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Design and Experimental Analysis of Oil Skimmer for Water Filtration

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Abstract: *In this era of modern civilization, liquid fuel transport is mandatory around the world. But there has been several oil spilling accidents around the world and their negative effects are against all the living elements. In the last decades Bangladesh face such problem randomly in sea area and as well as in the river side damaging a large number of livings alongside the river having a badly effect on the entire ecology. The local residents collect the spilled oil manually. The system is less efficient, slow and health hazardous. Belt Oil skimmers using Polymer, Teflon, Elastomer, Corrosion Resistant Steel materials belt are widely used for recovery of this oil. However, they are costly and unavailable. In this work a low cost simple blanket belt skimmer device by using locally available equipment that will be capable to absorb the spilled oil rapidly from river water that is filled with animal and plant waste. After constructing such oil skimmer, the performance is evaluated that accomplish, oil having different physical properties. Our constructed device with minimum cost compare to the other conventional belt oil skimmer. Also this oil skimmer machine is totally floating on the sea or river.*

Key Word*: Polymer, Teflon, Elastomer, Corrosion Resistant Steel.*

I. Introduction

An oil skimmer is a device that separates oil or particles floating on a liquid surface. Oil skimmers are not oil water separator devices. They are used for oil spill remediation, as a part of oily water treatment systems, removing oil from machine tool coolant and removing oil from aqueous parts washers. The use of skimmers in industrial applications is often required to remove oils, grease and fats prior to further treatment for environmental discharge compliance. By removing the top layer of oils, water stagnation, smell and unsightly surface scum can be reduced. Placed before an oily water treatment system an oil skimmer may give greater overall oil separation efficiency for improved discharge wastewater quality. There are many other methods of removing oil spillage. Oil spillage can be removed by incorporating chemicals, but they have a disadvantage that the chemicals may cause danger to the ecosystem. Another method is the incorporation of Bacteria (Pseudomonas). In this method the bacteria decompose oil and oil recovery becomes impossible. The main advantage of using a skimmer is that the spilled oil can be recovered and can be reused. Generally, the common types of skimmers used are Disk type, Belt type, Rope type, Brush type, Weir type, Drum type. Of these types of skimmers disk type skimmers are most widely used, while drum skimmers are used rarely. The main reason is due to the weight of the drum and inefficiency of adsorbing oil effectively. In this report design modifications in a belt type skimmer which may increase oil adsorbing are discussed.

Problem Statement:

1) During the recent decade, World has witnessed big oil spillage accidents into ocean and made huge impact to the environment. Apart this, sometimes Oil is getting spillage through being the results of chronic and careless habits in the use of oil industries and oil products.
2) It is estimated that approximately 706 million gallons of waste oil enters the ocean every year; whereas more than half of that sourced from land drainage and waste disposal.
3) The use of an oil skimmer in the machine shop setting holds many benefits. Removing the oil from a machine coolant tank will initiate some aesthetic benefits such as cutting down on the amount of smoke generated from the cutting tool coming into contact with oil laden coolant. When a machine is shut down for the weekend, oil has a chance to come to the surface of the coolant tank. Bacteria that are living in the coolant tank use up the dissolved oxygen in the coolant mix, a process that is sped up by having a layer of oil on the surface. This allows odor causing anaerobic bacteria to thrive diving off that familiar "rotten egg" smell.

4) Oil pollution occurs in harbor basins when leaks from shore facilities for the supply of diesel fuel to fishing vessels find their way into the harbor water; when vessels pump out oily bilge water in port; when used engine oil is dumped overboard and when an accident results in leakage of fuel oil. A fishery harbor which is contiguous with the main harbor also faces the risk of major oil spills if the main port is a transfer point for crude oil or refined products from oil tankers.
5) The oil skimming is the operation of removing or separating the oil from the oil polluted water. Oil being the lighter element as compared to coolant mixed with the water, it floats over the coolant. The endless belt running over the roller is adjusted such that the belt will violently smash the layer of the mixture coolant. The oil being the lighter and sticky will stuck to the belt. The belt then is rubbed against the resting scoop or the container where the oil is collected after separation.

Objectives of the Project:

Solution to above problem is to design and develop a continuous floating oil skimmer machine to reduce the idle time to a minimal value. The objective is to make a fully automatic machine which will solve above problem. , this project also consist of renewable energy source i.e. solar panel to charge battery and also no maintenance required to run this machine. The list is as follows,

1) Separation of spilled oil from sea water.
2) To separate the oil from the coolant solution.
3) To increase the life of coolant.
4) To increase the tool life.
5) To avoid change in properties of material.
6) Use of solar panel to charge battery
7) Floating base on water
8) Use of belt type oil skimming mechanism
9) Collection tray for oil

Methodology:

Although designs vary, all oil skimmers rely on specific gravity, surface tension and a moving medium to remove floating oil from a fluid's surface.

