Autonomous Robotic Vehicle for Oil Spills cleaning with Nano Particles

Mohanish Shah (1st *Author*)
School of Mechatronics
Symbiosis Skills and Open University
Pune, India.
Mohanish.shah@ssou.ac.in

Sakshi kokil Shah (2nd *Author*)
Department of Mechanical Engineering
TSSM's Bhivarabai Sawant College of Engg. & Research, Pune, India.
kokilsakshi@gmail.com

Mitesh Shah (3rd *Author*)
Assistant System Engineer
Tata Consultancy Services
Pune, India
mitesh2804@gmail.com

***Abstract*—In an era of increasing environmental concern, oil pollution arising either from marine accidents or from routine ship operations (tanker loading and unloading, etc.) is a major threat for the marine environment. The average quantity of ship-generated oil that ends up in the sea exceeds 350,000 tonnes per year .When an oil spill occurs, either in open or confined sea, the ecological damage on the local ecosystem could be huge and irreversible.**

In view of the above, there is a pressing need for continuous refinement of the existing means and the development and implementation of new technologies with help of Robotics for oil spill combating. To minimize the adverse environmental effects of an oil spill, research should focus to devise technologies that are able to confront the oil, aiming at its actual removal when this is still floating at sea.

This paper describe robotic unit of high-power autonomy that adsorb oil over water surface with the help of Nano-particle and are able to recover oil from Nano-material when placed in magnetic field. A prototype model of robot with constraint design of floating and assembly of different parts inside it has been made with the help of 3D printing for above investigation. The robots suck oily water separating clear water to the outside and creating a stream of oil in the center. Oil collected during the process is stored in box, which can later be removed by crew members to recycle in magnetic field. Towards these directions, in this paper we present a novel concept for effective oil spill confrontation which is based on autonomous robotic systems using nanotechnology-based techniques.

Keywords—Autonomous Robot, Nano-particle, oil spill, water cleaning, oil recovery.

I. INTRODUCTION

During oil extraction and processing (especially in accidental situations), barely separated oil and water mixtures appears, representing serious problems for the environment. In the sea, oil can be present in different migration forms, such as surface films (slicks), water-in-oil and oil-in-water emulsions, oil aggregates and lumps, in dissolved forms. In case of oil spills in the ocean, disorder to marine ecology (sea birds, mammals, algae, coral, sea grass etc.) can be caused, beside the health hazards to the human population located in nearby coastal zones. Moreover, the economic loss suffered by oil companies resulting from oil-spillage is enormous.

Nanotechnology-based methods for removal of oil in petroleum spills and its separation from water are discussed in this review with the help of robot. In addition to classic methods of oil removal, the "Nano"- techniques are being currently developed like carbon nano-tubes, sponges, aerogels and nano-composites, metal and non-metal nano-structured oxides, nitrides, salts, and zeolites. Some of these nano-materials can be prepared by "greener" methods at lower costs and without damage to the environment.

Surface cleaning robots on lake, pond, or reservoirs which are motion controlled and has autonomous driving can be technological solution for above problem. Motion of the robot can be represented by hydrodynamic model and maneuver ability performance. Simplicity of fabrication of Robot, cost reduction for making Nano-particles, and commercial availability of applied Nano-materials are main objectives of current investigations.

This work presents a method for identifying and locating oil waste floating on sea water surface by using low cost Bio-sensor before the cleaning robot starts navigation. A Bio-sensor in collaboration with GPS unit is utilized as a waste detector heading into water surface and scanning for floating oil spills. As the Robot floats over sea surface, acoustic wave device is used to keep animals away from the polluted source and expels them during the cleaning process.

II. LITERATURE REVIEW

In history there are many more incidents where oil-spill cleaning cost was very high and it was not effective. For instance, the most expensive oil spill in history is the one caused by Exxon Valdez in Alaska in 1989, where clean-up alone cost about USD 2.5 billion and total costs (including fines, penalties and claims settlements) are estimated at USD 9.5 billion . Despite the effort and resources allocated, the clean-up operation had little success and the whole incident led to a major environmental disaster. It is impossible to avoid accidents but preventive measures may reduce the frequency of spills.

