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An Oil Retrieval Technique using Magnetic Tube Type Oil Skimmer

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ABSTRACT

An increasing awareness of the environmental damage caused by industrial waste and oil spills has propelled the growth of oil recovery technologies. Many oil recovery technologies are now being adapted for use by manufacturers in a diverse range of industries. Businesses are discovering that they can recover oil for disposal or reuse that would otherwise contaminate manufacturing processes. A primary component of oil recovery is the oil skimmer. It is estimated that approximately 706 million gallons of waste oil enter the ocean every year, with over half coming from land drainage and waste disposal; for example, from the improper disposal of used motor oil. Offshore drilling and production operations and spills or leaks from ships or tankers typically contribute less than 8 percent of the total. The remainder comes from routine maintenance of ships (nearly 20 percent), hydrocarbon particles from onshore air pollution (about 13 percent), and natural seepage from the seafloor (over 8 percent). The research work deals with design and fabrication of an oil skimmer. The function of this device is to separate oil from water and thus carry out waste water management. This skimmer works on the principle of surface tension. The affinity of oil to water and differences in surface tension between oil and water, cause oils to adhere to a skimming medium. The primary objective of the project is cost reduction. The main idea of this research is to identify the lack of use of proper oil water separation apparatus in the Indian industries. Many aspects have been identified bearing the lack of proper laws against polluting the water bodies, cost of the required machinery being very high small industries having a relatively smaller turnover do not think of investing in this kinds of oil recovery systems and thereby turn a blind eye towards the harm done to our environment.

Keywords:— *Oil skimmer, Environmental damage, wastage, magnetic tube, Oil recovery technologies.*

I. INTRODUCTION

Oil is any substance that is liquid at ambient temperatures and is hydrophobic but non-polar substances. The general definition above includes compound classes with, soluble in organic solvents. Oils have a high carbon and hydrogen content,

including vegetable oils, petrochemical oils, and volatile essential oils. All oils can be traced back to organic sources [1].

1.1. Oil-water relation

The relationship between oil and water in a mixture is well-known and governed by two physical properties stated below

1.1.1 Specific gravity:

Most hydrocarbons have a lower specific gravity than water. Without agitation, oil separates from the water and floats to the surface Figure 1. These oils are known as LNAPL's (Light Non-Aqueous Phase Liquid). Oils (and other compounds) that sink in water have a higher specific gravity and are known as DNAPL's (Dense Non-Aqueous Phase Liquid).

1.1.2 Surface tension and affinity:

Normally, oil bonds more tightly to itself and other materials than to water. This affinity, coupled with the differences in surface tension between oil and water, cause oils to adhere to a skimming medium.

Figure 1. Oil water mixture (immiscible)

1.2. Skimmers

An oil skimmer is a device that is moved through a liquid medium to capture floating surface oil. Oil skimmers are most often used with a motor to maneuver the skimmer through the liquid. Oil skimmers rely on the fact that oil has a low specific gravity. Meaning it separates from heavier materials and floats to the surface. Oil skimmers use media like polypropylene and PVC to attract oil from liquid. In industrial applications, skimmers are excellent at recovering oil on their own.

II. Objective of the Project

Objective of the project is the source reduction which is better in case of, energy and labour, required to convert the material. This helps in the reduction of the waste generated by each manufacturing operation. Source reduction equates to process cost reduction. Cost reduction is the main objective of this project, for example the use of wooden body with aluminum casing instead of cast iron has helped achieve the prime objective. The use of polyvinyl chloride (PVC) material for the skimmer tube which has helped use reduce the cost of the project. Another objective is to make an environmental friendly oil skimming process without the use of any toxic chemicals.

Description of experimental setup

3.1 Components:

The whole skimmer unit is divided into four components namely:-

1. ***Skimming unit:*** The skimming unit consists of board, pulleys, Teflon scrapers, polypropylene tube as shown in Figure 2.

2. ***Magnetising unit:*** The magnetising unit consists of magnetite and magnets.

3. ***Drive unit:*** The drive unit consists of the motor, the transmission pulleys, roller chain, sprocket wheel, circlips, bearing 6004 and shafts.

