International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 09 | Sep 2021 www.irjet.net p-ISSN: 2395-0072

Design and Manufacturing of Oil Skimmer

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Abstract – *A device used to extract floating oil from a liquid medium is known as an oil skimmer. Oil floats on the surface because it has a lower density than water. Water molecules are more attracted to each other than oil molecules since they do not mix. Our objective intends to build a belt type oil Skimmer due to the necessity of oil skimmer. Belt, bearings, engine, pulleys, shaft, and collecting tank are all included in the belt type oil Skimmer. Our project strives to ensure that the dimensions of the components are properly selected and designed, as well as that they are assembled correctly. With a tiny amount of water, the skimming medium runs over the water's surface, eliminating oil. The primary purpose of this produced skimmer is to filter water by eliminating various dirt oils and impurities. The skimmer is much economical and easier to manufacture than more expensive treatments like membrane filters and chemical treatments.*

***Key Words*: Water molecules, Oil molecules, chemical treatments, cost effective, oil skimmer.**

1. INTRODUCTION

Pollution is a big source of concern in today's world. Water contamination is primarily caused by oil and oil spills all over the world. As a result, our goal is to develop technology that separates oil from water in order to prevent pollution. As a result, proper oil collection, disposal, and storage are all necessary.

Many countries have adopted rigorous restrictions for the disposal of wastewater containing oils, especially from the petrochemical and process industries, requiring these companies to build oil skimmers/Skimmers to separate the oils from the wastewater. Oil skimmers/Skimmers are special vessels that are used to recover spilled oil. The ultimate purpose of any oil recovery operation is to gather as much oil as is reasonably and economically possible.

A skimmer is a mechanical device that is specifically designed to remove oil (or an oil/water mixture) off the surface of the water while preserving the physical and/or chemical features of the water. The fluidity qualities of oil and oil/water mixtures, density discrepancies between oil or oil/water mixtures and water, or variances in adherence to materials are all used to operate skimmers.

These technologies are typically utilized for oil spill cleanup, but they're also used in industrial applications including eliminating oil from machine tool coolants and aqueous parts washers. They are frequently needed to remove oils, grease, and fats before proceeding with additional treatment in order to comply with environmental discharge regulations. Water stagnation, odor, and ugly surface scum can be minimized by removing the top layer of oils; placed before an oily water treatment system, it may provide increased oil separation efficiency for enhanced wastewater quality. It should be noted that all oil skimmers will pick up some water with the oil, which must be decanted to produce concentrated oil.

2. Problem statement

Oil leakage in industries and reservoirs must be effectively managed. Oil is squandered, and the ecosystem is harmed as a result of the spill. It is necessary to segregate the oil that pollutes the environment.
As a result, our study intends to achieve effective oil separation and collection in both domestic and industrial settings. In our project, we use a belt-type oil skimmer.
The project's work entails the creation of the following components:

1. Shaft
2. Bearings
3. Pulleys (Driver, Driven)
4. Belt

After the project is completed, the benefits will include efficient, portable equipment that may be employed in the affected areas.

2.2 Working of Oil Skimmer

Water has a higher density than oil, as we all know. Oil floats on the surface of water because it has a lower density than water. Oil is easily visible on the surface as a result. It is impossible to overstate the importance of viscosity in equipment operation. Because of its higher viscosity, oil adheres fast to the surface of the oil Skimmer's belt.

A motor propels the shaft forward. A pulley is attached to the shaft. The pulley is looped with the belt. Two pulleys may be seen in the photograph. The belt circles between the two pulleys while the motor rotates the shaft. A mixture of water and oil is used to draw the belt.
The oil adheres to the moving belt's surface, sealing it off from the water. After that, the wiper (scraper) that comes with the device makes contact with the belt. The oil falls into the collecting tray or tank due to contact between the belt and the scraper blade and can be reused if necessary.
This ensures that the oil is sufficiently removed and isolated from the water supply. As a result, the technique is simple and straightforward. The belt may become worn out after a long time of use. It's a simple task to replace it.