Methods available for Oil Removal are:

a. **Bio-Remediation**: It refers to the use of specific microorganisms to metabolize and remove harmful substances

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b. **In situ burning or ISB:** Technique sometimes used by people responding to an oil spill. In situ burning involves the controlled burning of oil that has spilled from a vessel or a facility, at the location of the spill

c. **Oil-Booms**: A containment boom is a temporary floating barrier used to contain an oil spill. Booms are used to reduce the possibility of polluting shorelines and other resources, and to help make recovery easier.

d. **Dispersants**: Dispersants are chemicals that are sprayed on a Oil surface to break down the oil into smaller droplets that more readily mix with the water. Dispersants do not reduce the amount of oil entering the environment, but push the effects of the spill underwater. Small droplets are easier to disperse throughout a water volume, and small droplets may be more readily biodegraded by microbes.

e. **Skimmers**: Skimmers are often used in conjunction with booms. A skimmer is a device that collects and removes oil from the surface of the water. Skimmers can be towed, self-propelled, moored in river currents, or even used from shore.

In recent years, nanotechnology has emerged as a potential source of novel solutions to many of the world's outstanding problems. In the last 5 years, there has been particularly growing interest worldwide in exploring ways of finding suitable solutions to clean up oil spills through use of Nano materials.

In particular, the Nano-porous sorbents, namely thermally exfoliated graphite oxide (TEGO), CF3-functionalized aerogels and carbon nanotube sponges have outstanding oil absorption capacities, among other adsorbents.

The nascent area of the treatment of oil-spills with nano materials possesses a series of successful attempt sand has advantages. However, at the same time, there are certain risks associated with their use. The nano materials may have negative impact on human health when these nano-particles are inhaled, absorbed through skin, or ingested..

III. NANO PARTICLES

In comparison to "oil-removing" types of materials, the "water-removing" Nano-membranes with underwater oleophobicity can avoid fouling or even blocking by oils due to their oleophilic characteristics, and it can rapidly separate water from a variety of oil/water mixtures including hexane, petroleum ether, and crude oil.

Functional nano-materials can play an important role in the production of smart, reliable, and more durable equipment.

Conventional Method: Nano-particles or the Nano-material can be made by many conventional methods but the waste products generated during the manufacturing/synthesis of these nano-particles are toxic to human beings and the environment at large.

Bio-Synthesis: This assists in the reduction of the waste products generated during synthesis of the Nano-particles, wherein no toxic chemicals are used for the synthesis of the nano-particles. But these processes are not energy efficient and economical

In this research paper, we have used combination of above 2 processes for bio-synthesizing the metal Nano-particles, wherein the process is energy efficient and eco-friendly and economical.

A. Identification of the Nano-Particles

We have use biologically synthesized nano-particles which is an important aspect in nano-technology as well as plant biotechnology. Silver Nano-particles were synthesized by using aqueous leaves extract of Leucaena leucocephala Leaves shown in fig.1 from green synthesis method. This leaves are used as bio-reducing and stabilizing agent. The characteristic of synthesized silver nano-particles were studied using UV-Visible spectrophotometer (UV-Vis), Fourier transform infra-red spectroscopy (FT-IR), Energy-dispersive x-ray spectroscopy (EDX), Scanning electron microscopy (SEM) and X-ray diffraction (XRD) analysis shows the average particle size is about 20.18 nm.

Fig. 1 Leaves of Leucaena leucocephala L.

B. Process of Synthesis

- Collection of Materials i.e. Fresh leaves of Leucaena leucocephala L.
- Preparation of Leucaena leucocephala L. Leaves Extract
- Biosynthesis of Silver Nano-particles Using Leucaena leucocephala L. Leaf Extract
- Characterization of the Synthesized Silver Nanoparticles
- Finally nano-particle are produced which are embedded in honey comb structure for operation.

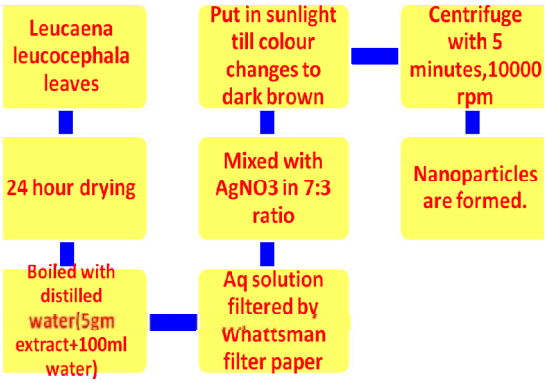

Fig. 2 manufacturing process of natural nano-particles

C. *Nano-Particle cluster*

Practical implementation of nanotechnology for oil spill remediation demands that the nano-materials in the form of nano-particles/ foams/sponges etc. be suitably engineered or packaged to facilitate their application. One example is TEGO, which is a powdery material that has to be contained in large porous sacks made from polypropylene or polyethylene fabric or porous film. Alternatively TEGO can be co-processed with a polymer binder in the form of a foam sheet. The advantage of this system is that the absorbent system can be rolled for storage.