Floating oil and grease cling to skimming media more readily than water, and water has little affinity for the media. This allows skimming media in the shape of a belt, disk, drum, etc. to pass through a fluid surface to pick up floating oil and grease with very little water. This oily material is subsequently removed from the media with wiper blades or pinch rollers.

Figure1: Methodology of the project

II. Literature Survey

Table no 1: Authors and Their Work

Sr.No.	Author	Parameter Studied	Conclusion
1	Rafi Jamal Algawi, Maha Adnan Dawood (2017)	The experiment of separating oil from water by using the skimming belt best operating conditions.	Oil recovery rate increases with increasing belt rotational speed, oil recovery rate increases with decreasing oil temperature and the belt material polyvinyl chloride was more effective than synthetic Rubber and polypropylene.
2	Sathiyamoorthy V , Arumugam K. et.al.(2017)	Experiment of the oil skimmer is used to separate oil, from mixtures of aqua and oil.	Significantly improve the oil recovery efficiency and also it's becomes simpler.
3	Lokhande M. M. , Pawar R.R.et.al.(2017)	Experiment of effective way to clean this oil from the surface without actually wasting it.	Simplified the complex driving mechanisms used in earlier projects and giving it simple and high working capability. They achieved process at cheaper side and eco-friendly.
4	Abdul Rahman, S. Manojkumar, M. et.al. (2018)	Oil skimmer is used to remove the floating oil from liquid medium.	The volume of oil removed can be improved by using large size belt and disc which results in effective oil removal rate.
5	Sumon Khandakar, Md. Nasiqul Islam, et.al. (2017)	Oil spilling accidents around the world and their negative effects are against all the living elements.	Skimmer performance is affected by the thickness of the oil layer, they rather and emulsification of oil, presence of debris. Thus practical application is necessary before adoption. The longevity of the Blanket belt will Significantly affect the cost.
6	N Widiaksana, A A Yudiana et.al. (2017)	14 major accidents of oil spill in Indonesia, mostly as results of ship collisions. There are several methods in handling oil spill accident.	Oil tends to gather at the tip of the disc. In order to gain higher amount of recovered oil, it is necessary to consider the depth of disc on the water. If possible, the depth of dipped disc should reach its own radius to recover the oil from sea.
7	S. S. Godawarikar, A. T. Gavhane (2020)	On large scale due to these huge cargo shipping these are so many cases of oil spill in the sea.	The material of the component parts and the rotational speed of the belt to get effective oil recovery efficiency from the skimmer.
8	Vignesh. T, Bhuvaneswari M, et.al.(2020)	Removing oil from the water which is wasted from the machines.	The recovery test has done in the industry. The system gives the good performance result. The system works well in harsh surface. This method is more cost efficient and less material requirement. This system is designed and tested and it shows that it can regain most of the oil from water.

III. Design and Modeling

Design of dc motor:-

DC motor: 12-volt rpm viper motor
Power of motor = 30 watts
Rpm of motor = 60
P = 2πNT/60
Where, N = rpm of motor shaft = 60
T = torque transmitted
30 = 2×π×60×T/60
T = 5.12 N-m
T = 5200 Nmm

Table no 2: Motor Specification

Model	Voltage (V)	Power(W)	No Load Speed (RPM)	No Load current (A)	Load Speed (RPM)	Load current (A)	Rotation	Motor Length (mm)
59ZYT	12	30	65±3	≤1.2	60±3	≤5.5	1:56	80

Design of oil skimmer belt:-

Velocity ratio of open belt drive:
The peripheral velocity of belt passing over the driving pulley: V = πd1N1/60
The peripheral velocity of belt passing over driven pulley: V = πd2N2/60

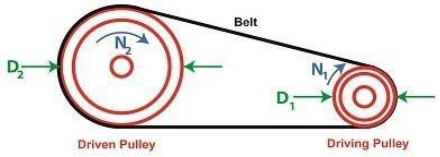


Figure no 2: Skimmer Belt with Pulley

Here Assume: Roller Diameter d1, d2 = 50mm
Motor rpm = 60 rpm,
V = Π d n / (60x1000)
V = 3.14 x 50 x 60/60
V = 157 m/s

