Development of an Oil Spill Mitigation System

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***Abstract*— Oil spills are horrendous man-made disasters, capable of reaching to biblical proportions in no time. The past accidents show one thing for sure, that we are not even near to being prepared for handling what we have our hands on. The aftermath of this disaster is apocalyptic; the death of marine life, along with sea birds and the life on the shore is drastic and rapid. The paper is regarding the project which aims to minimise the time of mitigating this disaster by deploying cheap, efficient oil cleaning robots in large numbers. At first, the concentration was based upon building a mechanism by breaking emulsions of oil and then recovering the oil. The concept, however proved to be better at a macro level, which deviates from the objective. The other mechanism used is that of sorbents to absorb the oil.Thecurrent practice involves using sorbents as a tail for boats. Suited for one run. The mechanism discussed continuously uses the sorbent up till its optimum life cycle. The model developed can also be used as an appendage that can be scaled to fit at the rear of boats or customized as per the marine vehicle with which it is to be used. The model entails the use of a poly urethane foam as a conveyor belt. The oil is absorbed by PUF and squeezed out at the end of the cycle. The recovered oil is taken and stored in the storage tank. The most ideal material is the graphite foam developed at Rice University, but taking into consideration the cost and availability, it has the dual advantage of using it as efficient means to recover oil, as well as, by burning it at the end of its life cycle energy can be obtained.**

***Keywords*— Oil spills, Emulsion breakers, Sorbents, Polyurethane Foam (PUF), graphite foam**

I. INTRODUCTION

Emulsions of water, oil and solids are formed as a consequence of spilling into the ocean [1]. A large portion in forms of oil in water (o/w) or water in oil (w/o) emulsions is generated in process of mixing with sea water. Only a few papers describe separation of emulsions [2]. Demulsification becomes one of the most critical processes associated with the oil spill cleaning if desired for chemical separation technique. Typical demulsification methods are addition of demulsifying agents; pH adjustment; gravity or centrifugal settling; filter coalescers; heater treaters; electrostatic coalescers and membrane processes. There are advantages and disadvantages to each of these demulsification techniques. pH adjustment can sometimes be used to break o/w emulsions, but it is not effective in w/o emulsions [1]. A standard method for treatment of emulsions is chemical demulsification followed by gravity settling. This process requires a variety of chemicals. The one that can be used in this model is EC2003A [3].

The second concept utilizes sorbents. Sorbent materials can provide a useful resource in a response to a spill of oil to be recovered in situations that are unsuitable for other techniques. However, sorbents should be used in moderation to minimise secondary problems, particularly by creating excessive amounts of waste that can greatly add to the costs of a response.

Actually a sorbent is a material used to absorb or adsorb liquids or gases. Examples include:

- A material similar to molecular sieve material, which acts by adsorption (attracting molecules to its surface). It has a large internal surface area and good thermal conductivity. It is typically supplied in pellets of 1 mm to 2 mm diameter and roughly 5 mm length or as grains of the order 1 mm. occasionally as beads up to 5 mm diameter. They are typically made from aluminium oxide with a porous structure.

Materials used to absorb other materials due to their high affinity for doing so. Examples include:

- In composting, dry (brown, high-carbon) materials absorb many odoriferous chemicals, and these chemicals help to decompose these sorbents.
- A sponge absorbs many times its own weight in water.
- A polypropylene fiber may be used to absorb oil.
- A cellulose fiber product may be used to absorb oil.

In addition to using sorbent materials as booms, to contain and soak up oil spills, sorbents can also be applied to the water surface as powders. Sorbents are often the final step of clean-up, because they can absorb trace amounts of oil that could not be skimmed off. Commonly used sorbents include natural organic materials, such as peat moss and sawdust, or synthetic organic materials, such as polypropylene, polyester foam or polystyrene. Sorbents are generally applied by hand, and recovered with the use of nets and rakes.

While searching for different sorbent materials, PUF (Poly Urethane Foam) caught attention, which is normally used in the sophisticated mattresses. It has a unique property to absorb oil and not water while being afloat over oily water. Actually, there is graphite sponge available, fabricated at Rice University, which is actually far more efficient and after its life span is over. It can be burnt to obtain energy. Cost and availability being a factor PUF is proposed for generic models. Now, considering the long reusability of PUF, two models have been developed, that can be implemented.