Therefore Nano-particles are embedded in Hexagonal web structure a shown in Fig.3 for maximizing the surface area for oil adsorption. This web structure is used in Robot for quick and easy operation.

Fig. 3 Hexagonal Structure with Nano-particle

D. *Oil and Nano-particles separation*

These nanometer-sized particles are super paramagnetic, they are not magnetic when located in a zero magnetic field, but they quickly become magnetized when an external magnetic field is applied. Super paramagnetism is one of the most important properties of Nano-particles used for bio-magnetic separation. Use of such nano-particles to remove oil droplets from water is 90% efficient and can be reuse again as shown in fig 4.

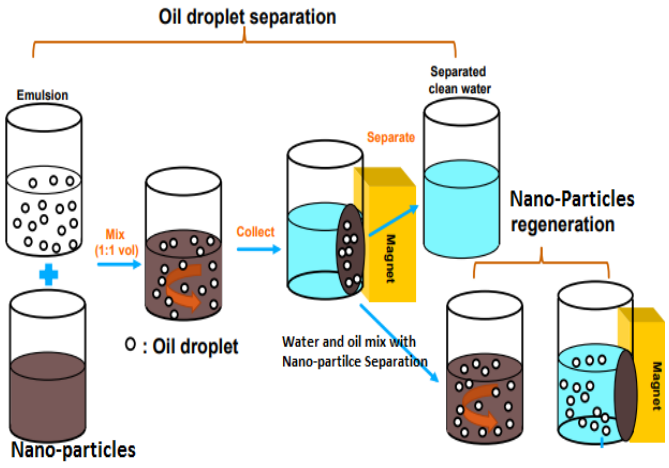

Fig4 Separation of oil & Nano-particles

IV. AUTONOMOUS ROBOT

To gather information on sea surface and to clean oil spill, we rely on underwater robots to do that hard work. Remotely operated vehicles (or ROVs) are connected to a cable that allows a human to control the robot from a ship or boat on the ocean surface or from within the robot. Autonomous underwater vehicles (or AUVs) are programmable, and can operate without being connected to the surface.

Design parameters for building a robot boat are weight Distribution, balance on water surface, hydrodynamics, waterproofing, the actuator, and sensing problems. It needs motors, batteries, sensors, controllers, which all adds to its weight. Therefore design of outer periphery and location of inside accessories is very critical and force due to sea wave has to be balanced. Hence the condition of stable equilibrium for a floating body is positive metacentric height which is achieved by effective design.

The GPS-equipped floating robots demonstrated the next generation of water monitoring technology, promising to transform the way mechanical system used to do it.

A. *Robot Component Designing and Manufacturing*

1. Bottom part

This is manufactured with the help of 3D Printer. Thermoplastics used in 3D printing are high performance, engineering-grade materials which exhibit many of the same properties of injection moulded plastics.

3D printing thermoplastics include polycarbonate (PC), acrylonitrile butadiene styrene (ABS), ,PP copolymer ,acrylonitrile styrene acrylate (ASA) and even ULTEM. These materials are typically manufactured using Fused Deposition Modeling (FDM) 3D printing technologies. FDM is an additive manufacturing process which extrudes molten materials layer by layer to result in a final product.

Fig. 5 Robot Base

It provides the space for the other components to rest inside it and it contains all the assembly elements which helps for the cleaning of the oil spill and/or for functioning of the whole system as shown in Fig 5.

It also provides large surface area for buoyancy and keeps the robot stable in sea environment.

Fig.8 Nano particle structure

2. Top part

The manufacturing process for this part is same as the above part as it is the same body made from the 3D printing process with same mechanical properties.

Fig.6 Robot Top

It also fix the container position and kept it stable on the robot as shown in fig 6. Top part provides the area for solar energy production and/or resting the solar panel on it as shown in fig.7.

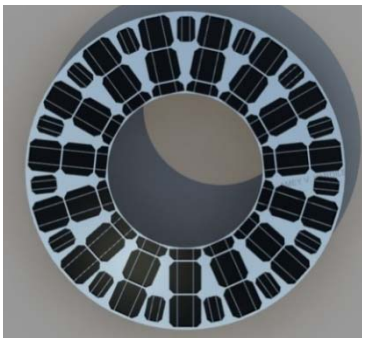

Fig.7 Robot Top

3. Rubber Connector

This rubber is mainly used to fix the robot base and top part firmly & provide flexible support and prevents the striking of wave on the rim part and protect them from wear and tear. The material used for this rubber is Hypalon, Which have high strength, good corrosion resistance, Low wear and tear and can withstand in adverse environmental condition as well as low elongation property.