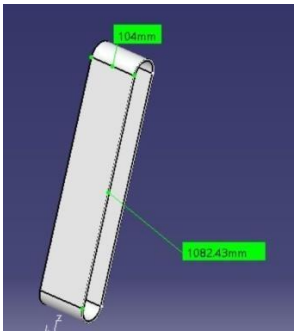


Figure no 3: Belt

Design of float:-

Let ρ = Density of water
g = Acceleration due to gravity
v = Volume of the float
r = Radius of the float h = Height of the float
W = Weight of the system
T1 = Tension in tight side of belt

T2 = Tension in slack side of belt
TR = Torque transmitted by the shaft
θ = Angle of contact between drum and belt
μ = Coefficient of friction between drum and belt
s = Slip of belt
VD = Linear velocity of drum or shaft
VB = Linear velocity of belt
vr = Volume recovery rate
t = Thickness of film = Width of belt
N = Speed of rotation of shaft
ω = Angular velocity of shaft
P = Power of motor
R = Radius of the drum
D = Diameter of the drum
Balancing of float:
W= ρgv ρ = 1000 kg/m3
g = 9.81 m/s2 v = πr2h
v = π x (0.08)2 x 1 v = 0.0201 m3
So, ρgv = 1000 x 9.81 x 0.0201
= 197.181 N (on a single float)
= 197.181 x 2 (for double float)
= 394.362 N
W = 25 x 9.81 (mass of the system = 25 kg)
= 245.25 N
ρgv > W
So the body will float until
W=ρgv= 394.362 N
W = 394.362/9.81
W = 40.2 kg
So, the float can hold a maximum mass of 40.2 kg
Volume rate of oil recovered per turn when shaft is rotating at 60 rpm
Here we assume 1 mm thickness of oil film
Volume rate = thickness of film × width of belt × circumferential area of shaft × speed rotation of shaft
Vr = t×w×π×d×N
= 0.001×0.1×π×0.015×60
=282.74 ml/min

Design of shaft:-

Following stresses are normally adopted in shaft design
Material = C45 (mild steel)
σ ut = 320 N/mm2 PSG design data book.
factor of safety = 2
σt = σb = σ ut/ fos =320/2= 160 N/mm2
σs = 0.5 σt
= 0.5 x 16
= 80 N/mm2
σs is less then allowable so our shaft design is safe.
T = 5200 Nmm
Fs allowable
= 80 N/mm2 5200 = 3.14 / 16 x σs x d3/16
d^3 = 342
d = 6.99 mm
Considering factor of safety on shaft diameter 3 d = 6.99 x 3 = 20.7mm
But standard size available is 20mm, therefore, from manufacturing CatLog. We selected 20mm shaft.

Figure no 4: Bearing

For 20mm Shaft diameter we take standard breaking no. P204 P=pedestal bearing
2=spherical ball
=04=5 * 4 = 20mm
Bore diameter of bearing