2.3. Motor

After completing considerable research on the application of the oil skimmer from a number of sources, the motor was picked. The motor market was thoroughly investigated, and information from vendors was obtained. Motors with speeds ranging from 720 to 1440 rotations per minute were available. After examining the motor's availability and cost, the decision was taken. An electric DC motor was ruled out due to the time required for its availability from the date of order. The following specs were appropriate for the project:

Power rating: 0.5 HP (373 W)

Voltage supply: 415V 50Hz, 3ϕ

Speed: 1440 rpm

2.4. Gearbox

After an examination of numerous types of gearboxes, worm and worm type gearboxes were chosen. The first step was to undertake calculations on helical-spur and helical-helical combinations. These two types of gearboxes were ruled out due to the following factors: Both helical and spur gears are incompatible with a gear ratio of 1:70; spur and helical gears are best employed for high-power transmission. The dimensions acquired after final calculations resulted in a large gearbox design. For a compact design and low weight, we chose to build a worm and worm type gearbox, taking into account the shaft's required output speed of 30 rpm and the gear ratio of 48.

Design calculations;

Gear ratio G= Input speed/Output speed

= 1440/30

= 48

Material Selection: From manufacturer's catalogue,

I. Worm: EN 24 S_{ut}= 850 N/mm^2, 248 BHN

II. Worm Gear: Phosphor Bronze: S_{ut}= 245 N/mm^2, 95 BHN

$\tan\lambda = z_w/q$

Where,

z_w= No. of starts on worm= 1

q= Diametral quotient= 10

Therefore, λ=tan^-1(1/10)

= 5.7105 degrees

G=z_g(No. of teeth on gear)/z_w(No. of starts on a worm)

Therefore, z_g= 48

In worm gear pair, always worm gear governs the design.

Beam Strength of worm gear tooth:

$F_b = \sigma_{bg}.b.m.Y.\cos\lambda$

Where,

F_b= Worm gear tooth beam strength (N)

σ_{bg}= Permissible bending stress for worm gear, N/mm^2

b= Face width of worm gear, mm

m= Transverse module, mm

λ= Lead Angle of worm

Y= Worm gear teeth Lewis Form Factor

σ_{bg}= (S_{ut})g/3

= 245/3

= 81.67 N/mm^2

Where,

S_{ut}= Ultimate Tensile strength of worm gear material

b= 0.75dw

d_w= mq

Therefore, b=0.75m.q.

= 0.75.m.10

= 7.5m mm

For 20 degrees FDI, Y=[(0.484)-(2.87/z_g)]

= 0.484-(2.87/48)

= 0.4242

F_b= 81.67 x 7.5m x cos(5.7105)x0.4242xm

= 258.57m^2 N

Wear Strength of Worm gear tooth

F_w= d_g.b.K

Where,

d_g= PCD of worm gear, mm

K= Worm gear wear factor/Material combination factor, N/mm^2

Design of Machine Elements II- R.B.Patil (Table 5.14.1)

For materials selected, λ=<10 degrees, K= 0.52

Therefore, d_g= m.z_g

= 50m

F_w= 7.5mx50mx0.52

= 197.76m^2 N

As F_b>F_w, Worm gear is weaker in pitting.

As a result, it should be built to prevent pitting failure.

Effective load on worm gear tooth

F_{eff}= [Ka.(F_g)t]/K_v

Where,

F_{eff}= Effective load, N

K_a= Application factor= 1

K_v= Velocity factor= 6/(6+vg)= 6/(6+ 0.07539m)

V_g= d_g.n_g.π/60000= (π.m.48.30)/60000= 0.07539m m/s

(F_g)t= Tangential force acting on worm gear tooth= P/v_g= 4.955x(10^3)/m N

F_{eff}= [1x4.955x(10^3)]/(6/(6+ 0.07539m)

i. Estimation of module

To avoid pitting failure,

F_w= N_f.F_{eff}

197.76m^2= 1.5x [1x 4.955x(10^3)]/(6/(6+ 0.07539m)

Therefore, m= 3.39 = 4mm (Approx.)