4. ***Skimmer stand:*** The skimming stand consists of the stand, the L-angles, the collector tub and the oil tank.

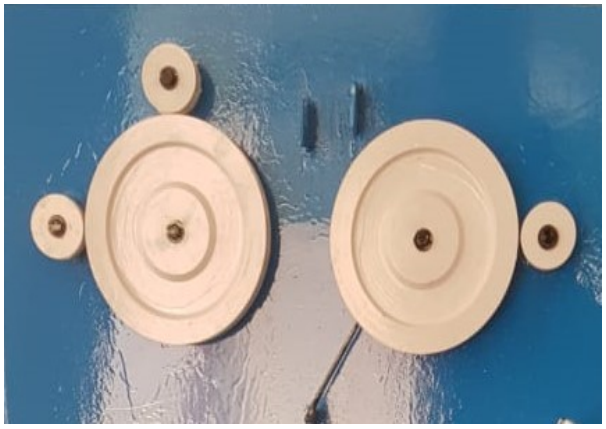

Figure 2. Skimming Unit

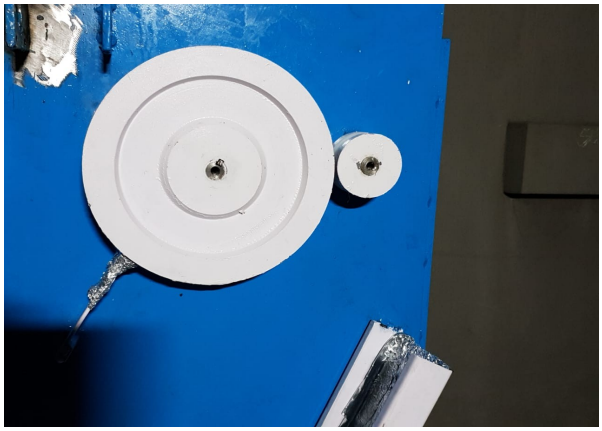

Figure 3. Driven Pulley

3.2 Fabrication procedure

3.2.1 Skimming unit:

Figure 2 shows the set-up for skimming unit.

3.2.1.1 Board: The board used in the industries is usually made of aluminium or mild steel (M.S.).Mild steel has high resistance to breakage. Mild steel, as opposed to higher carbon steels, is quite malleable. This means it has high tensile and impact strength. Mild steel is selected so that it can withstand the load acting on the motor. The size of the board is 71cm length, 75cm height.

3.2.1.2 Pulley: Machining of the shaft is done to suit the diameter of the pulley. We decided on using a lighter material for the pulley. We happened to come across a set of pulleys made up of nylon which has high strength and greater durability. Nylon pulley was selected due to its light weight and due its low friction. A U-groove of 7mm was machined on the pulley for an easy movement of the tube while skimming.

Table 1. Drive & Driven Pulley Specification

Material	**Nylon**
Diameter	200 mm
Construction	Arm construction
Hub thickness	50 mm
No. of arms	8
Groove	U groove
Groove depth	7 mm

3.2.1.3 Scraper

As shown in Figure 4, the scrapers are U-shaped and are made up of mild steel for greater removal rates of oil and due to its non sticky property and low friction, it is an ideal material for scraping oil off the skimming tube and at the same time letting the tube slide. Its specifications are tabulated in Table 2.

Table 2. Scraper specifications Physical Properties of teflon

Physical Properties	Teflon
Co-efficient of friction	0.05 – 0.1
Thermal conductivity	0.25 W/m-K
Affinity to water	Highly hydrophobic
Reactivity to oil	Non reactive

3.2.1.4 Skimming tube

This is by far the most important component of the whole skimmer shown in Figure 5. The tube material should be such that the oil adheres to the surface of the tube more than on water and at the same time it should be easily scraped from the tube and led to the collector tub.

The tube should also be flexible enough to follow the required path. It should also not react chemically with the oil. Also the tube should be cost-effective and lasting.

A number of materials were found to satisfy the required criteria. Of these polypropylene (PP) and polyvinyl chloride (PVC) were found to be the ideal choices. Polypropylene was selected after referring to its physical properties. Its specifications are tabulated in Table 3.