Proposed Model:-

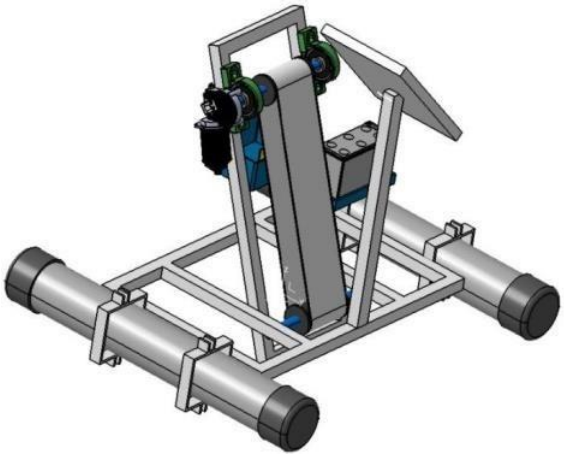


Figure no 5: Assembly

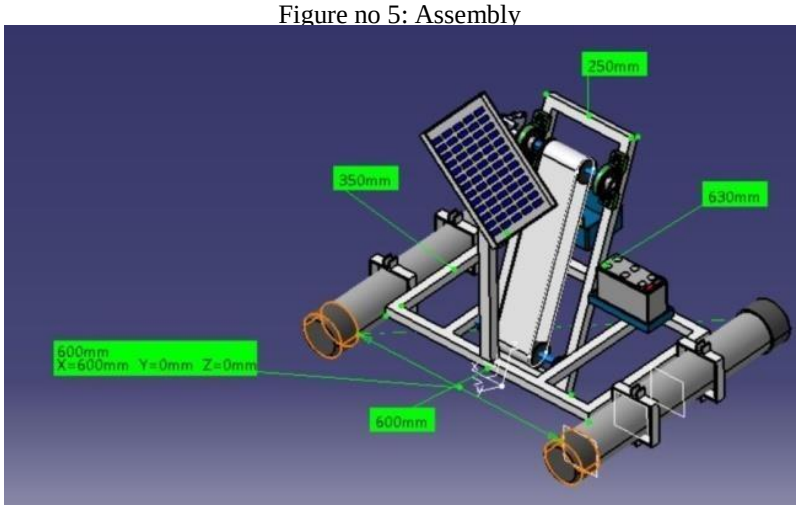


Figure no 6: Pictorial View of Assembly

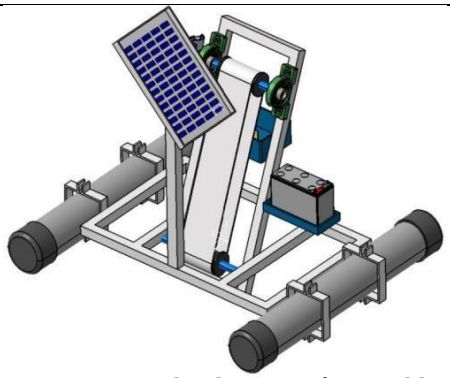


Figure no 7: 2nd Side View of Assembly

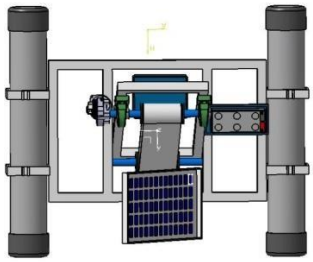


Figure no 8: Top View of Assembly

IV. Experimental Analysis

Experiments are performed using a steel test tank of :-(20cm) length, (15cm) width and (20 cm) height, the water depth is (8.35cm). The skimmer supported vertically above the tank by a metal holder, the angle inclination of the belt constant (θ=90°) cannot be change and a scraper metal fixed was used to wipe the oil collected from the belt in the oil collecting cylinder. The belt has the following specifications:- The belt effective length is 18 in.(458mm), and belt width is 1in. (25.4mm). The belt drives system consists of AC motor (12/24v), installed on the top of the skimmer.