Hence, the designation of worm gear pair: z_w/z_g/q/m= 1/48/10/4

Dimensions of worm and worm gear:

Module (m) = 4mm

z_w= 1, z_g=48

d_w= 40mm, d_g=192mm

Pitch (pa)= 12.56 mm

L= 12.56 mm

λ= 5.71 degrees

b= 30 mm

Center distance (a)= 116 mm

Addendum (h_a)= 4mm Dedendum (h_f)=4.8mm

Length of worm (L_w)= 68 mm

Force analysis:

(F_t)w= P_i/V_w

= 373/3.015

= 123.71N

(F_t)w=(F_g)g= 123.71N

(F_g)w= (F_t)w/tan(Φ_v + λ)

= 123.71/tan(1.4+5.71)

= 991.43N

(F_a)w=(F_t)g= 991.43N

(F_r)w= (F_t)w/sinλ x tanΦ_n(tanλ/tanΦ_v)

= 123.71/sin5.71 x tan20(tan5.71/tan1.4)

= 1848.9N

Weight of worm and worm gear

Volume of worm (vol_w)= π/4 dw^2 x L_w

= 8.54 x (10^-5) m^3

Mass= Density x $(vol)_w$

m= ρ x v_w

= 8900 kg/m^3

m= 8900 x 8.54 x (10^-5)

= 0.7605 kg

$w_{(w)}$= mg

= 0.7605 x 9.81

= 7.46N

ii. Volume of worm gear

$(vol)_g$= Π/4 x(d_g)^2 x b

= 8.68 x (10^-4) m^3

Mass of worm gear

m= ρ(v)g

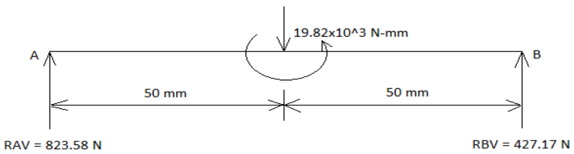
= 7850 kg/(m^3)

m= 7850 x 8.68 x (10^-4)

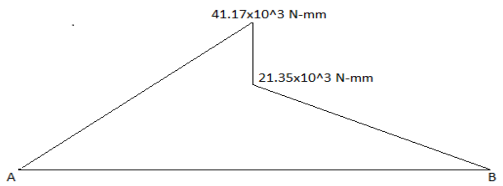
Therefore, $(m)_g$= 0.681 kg

Weight of worm gear w= mg= 6.688N

Vertical loading diagram & bending moment diagram:



(a) Vertical Loading Diagram



(b) Bending Moment Diagram

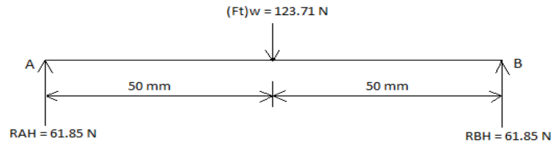
iii. Input shaft of gearbox:

1. Radial force at C (F_r)w= 1243.29

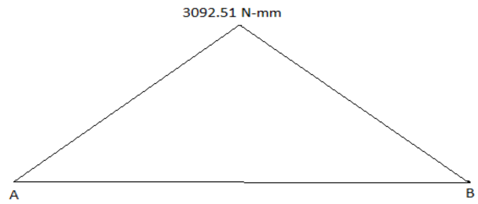
2. Weight of worm, W_w= 7.46N

3. Moment by axial force= 19.82 x (10^3) Nmm

Horizontal loading diagram & bending moment diagram:



(a) Horizotal Loading Diagram



(b) Bending Moment Diagram

Taking moment about point A,

∑MA=0

7.46 x 50 + 1243.29 x 50 – 19.82 x 10^3 – RB_V x 100 + 0

Therefore, RB_V= 427.17N

Now, ∑Fy=0

RA_V + RB_V = 7.46 + 1243.29

RA_V= 823.58N

Bending moment calculations,

MA_V=0

(MC_V)L= RA_V x 50= 41170 Nmm= 41.17 x (10^3) Nmm

(MC_V)R= RA_V x 123- 19.82 x (10^3) = 21.35 x (10^3)Nmm

MB_V= 0

Taking larger moment at C

MC_V= 41.17 x (10^3) Nmm

Forces in Horizontal load diagram

Tangential Force (F_t)w= (F_t)c= 123.71N

Taking moment at point A

∑MA= 0

123.71 x 50 – RB_H x 100= 0

RB_H= 61.85N

$∑F_Y$=0

$RA_H + RB_H - 123.71 = 0$

$RA_H = 61.88N$

Bending Moment calculations

$MA_H = 0$

$MC_H = RA_H \times 50 = 3092.5$ N-mm

$MB_H = 0$

Resultant moment at point C

MC= [(MC_v)^2 + (MC_H)^2]^(1/2)