II. THE EMULSION BREAKER MODEL

The concept that has been discussed here relies on the principle of demulsification. Time is a key factor for effective on-line separation, both with regard to residence time in a separator and time available for chemical treatment and heating.For example, for an on-line VOSS, the time available for treatment and separation is approximately 5-15 minutes from skimming until discharge into a storage tank. The concept entails a continuous flow of oil water emulsion instead of storing and settling, as in most of the cases. Construction

The model apparatus comprises of 2 cylindrical tanks connected with a pipe. One tank is connected with the oil intake pipe and has a hole at its bottom. The hole is so shaped that there is a constriction at its middle. Two floating blocks are joined with a link. The combination is such that the floating block will float over oil and sink in water. It is placed in such a way that both the floating chambers are on either side of the constricted hole. On the other cylinder there is a nozzle provided so that liquid escapes the cylinder through there so as to accommodate more incoming fluid. Additionally, an inclined member needs to be provided so as to prevent excessive agitation in the container when there is intake of the emulsion. A constant emulsion breaker supply needs to take place from another pipe over the container where oil is input.

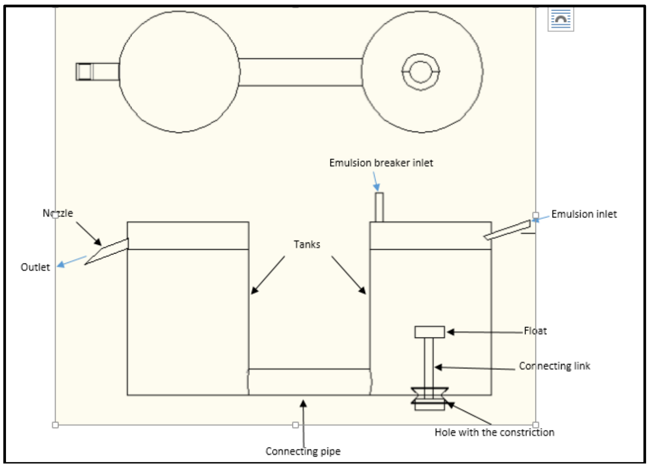

Fig. 1 Emulsion Breaker model

A. *Working*

When oil water emulsion flows in the container, a calculated amount of emulsion-breaker is added. Considering the case when the system has just started, the entire system has been filled with water. This has been done as we are not aware of the properties of the oil in the particular spill. Then the emulsion is input along with the emulsion breaker. Let us say that there was intake of 3 ml of oil and 2 ml of water in the form of emulsion. Now let us consider 3 ml of oil is equivalent to weight of 1 ml of water. So, now following the principle of displacement of equivalent weights, there will be 1 ml + 2ml of water displaced from the other tank through the nozzle. So, the net amount of water in the system decreases. Now, the previously entered emulsion moves down as water from other container spills out and more of the emulsion enters. This so happens that there is the least bit of agitation in the emulsion breaking process that has initiated. The floats have been designed such that they float in water and sink in oil. So, in the initial conditions, the float that is in the container floats thus pulling its counterpart up and keeping the hole closed. Now, as with separation the oil and water separates the net water in the system decreases the oil layer starts moving down. When the oil layer reaches up to the float, the float starts lowering owing to its property of its sinking in the layer of oil. As the lowering starts, the hole that was being held closed by the float counterpart opens. As soon as the hole opens, the entire bulk of water including that present in the other cylinder starts flowing out of the hole. Due to the drainage of water, the oil layer starts lowering down as well. Now, when the oil layer reaches the upper portion of the constriction, the float covers the hole and the oil is prevented from being drained off. Now, the other containers starts filling completely with oil. From the nozzle, we get the oil now, instead of water which can be directed to the storage tank. Now, when the oil emulsion enters, there will be displacement of oil from the other container, and once the water separates and sinks down, a thin film is formed. When the film forms substantially to lift the float, the water would once again seeps out through the hole. In this manner, water can be continuously separated from oil and oil can be stored at the same time.

The dimensions of the cylinder can be so made that the time taken by the emulsion to separate complies with the propagation of the layer in the downward direction, so as to prevent emulsion seeping to the other side of the pipe and going into storage in lieu of pure oil. In the same manner the dimensions of the link connecting the floats also plays a vital role in the smooth running of the mechanism and shall be adjusted in a manner that it is longer than the distance between the bottom of the container and the upper portion of the connecting pipe.

III. THE SORBENT CONVEYOR MODELS

Sorbent materials can provide a useful resource in a response to a spill of oil to be recovered in situations that are unsuitable for other techniques. However, sorbents should be used in moderation to minimise secondary problems, particularly by creating excessive amounts of waste that can greatly add to the costs of a response. We have conceptualized mechanical models which will serve as an 'Oil spill cleaning Robots' or can be used as an appendage to the boats or steamers.