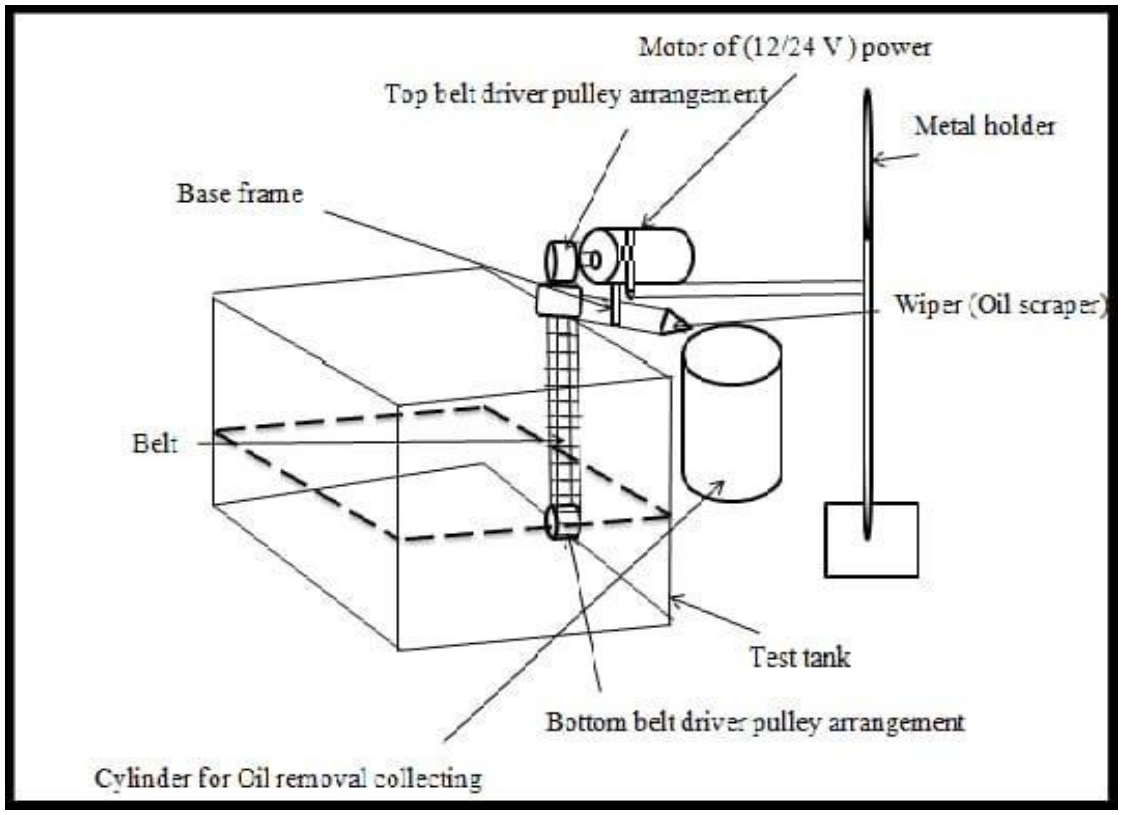


Figure no 9: Experimental Setup

There are various result related to ORR with graphs with respect to their parameters:-

Variation of ORR for different oil thickness:-

Table no 3: Variation of ORR for different oil thickness

Sr. No.	**U (RPM)**	**ORR at TH=3.333 mm**	**ORR at TH=6.66 mm**	**ORR at TH=10 mm**	**ORR at TH=13.33 mm**
1	2.5	0.2	0.16	0.12	0.11
2	5	0.25	0.18	0.16	0.15
3	7.5	0.259	0.2	0.17	0.16
4	10	0.238	0.21	0.2	0.2

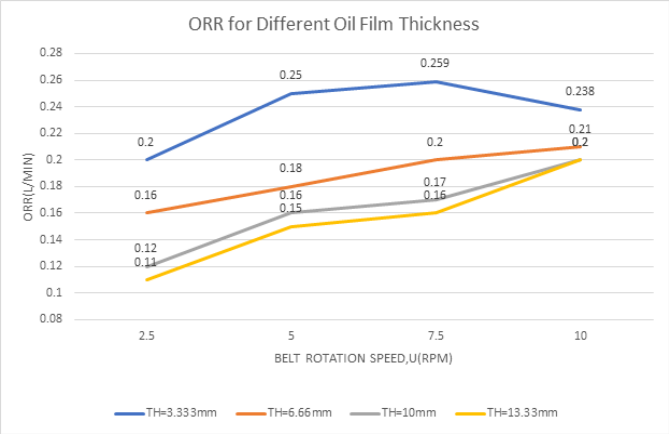


Figure10: Variation of ORR for different oil thickness

Variation of ORR for different oil temperature:-

Table no 4: Variation of ORR for different oil temperature

Sr. No.	U(RPM)	ORR at T=O©	ORR at T=15©	ORR at T=30©	ORR at T=45©
1	0.25	0.2	0.15	0.15	0.13
2	5	0.22	0.14	0.157	0.14
3	7.5	0.24	0.15	0.159	0.15
4	10	0.2	0.16	0.16	0.16