= 41.28 x (10^3) N-mm

Torque at point C

T= F_t x d_w/2

Therefore, T= 2.47 x (10^3) N-mm

For resolving shaft with sudden load and minor shock,

$K_b = 1.5$

$K_t = 1$

Equivalent torque1

T_e= [(K_bM)^2 + (K_tT)^2]^(1/2)

Therefore, T_e= 61.96 x (1063) N-mm

Applying ASME code and considering keyway effect,

$\tau_{(permissible)}$= 0.75 x 0.18 x S_{ut}

= 101.25 N/mm^2

$\tau_{(permissible)}$= 0.75 x 0.3 x S_{yt}

= 85.5 N/mm^2

$\tau_{(max)}$= 16T_e/πd^3

Therefore, d = 15mm

2.5. Belt

After performing research on the belt-type oil skimmer, the belt was chosen. The material for the belt has been chosen as polyurethane. Among the materials available were steel, polyurethane, and nylon. The polyurethane belt is easily available on the market. The amount of oil to be removed determines the size of the belt. The expected capacity is in the range of 2-4 lph. For this project, the following belt size was chosen:

Belt width b= 86mm

Thickness of belt= 1.4mm

Full length of belt= 1550mm

2.6. Pulley

The belt must be properly oriented on a rotating element, such as a pulley or drum.

After analyzing the belt parameters, the type of pulley was established, and clearance according to Indian requirements was reported.

In terms of Indian standards,

Width of pulley B= 110mm (Including outer rims)

Outer Diameter of pulley= 100mm (Ref. Manufacturer's catalog & availability)

Belt width in mm	Width of a pulley to be greater than belt by (mm)
Up to 125	13
125-150	25
250-375	38
475-500	50

Table 3.1 Width of Pulley

[Reference: Table No. 19.2, Page Number 719 Design of Machine Elements- R.S. Khurmi]

2.7. Shaft

The shaft was designed according to ASME standards. The diameters of conventional pulleys were taken into account. On the home market, the most common material was picked.

Let's pretend the shaft is made of EN 19 steel. EN 19 was chosen as the preferred material due to its ductility, stress resistance, and wear resistance.

S_{ut}= 900 N/mm^2

S_{yt}= 460 N/mm^2

G= 80 x 10^3 N/mm^2

E= 200 x 10^3 N/mm^2

μ= 0.40

θ= 180 degrees

Allowable Shear stress for shaft is

τ_s= 0.75 x(0.18S_{ut})

= 0.75 x (0.18x900)

= 121.5 N/mm^2

τ_s= 0.75 x(0.3S_{yt})

= 0.75 x(0.3x460)

= 103.5 N/mm^2

Torque

P= (2πNT)/60000

373= (2π.30.T)/60000

T= 118.73 x(10^3) N.mm

Now,

F_1/F_2=e^(μθ)

F_1=3.51F_2

Where,

F_1= Tension in tight side

F_2= Tension in slack side

T=(F_1-F_2)xr_p

Where,

r_p= Radius of pulley= 50mm

118.73x (10^3) = (2.19F2-F2) x50

Therefore, F_2= 519.37 N

F_1= 2491.21 N

F= F_1+F_2= 3017.58N

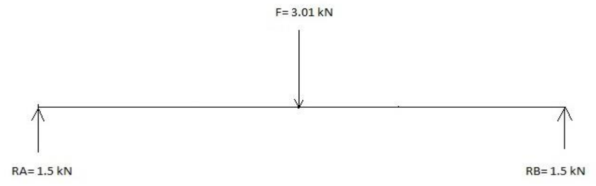
Reaction at end supports:

RA=RB=(F/2)

Therefore, RA=RB= 1508.29 N

Bending moments

∑MA=0 ∑MB=0



Loading Diagram of shaft

Length of shaft is 400mm

Max bending moment occurs at center point P.

MP= RAx200=241.40 x (10^3) N.mm

For revolving shaft of gradual loading,

k_b=1.5, k_t=1 [Ref. PSG design data book Pg. No. 7.21]

Equivalent Torque (T_e)

T_e= √[(k_b.MP)^2+(k_t.T)^2]

T_e=381.06x(10^3) N.mm

Dia. Of shaft

τ_{max}= 16T_e/π(d^3)

Therefore, d= 24 mm

2.8. Design of key:

We assume the square key made up of the same material as that of the shaft

For sq. key,

d= Dia. Of shaft= 24mm

l= Length of hub= 1.5d= 36mm

τ_d = Allowable shear stress, N/mm^2

T= Torque transmitted= 118.73 x(10^3) N.mm

Direct shear stress induced in the key is,

τ_d = 2T/dwl

Therefore, w = 2 mm

For square key, h=w=2mm

2.9. Bearing

We chose the standard bearing based on the calculated diameter of the shaft from R.B.Patil Design of Machine Elements II.