(i) Model-A : The cylinder-blade model

A. *Construction*

The model depicted hereis based on the usage of sorbent cleaning technique of oil spill cleaning. The sorbent used, PUF literally acts like a sponge which selectively absorbs oil over water. Hence, the foam is cut in shaped in the form of blades, so that when the boat is in motion there is the least bit of resistance as possible from the sponge. The foam is firmly affixed on top of the cylinder with multiple holes which acts as a rigid sieve, for letting the oil absorbed by the foam in when squeezed upon.

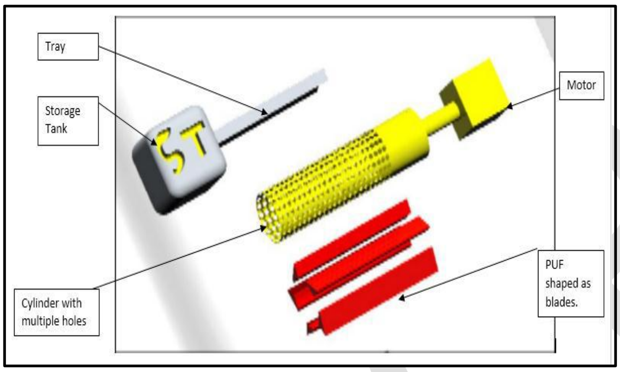

Fig. 2 Cylinder blade model

B. *Working*

The tray collects the oil from the inlet of the cylinder and stores in the storage tank. The cylinder is rigidly coupled with a motor, so as to obtain a positive drive for motion. A stationary portion that is affixed with the rest of the body can be used as a better replacement for the old fashioned roller motion to squeeze, as the relative motion remains quite the same.

C. *Limitation*

There are quite a few limitations of this model obtained while brooding over this idea for a long time. The main limitation would be the actual contact time of sponge blade with the oily water which has direct implications over the quantity absorbed and so does the efficiency. The less time of contact leads to unsatisfactory results. There is also a limitation of the oil collection mechanism, as a large bearing which has to be water-proof was required for sealing the non-motor connected side of the cylinder. In order to rectify these limitations we modified the first model to accommodate some flexibility and more use of some standard available components, rather than fabricating all of them, thereby achieving our objective of making it cost effective.

(ii) Model-B The Sorbent Conveyor model

A. *Construction*

The model is basically based on the use of sorbents as conveyor. Two hollow cylinders are fixed in position by separating rods. The waterproof motors are so assembled over the hollow cylinders such that four output shafts of the motors are obtained at the four ends of the cylinders. The output shafts are in turn fit with timing belt pulleys. There emerges two pairs of the timing belts pulleys and the timing belt is wound upon them. Holes are drilled on the belts and with help of metal wires the polyurethane foam is firmly bound on that. The entire assembly is fixed with help of C arms to the storage tank. The storage tank has a protrusion of a plate that enables a similar relative motion as a roller, except that the cylinders are steady and the foam is moving.

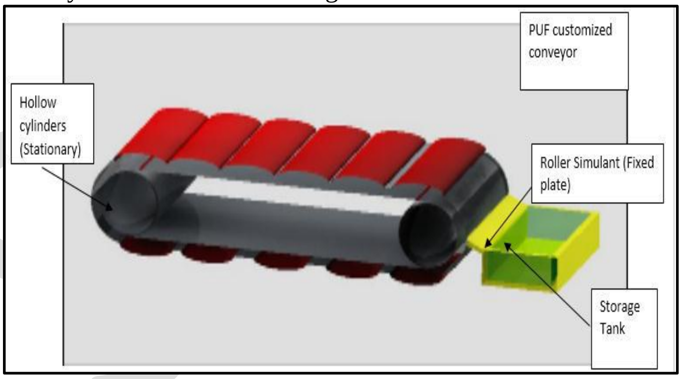

Fig. 3 Sorbent Conveyor model

B. *Working*

When the motors are turned on, the timing belt pulleys move and so does the timing belt. This subsequently leads to the motion of the PUF conveyor. When in contact with water the PUF absorbs oil selectively. At the end of the cycle PUF is squeezed and oil flows over a plate and into the storage tank. This model can be used as an appendage by connecting it at the rear of boats and at the same time it is made of materials that are easily available and very cheap. This model can be fixed with a propelling head and autonomous robot can be obtained.