Figure 4. Mild Steel Scraper

Figure 5. Skimming tube

Table 3. A comparison of both their physical properties is given below.

Physical properties	Polypropylene	Polyvinyl chloride
Yield Strength [MPa]	12 – 360	10 – 25
Water Absorp-tion [%]	0.000 – 1.00	0.04 – 0.4
Co-efficient of friction	0.1 – 0.3	0.2 – 0.34
Melting Point	160 - 166	100 – 260

3.2.2 Magnetising unit

3.2.2.1 Magnetite: It is a rock mineral and one of the main iron ores, with the chemical formula Fe_3O_4. It is one of the oxides of iron, and is ferromagnetic. It is attracted to a magnet and can be magnetized to become a permanent magnet itself. It is the most magnetic of all the naturally-occurring minerals on Earth. Naturally-magnetized pieces of magnetite, called lodestone, will attract small pieces of iron.

Small grains of magnetite occur in almost all igneous and metamorphic rocks [2]. Magnetite is black or brownish-black with a metallic luster, has a Mohs hardness of 5–6 and leaves a black streak. The chemical

IUPAC name is iron (II, III) oxide and the common chemical name is ferrous-ferric oxide. Magnetite is found in large quantities in beach sand. Such black sands are found in various places, such as Lung Kwu Tan of Hong Kong; California, United States; and the west coast of the North Island of New Zealand.

Chemical Formula:

iron (II,III) oxide, $Fe^{2+}Fe^{3+}{}_2O_4$

Table 4. Physical properties of magnetite

Physical Properties	Magnetite
Chemical Classification	Oxide
Color	Black to silvery gray
Streak	Black
Luster	Metallic to sub metallic
Diaphaneity	Opaque
Cleavage	None
Mohs Hardness	5 to 6.5
Specific Gravity	5.2
Diagnostic Properties	Strongly magnetic, color, streak, octahedral crystal form.
Chemical Composition	Fe_3O_4
Crystal System	Isometric

3.2.2.2 Magnets: A magnet is a material or object that produces a magnetic field as shown in Figure 6. This magnetic field is invisible but is responsible for the most notable property of a magnet: a force that pulls on other ferromagnetic materials, such as iron, and attracts or repels other magnet. There are typically four categories of permanent magnets: neodymium iron boron (NdFeB), samarium cobalt (SmCo), alnico, and ceramic or ferrite magnets. This type of magnet is composed of rare earth magnetic material, and has a high coercive force. Figure 7 shows motor and its specification is shown in Table 5.

Figure 6: Magnets

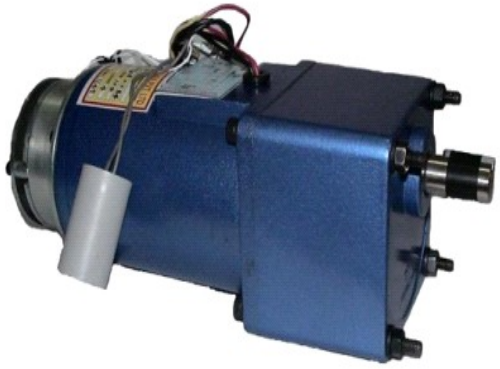

Figure 7. Motor

Table 5. The motor specifications

Type	AC
Power	0.25 HP
Speed	80 rpm
Volts	240
Amps	6
Hertz	50
Frame no.	63 (IS-1231)
Service Factor	1.2

***3.2.2.3. Shaft*:** The shaft was designed once the pulley was fixed. The diameter of the shaft was taken to the inner diameter of the nylon pulley. The shaft was then threaded to stop the to and fro motion of the shaft during power transmission.

Table 6. Shaft Mild Steel specifications

Material	**Shaft Mild Steel**
Diameter	8 mm
Length	200 mm
Threading	V threads

Table 7. Flange Mild Steel specifications

Material	**Flange Mild Steel**
Length	80 mm
Inner diameter	8 mm
Outer diameter	40 mm
Flange thickness	10 mm

3.2.2.4 Roller chain: Roller chain or bush roller chain is the type of chain drive most commonly used for transmission of mechanical power on many kinds of domestic, industrial and agricultural machinery, including conveyors, motorcycles, and bicycles. It consists of a series of short cylindrical rollers held together by side links. It is driven by a toothed wheel called a sprocket. It is a simple, reliable, and efficient means of power transmission as shown in Figure 8.