From Table No. 4.14.2 Design of Machine Elements II, R.B.Patil,

For Conveyor applications, Lh=8000 hrs

L10=Lh10.n.60/(10^6)

= 691.2 million revolutions

L10=[C/P_e]^a

Where P_e= XVF_r=8547.34 N(X=V=1 For machinery with no impact & self-aligning bearing.

From Table No. 4.15.1 Design of Machine Elements II, R.B.Patil

Diameter of shaft= 23mm

Bearing selected= 6204

Therefore, the Bearing selected is 6204. [Ref. Table 4.15.1 Design of Machine Elements II, R.B. Patil]

3. Modeling of Oil Skimmer parts using CATIA software

3.1. Pulley

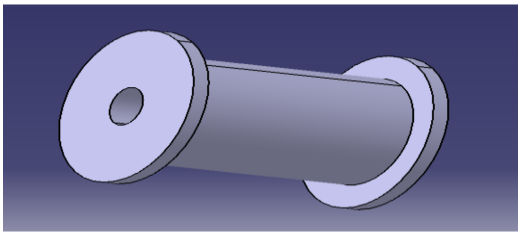


Fig 3.1 CATIA sketch of Pulley

3.2. Shaft

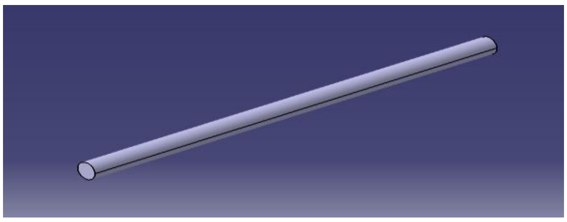


Fig 3.2 CATIA sketch of Shaft

3.3. Bearing

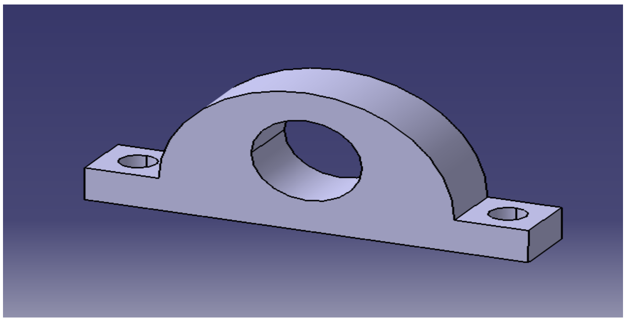


Fig 3.3 CATIA sketch of Bearing (With Bracket)