(iii) Modified Sorbent Conveyor model

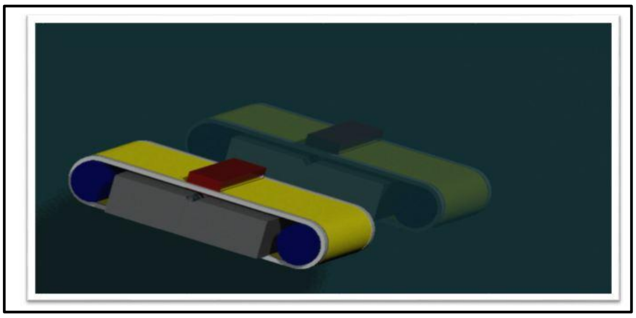
Fig. 4 Modified sorbent conveyor model

This is the final setup of the sorbent conveyor model. The setup comprises of a long sheet of polyurethane foam and a tank with two cylinders attached to it on the opposite sides. These cylinders house two water proof motors each which are eventually connected to the timing belt pulley and the timing belt. The timing belt is fastened with the polyurethane foam sheet with help of metal wires so as to achieve a means of a positive drive.

The squeezing action can be most efficiently carried out with the special casing prepared for it, which is fastened on top of the tank casing. The slit in the bottom directly opens up in the tank so as to avoid any water by any chance to seep in the tank. The tank casing houses the ends of the fasteners that connect the tank to the cylinders and the squeezer casing. A removable tankcan be inserted in the casing and when the tank gets filled up another can be inserted, so as to keep the rounds going without repeated needing attention.

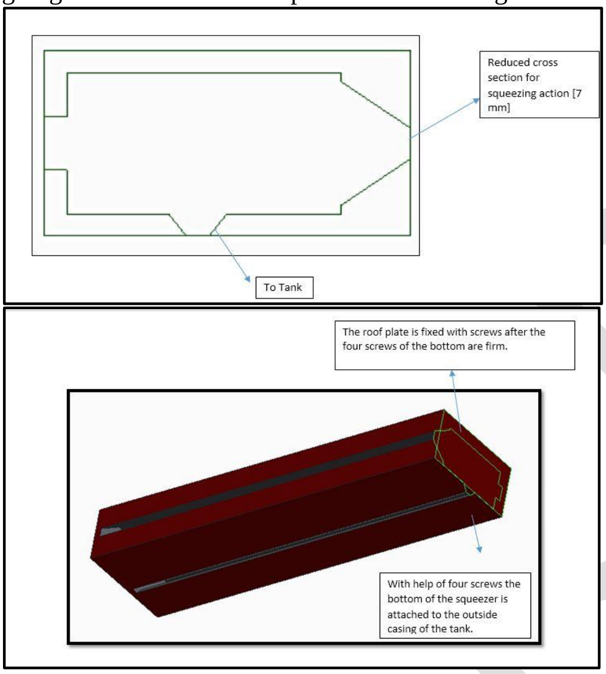

Fig. Squeeze mechanism

Working:

The model upon being inserted with a tank, is ready for use. Upon switching ON the motors, the conveyor action is set into motion. The oil upon being absorbed when the sheet of foam is in contact with water, is squeezed out in the squeezer casing due to the differences in the heights of the slits of entry and exit. The squeezer allows reasonable accumulation space while the oil drains down the opening to the tank. The tank upon filling up can be replaced by another one, without stopping the operation, hence a continuous process motion can be obtained.

IV. COMPARISON OF EMULSION MODEL & SORBENT MODEL

i. Material needed for Emulsion breaker is EC200A which is quite costly while Sorbent model requires sorbents like POF which is comparatively cheap.
ii. Emulsion breaker model takes more time to complete the process than Mechanical sorbent type model.
iii. Emulsion breaker model requires less complex mechanical design while sorbent conveyor model needs complicated motor, pulleys, timing belt and tank design.
iv. Main challenge for emulsion breaker model will be separation of oil-water layer efficiently while main challenge for Sorbent model is effectiveness of sorbent to absorb oil only.

V. CONCLUSION

There are many different models available in the market that can be used for cleaning up the oil spill. The one demerit that they all have in common is high price. At the same time, the maximum clean up rate per day achieved has been 3% of the total oil spill. Not only is this, but the current research and development process in the field of Oil spill cleaning also not up to the mark. If this model can be deployed as autonomous robot in large numbers, then it is quite possible that a significant portion of the oil spill can be cleared in less time, leading to sparing of lives of countless marine creatures. We do firmly believe that this model can prove highly efficient, Cost effective and cater the urgency of situation in very less time.

VI. REFERENCES

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