4. Nano-mesh Assembly

This used to store the oil after the separation from water. This mainly contains the Honey comb structure with support on top and bottom side.

5. Pumping Assembly

- Voltage input = 12 V
- Power = 60 Watt

For transportation of oil & water mixture from pump to the container part piping system is used. This include the 2/1 way connector , Hose , 3/1 way connector.

6. Bio-sensor

For automatic detection of the oil spillage and processing it on sight is done with the help of bio sensor. It is mainly based on the principle of detection of the hydrocarbon in the polluted environment & it is available in the market for special purpose only.

7. Battery

Lithium polymer –LIPO are type of rechargeable battery. LIPO batteries are light weight and hold huge power in a small package. They have high discharge rates to meet the need of the powering robots. Capacity=4500mAH and also salt water batteries are used for quick charging with sea water.

8. Acoustic Wave Device

As the many animals get harmed due to polluted sea by mean of oil spill. So to keep animals away from the polluted source, and expels them during the cleaning process this device is useful. Range of this device is 5-10 m.

9. GPS & LED Device

This is mainly used to track the location of the robot in the sea by mean of GPS signals. And the LED indicates the process of cleaning. The red light indicates the cleaning process is going on & green is indication of process completion.

10. Solar System

To overcome the problem of the power source in the middle of sea we are providing the solar system with advance polycrystalline technology which can produce the maximum energy from the given surface along with the series and parallel combination within the interconnected cell.

Total Solar Current output = 5A - 15A,
Voltage output = 5V- 12V

This is sufficient for the pump and for the working of other electronic components.

11. Assembled Model

All the above parts are assembled together precisely with proper tolerances as shown in fig. 9. The exploded view in CAD environment with detailed parts are shown in fig. 10. Manufacturing will be done with 3D-printer for good surface finish with PP copolymer material.

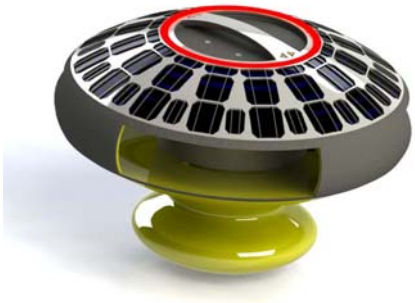

Fig.9 ROBOT Assembly

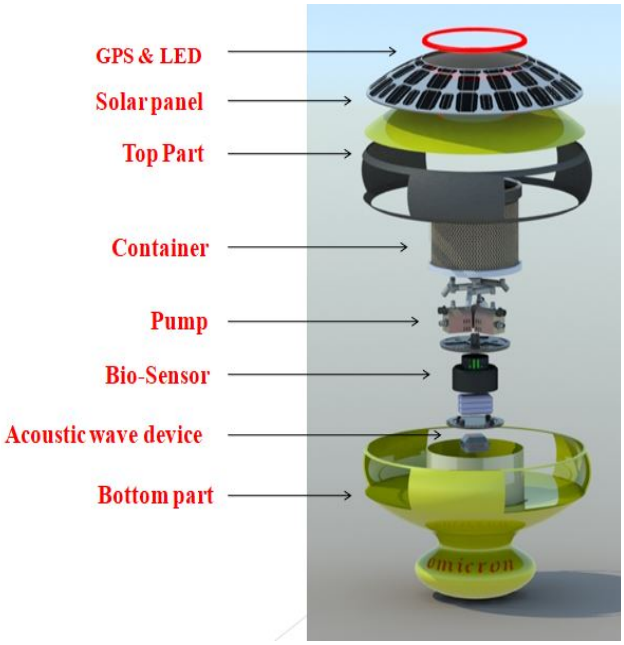

Fig.10 ROBOT Exploded View

V. WORKING OF ROBOT

A. Propelling of Robot

As this is Autonomous System so it has to move by itself. Figure 11 shows Inlet valve, battery, Arduino board, suction pump, Bio-sensor, 3/2 Direction control valve, Reverse flow control valve and pipe hoses.

Operation of Robot floating over water surface with oil spill is very precise and efficient. There is 3 assembly of pumping system at 120^0 to each other for giving direction to robot for propelling.