3.4. Belt

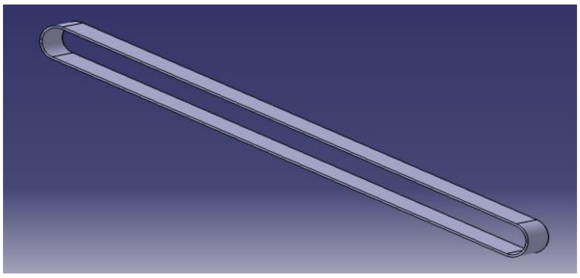


Fig 3.4 CATIA sketch of belt

3.5. Frame

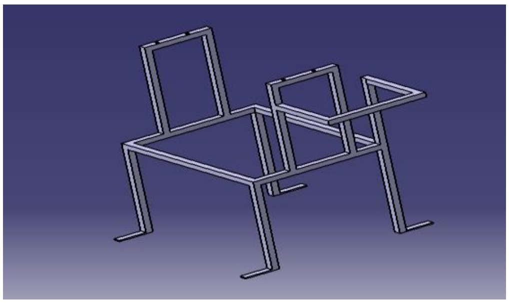


Fig 3.5 CATIA sketch of the frame

3.6. Scraper (Wiper)

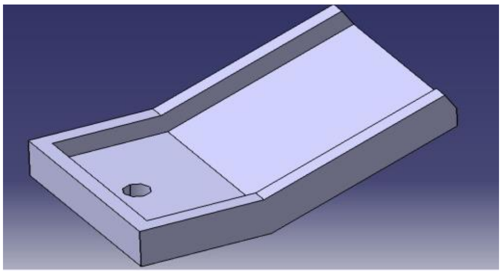


Fig 3.6 CATIA sketch of scraper

3.7. Tank

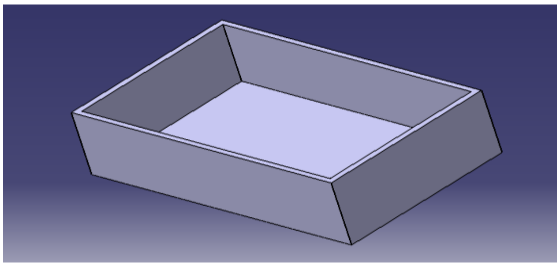


Fig 3.7 CATIA sketch of Tank

3.8. Nut & bolts

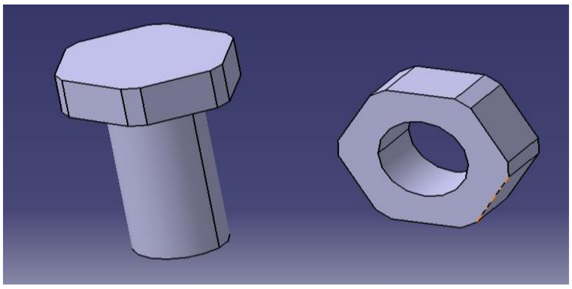


Fig 3.8 CATIA sketch of nut & bolt

3.9. Motor

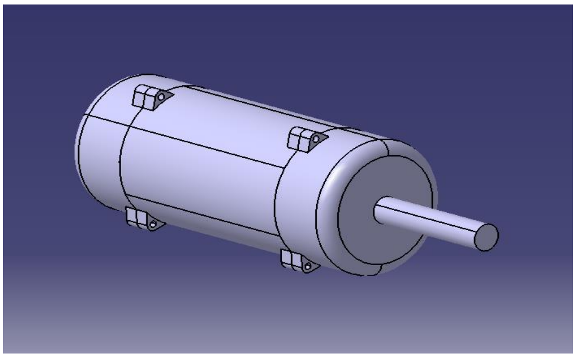


Fig 3.9 CATIA sketch of motor

3.10. Assembly

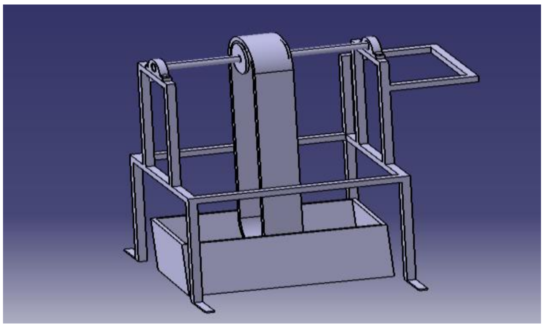


Fig 3.10 CATIA sketch of Assembly

4. Fabrication of Oil Skimmer

The material was chosen depending on what was available on the market. Mild steel was used for the majority of the components. The frame was designed with a 45-degree angle as the standard because it provided the most strength for the load on the base and frame. The metallic strips were removed with the use of a cutter. The markings were created with chalk.

Fig 4.1 Welded Angles

Sr. No.	Operation	Machine Used	Tool Used	Measuring Instrument	Time (min)
1	Marking			Measuring Tape	20
2	Cutting	Cutter	Cutting Wheel	Measuring Tape	15
3	Welding	Welding	Arc Welding	Measuring Tape	20

These strips were fused together at the joints using a welding gun and welding electrodes. The two sections were joined using an arc welding process. This is how the frame was created.

Fig 4.2 Frame Stage I

Bearings were purchased on the open market. The bearings were placed on the frame using a nut bolt system once the joints were created. Standard 3/8" and ¼" bolts are used.

Fig 4.3 Slots for mounting of bearings

A conventional lathe procedure was used to make the shaft. The huge rod was cut into little pieces with the required dimensions. Following that, the lathe machine was utilized for operations like facing and turning. This shaft was positioned between the bearings.