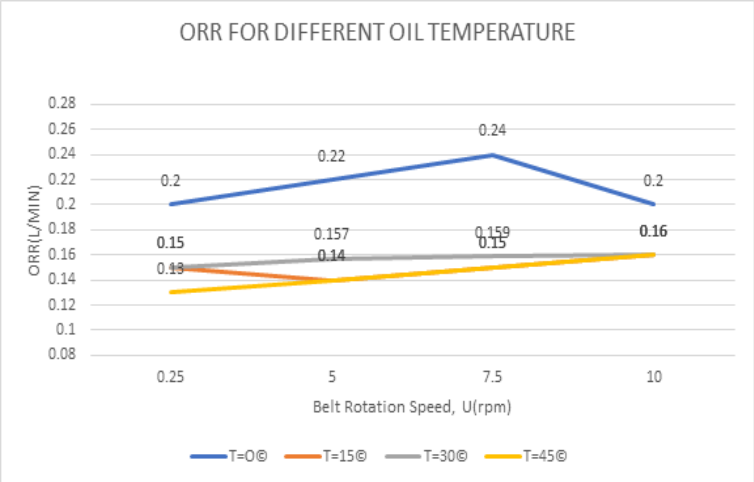


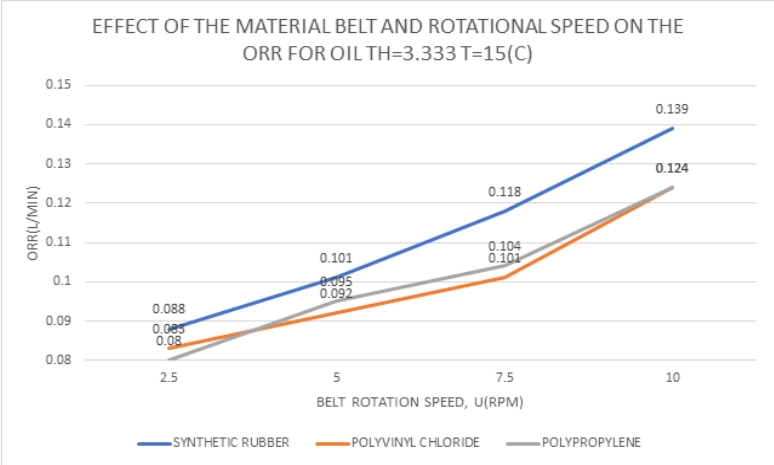
Figure 11: Variation of ORR for different oil temperature

Variation of ORR for different belt rotational speeds:-

Table no 5: Variation of ORR for different belt rotational speeds

Sr. No.	U (Rpm)	ORR For Synthetic Rubber	ORR For Polyvinyl Chloride	ORR For Polypropylene
1	2.5	0.088	0.083	0.08
2	5	0.101	0.092	0.095
3	7.5	0.118	0.101	0.104
4	10	0.139	0.124	0.124

Figure12: Variation of ORR for different belt rotational speeds



Effect of pH on ORR:-

Table no 6: Effect of pH on ORR

SR. NO.	U(RPM)	ORR FOR pH OF WATER
1	2.5	0.1001
2	5	0.1002
3	7.5	0.091
4	10	0.0842

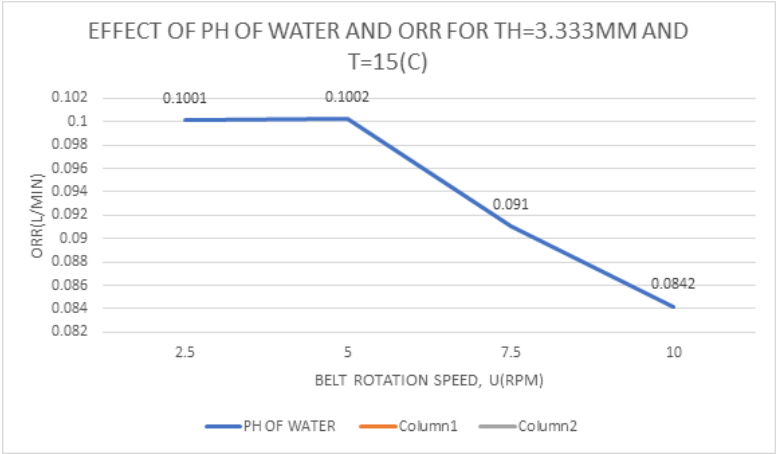


Figure13: Effect of pH on ORR

V. Conclusion and Future Scope

Conclusion:-

- The oil recovery rate and belt rotational speed varies directly whereas, the oil recovery efficiency varies inversely with the belt rotational speed.
- The oil recovery rate varies inversely with the oil temperature which decreases the oil recovery efficiency with increasing the belt rotational speed.
- The viscosity of oil is a major factor in oil recovery using belt skimmer, a lower temperature increases the oil recovery rate and the oil recovery efficiency by increasing is viscosity, a higher temperature decreasing the viscosity of oil.
- The material belt effect on the oil recovery rate and the oil recovery efficiency, for thicker oil film thickness and low viscosity (Polyvinyl chloride) is 7 times more effecting than (Synthetic rubber) and (Polypropylene).
- The surface structure [hydrophobic &hydrophilic] properties of the material belt is affecting to the efficiency of the belt.
- PH of water has a significant effect on oil recovery, because PH of water changes the physical properties of oil in the oil /water collecting volume.

Future Scope:-

- The literature survey shows that tremendous amount of work need to filtration of impurities of sea water and drinking water storage by many design modifications and structural optimization of the related components.
- In our research work we've considered petroleum fuels as impurities in water but there are more different types of impurities present in water for which work need to be done.
- Also, we have considered variation of impurities for thickness of oil film, viscosity and temperature of oil, material of belt etc. but further work can be done with other environmental parameters and design modification.
- It can be used for further different types of application like dock yard, oil refineries, coolant recycling processes.

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