or nuclear. Diesel submarines are cheaper but require air to run its engines. Nuclear submarines are very costly. These are the only present underwater transportations available, including other man-made exploration devices. The SWIPE opens up the possibilities of carrying out undersea and ocean exploration ventures or search, rescue and retrieval operations and is certainly a much better option than traditional vehicular engines, which are hindering quick action in times of distress. In the light of the recent need for quick, cheap and smarter action, the SWIPE can be the future alternative.

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