Figure 8. Roller Chain

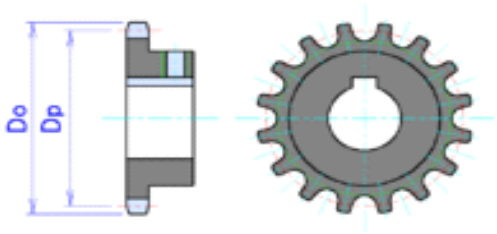

Figure 9. Sprocket Wheel

3.2.2.5 Sprocket wheel: A sprocket-wheel is a profiled wheel with teeth that mesh with a chain, track or other perforated or indented material. The name 'sprocket' applies generally to any wheel upon which radial projections engage a chain passing over it. It is distinguished from a gear in that sprockets are never meshed together directly, and differs from a pulley in that sprockets have teeth and pulleys are smooth.

Let D_o = Sprocket diameter. D_p = Pitch diameter

3.2.2.5 Circlips: A circlip is a type of retaining ring or fastener that takes the form of a flexible, open-ended ring, made from metal. Circlips fit into a groove on the inside of a bore or the outside of a shaft. They work as a load-bearing shoulder which positions and holds mechanical parts. They provide continuous radial force and are secure against high rotational speeds because they are retained within the groove. Most applications which need a part to pivot, spin, or turn, where a bearing is used, will need a circlip or lock ring fastening.

Circlips are commonly used in motors, turbines and pistons shown in Figure 10.

Figure 10(a). Circlip

Figure 10(b). Sizes of Circlips

3.2.2.6 Bearing of grade 6004:

Lightweight, stable and with good spinning characteristics. The deep groove ball bearing 6004-2RS is a true all-rounder and, due to its balanced properties, it is suitable for a variety of applications shown in Figure 11.

- extra light series with compact dimensions and low weight
- suitable for high radial loads and light axial loads in both directions
- offers high running accuracy, quiet running and high speeds
- seal: contact lip seal on both sides made of rubber for high sealing effect
- Here, for bearings, Do=50mm and Length =3 inches

3.2.3 Skimming Stand

Stand: The stand was required to lift the skimming unit to a height so that the skimming tube can skim the oil freely and does not get entangled.

Figure 12. Stand

Figure 11. Bearings

Table 7. Stand specifications

Material	Mild Steel
Length	30 inch
Breadth	13 inch
Height	36 inch
Type of welding	Arc welding

IV. METHODOLOGY

4.1 Working Principle

An oil is an substance that is liquid at ambient temperature and is hydrophobic but non polar. An oil skimmer is a device that is designed to remove oil floating on a liquid surface.

Oil skimmers rely on the fact that oil has low specific gravity hence separates from the heavier particles and floats on the surface. By magnetizing effect the removal rate is increased as compared to normal oil skimmers.

Skimmers are capable of removing oils, grease and floating sludge from a variety of containment systems, and can be adapted to any number of applications. These can range from small indoor tanks and sumps to large outdoor basins and ponds. The tube skimmers can extend as far as 16 feet, and when equipped with a balanced boom system, can move around as desired for maximum portability, eliminating the need for expensive bridging or foundations.

4.2 Standard Procedure

Tube oil skimmers run on a simple concept: continuously remove oil from the surface of the water using a closed-loop tube that floats on the surface of the water, attracting the floating oil or grease [3].

Oil adheres to the outside of a floating, closed-loop tube as it is drawn across the surface of the water, adjusting automatically to changing water levels.

The movement of the tube across the surface and the presence of magnets in the tube actually creates a current that draws in the oil. The magnetized oil on the surface of the tube passes through ceramic scrapers that remove the oil and clean the tube. And the clean tube returns to the surface to collect more.

The recovered oil flows into a collection container where magnetite and oil can be easily separated with the help of magnets, and then oil is virtually water-free [4].