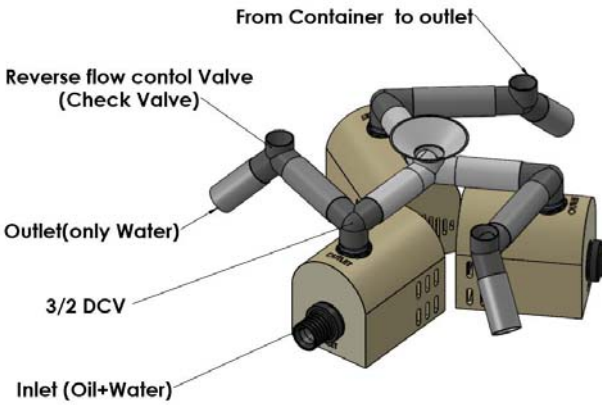

Fig.11 Propelling of Robot

- Battery is placed below pump which is powered by solar and also by sea water.
- Inlet valve takes in water mixture with the help of suction pump. .
- Then bio-sensor give input to Arduino board which is placed above the battery which in turn operates the Direction Control Valve (DCV).
- If Bio-sensor detect presence of oil then DCV allow water oil mixture to move in vertical direction which leads to container of Nano-particles.
- If bio-sensor detects no oil, then it signals Arduino which in turn controls DCV to regulate flow of water in horizontal direction to outlet pipe.
- Mechanism is built in such a manner that 1 Pumping station will send oil to Container for cleaning and other 2 Pumping station will help to propel the robot in forward direction.
- In this manner Robot is built as Autonomous unit floating on sea surface for cleaning of oil spills.

B. Cleaning of oil over water surafce

- Due to specific property of nano-particle i.e. oleophilicity and hydrophobicity only oil remains in the container and water drains out as shown in fig.12.
- Drained water gets out of the robot from the vents provided on bottom part on Robot..
- During the cleaning process, acoustic wave device is working to keep the marine animals away from the polluted source by mean of expelling them.
- Solar is provided for green energy production and overcome the excess need of energy required for various electronic devices in built in robot like GPS, LED etc.

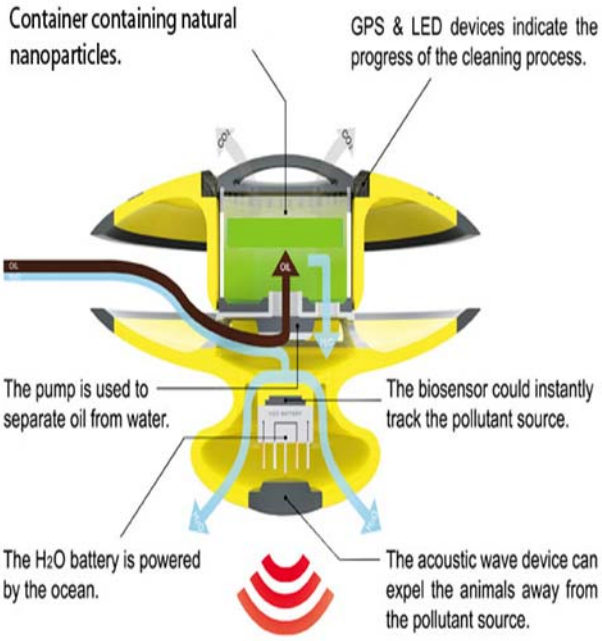

Fig.12 Cleaning of oil over water surafce

VI. RESULT

- System gives the recovery of the crude oil 80%.
- Eco friendly : as Nano are made by plant leaves
- 100 gm Nano = up to 5 lit oil adsorption capacity
- Nano are reusable by putting them in changing magnetic field for 80 cycles.
- Low manufacturing cost
- One time investment and durability of system is up to 10 years.
- Variable size and capacity
- Material used: **PP Copolymer**

Properties	**Aluminum Alloy**	**Steel Alloy**	**PP Copolymer**
Density	2680-3900	7300-8027	890
Flexural Strength	Moderate	High	Moderate
Cost	High Cost	Moderate Cost	Very low
Machining Cost	Moderate	Moderate	Very easy

VII. CONCLUSION

- This paper focuses on the modeling and the control of an Autonomous Vehicle for Intervention (I-AUV). To this aim, an accurate model of the robot has been designed, including the interaction with the fluid.
- Discovery of natural nano-particles with specific properties.
- Designing of the robot for the recovery of the oil with varying size and capacity.
- Proposed different methodologies for oil recovery using natural phenomenon.
- Giving highest oil recovery than the current existing system.
- The control system has to make sure that the system can autonomously reach the object to be manipulated and execute the planned task on it.

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