Tube skimmers can efficiently remove all petroleum-based oil, fats, greases, and oily wastes, as well as animal and vegetable oils that float on the surface of water. Other skimmers can get clogged with floating debris, which creates an oily dam preventing them from picking up oil and grease. However, tube skimmers have the ability to snake over, under, and through debris to continuously pick up oil [5].

V. RESULTS AND DISCUSSION

5.1 Oil Viscosity and Efficiency Measurement:

$$\eta = \frac{P\pi r^4 t}{8LV}$$

By using Oswald viscometer, we have measured the resultant oil viscosity of before & after separation. Oil viscosity can be determined through Poiseuille's Law [6]. The expression which governs the flow of liquid the capillary is given as

Where, V = Liquid volume flowing through capillary in time ‘t’, P = Pressure head, r = radius of the tube, L = Length of pipe and t = time taken by liquid to flow

$$\eta_{oil} / \eta_{water} = \frac{P_o t_o}{P_w t_w}$$

Since having same experimental set-up and procedure, oil viscosity is determined using the relative viscosity through Poiseuille's Law [7]. Let assume t_1 and t_2 be the time of the flow of a fixed volume (V) of the tube liquid thrown the same capillary and viscosity of liquid can be determined from above equation as following

5.2 Procedure

1. Weight accurately of empty pyknometer.
2. Add 10ml water in pyknometer.
3. Calculate the density of water.
4. Calculate the density of separated oil.
5. Calculate the density of pure oil.
6. Determine the time of flow for different oil with the help of Oswald viscometer.
7. Calculate the viscosity of oils.

Weight of specific gravity of empty pyknometer W1=21.69g

Weight of specific gravity of bottle + water W2=49.40g

Weight of specific gravity of pyknometer + SAE50 W3=46.22g

Now Density calculations,

Density of SAE50 =

$$\frac{Weight\ of\ sample\ liquid}{Weight\ of\ water} \times 1$$

$$\frac{46.22-21.69}{49.40-21.69} \times 1$$

=0.988g/ml

Table 8. Oil Viscosity Before and After Separation

S. No.	Types of Oil	Oil Viscosity		Efficiency
		Before separation	After separation	
1	Food oil	50.6	44.3	87.5%
2	SAE 40	160	149.8	90%
3	Mixed Oil	110.3	98.6	88.6%

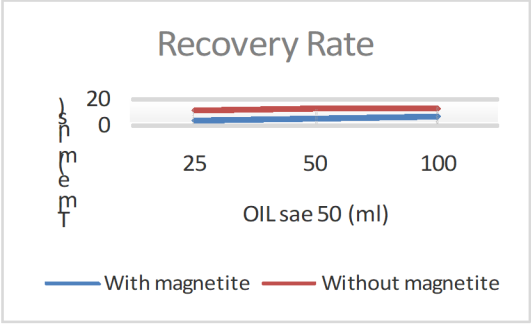

Figure 12: SAE 50 Recovery Rate

Table 9. Recovery Rate without Magnetite (A) and with Magnetite (B)

Type of oil	Oil (ml)	Water (ml)	Time (sec)		Oil recovered (ml)		Recovery rate (LPH)		Recovery Efficiency	
			A	B	A	B	A	B	A	B
SAE50	25	15000	752	240	10	15	0.1201	0.227	40%	60%
SAE50	50	15000	705	280	28	40	0.1401	0.514	56%	80%
SAE50	100	15000	672	310	60	75	0.3215	0.872	60%	75%

Table 10. Recovery rate without magnetite and with magnetite

Type of oil	Oil (ml)	Water (ml)	Time (sec)		Oil recovered (ml)		Recovery rate (LPH)		Recovery Efficiency	
			A	B	A	B	A	B	A	B
SAE40	25	15000	810	300	10	15	0.044	0.1807	40%	60%
SAE40	50	15000	845	370	25	40	0.106	0.3921	50%	80%
SAE40	100	15000	930	430	53	75	0.205	0.6302	53%	75%

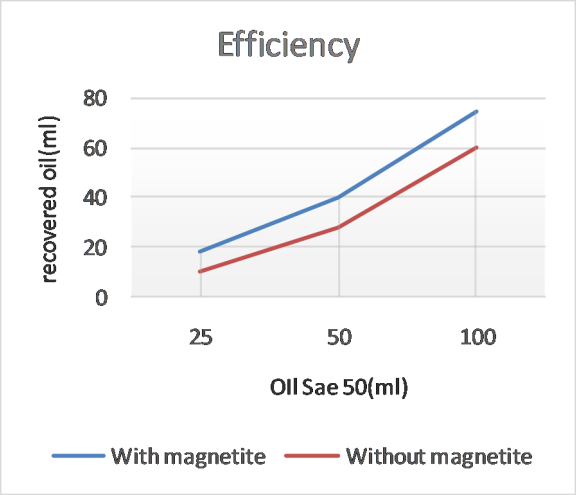

Figure 13: SAE 50 Efficiency

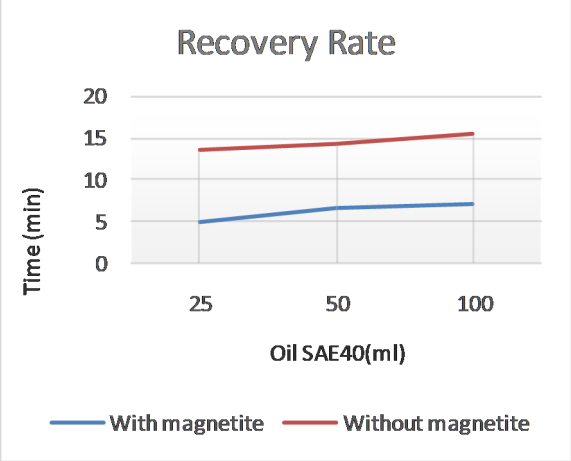

Figure 14: SAE 40 Recovery rate

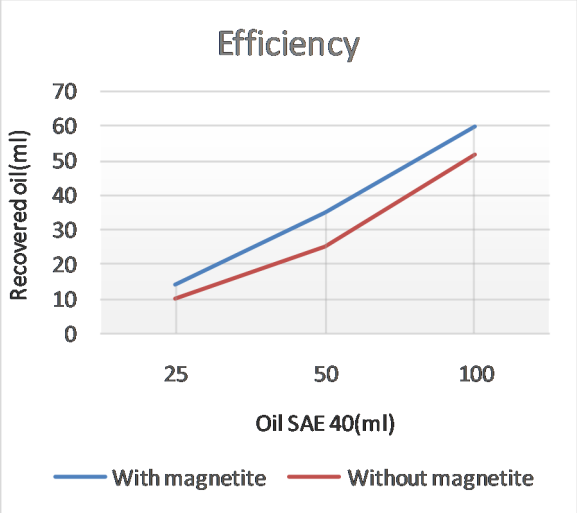

Figure 15: SAE 40 Efficiency

VI. Conclusion

With the increased use of chemicals and other harmful intoxicants for the recovery of oils from the oceans and industries which in turn leads to water pollution and thus damaging the aquatic life. Oceans are polluted by oil on daily basis from oil spills, routine shipping, run-offs, dumping. Oils spills make up about 12% of the oil in oceans. Cleanup and recovery is difficult and depends upon many factors including the type of oil spilled, the temperature of water and the types of shorelines and beaches involved. Other factors influencing the rate of long term contamination is the continuous inputs of petroleum residues and the rate at which the environment can clean itself. Spills may take weeks, months or even years to clean up. Considering all these aspects it is important for us to develop a mechanism which helps in the recovery of oils at faster rate with the use of natural elements which has no effect to the water and on the environment.

Tube type oil skimmer is one of the skimmer which is widely used for the removal of oil. We have improvised the tube type oil skimmer by introducing a natural mineral (magnetite) and the use of magnets inside the tube which in turn helps in the faster recovery rate of oils. Experiments were performed on the SAE50, SAE40 engine oils and their waste oils and their results have been recorded. Further development of this research can be planned beyond the current version, in order to make it more eco-friendly and efficient at a reasonable price.

VII. Future Improvements

It would be advantageous if oils of different densities could be separated instead of just separating oil and water. Further research in this direction might suggest the use of sensors which could detect different

densities of oils which would help in the separation of oil and also help automate the process at the same time.

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