Fig 4.4 Mounting of shaft

Plastic pulleys were chosen because they are lightweight and inexpensive. These came in standard sizes and were installed on the shaft.

Fig 4.5 Mounting of Pulleys

The bottom pulley is held in place by a separate shaft that is supported by two pedestal bearings that are bolted to the tank.

The belt was installed between two shafts, and the motor was connected.

PROCESS SHEET: I

Name of component: Base frame

Material: M.S.

Dimensions: ISMB 500 x 400 mm

Sr. No.	Operation	Machine Used	Tool Used	Measuring Instrument	Time (min)
1	Marking		Chalk	Measuring Tape	20
2	Cutting	Cutter	Cutting Wheel	Measuring Tape	30
3	Welding	Welding	Arc Welding	Measuring Tape	50
4	Grinding	Hand Grinder	Grinding Wheel		15

Table 4.1 Process sheet I

Total Time= 115 minutes i.e. nearly 2 hours

PROCESS SHEET: II

Name of component: Tank

Material: M.S.

Dimensions: ISMB 450 x 325 mm

Sr. No.	Operation	Machine Used	Tool Used	Measuring Instrument	Time (min)
1	Marking			Measuring Tape	20
2	Cutting	Cutter	Cutting Wheel	Measuring Tape	15
3	Welding	Welding	Arc Welding	Measuring Tape	20

Table 4.2 Process sheet II

Total Time= 55 minutes i.e. nearly 1 hour

PROCESS SHEET: III

Name of component: Shaft

Material: M.S. EN 19

Dimensions: Diameter: 23mm Length: 400mm

Sr. No.	Operation	Machine Used	Tool Used	Measuring Instrument	Time (min)
1	Marking			Measuring Tape	5
2	Cutting	Cutter	Cutting Wheel	Measuring Tape	10
3	Facing	Lathe	Single point cutting tool	Vernier Caliper	15
4	Turning	Lathe	Single point cutting tool	Vernier Caliper	25

Table 4.3 Process sheet III

Total Time= 55 minutes i.e. nearly 1 hour

Final Assembly

Fig 4.6 Final Assembly

4.1 Cost Analysis

4.1.1 Material cost

Sr. no.	Component	Material	QTY.	Cost (in Rs.)
1	Motor	STD	1	5600
2	Gear box	STD	1	4130
3	Shaft	MS	2	1000
4	Bearing	CI	4	790
5	Pulley	Plastic	2	100
6	Belt	Polyurethane	1	560
7	Coupling	STD	2	1230
8	Tank	MS	1	250
9	Angle	MS	15	450
10	Strip	MS	4	48
11	Rod	MS	2	150
12	Bolt	STD	16	96
13	Nut	STD	16	96
14	Scraper	MS	1	110

Table 4.1.1 Bill of material

4.1.2 Labour Cost

Lathe machining- Rs. 600/-

Welding- Rs. 900/-

Drilling- Rs. 400/-

Cutting- Rs. 600/-

Coating- Rs. 200/-

4.1.3 Total Cost

Total cost= Material cost + Labour cost

= Rs. 14610 + Rs. 2700

= Rs. 17310/-

5. Experimental Validation & Result

The test on our project was conducted with SAE Grade 10w-30 motor oil.

Density of oil = 865 kg/m^3 at 30°C [Reference: www.EngineeringToolBox.com]

Quantity of oil used= 1. 500 ml

2. 1000 ml

Volume of tank= 0.026 m^3

Sr. No.	Amount of oil extracted (ml)	Test conducted for time (min)	Amount of oil used (ml)
1	385	8	500
2	800	18	1000

Table 5.1 Results

Therefore amount of oil extracted in 1 hour in litres (lph):

Reading 1: 2.9 lph

Reading 2: 2.7 lph

6. Conclusions

As a result, we can deduce from the project that we have successfully designed and constructed a tiny, lightweight model of a traditional belt-type oil skimmer. In order to succeed, we conducted a thorough investigation and examination of the drive unit, which included the motor and gearbox. Shaft, pulley, coupler, and belt are all spinning members that are analyzed and designed. The overall dimensions of the entire unit, including the tank, are kept as small as possible. We've determined that our project has a capacity of lph. This result is produced by carrying out the project in the lab and recording the amount of oil that is separated from the oil-water mixture in the tank.

As a result, in light of the current state of the globe and pollution from numerous sources, our project attempts to reduce total water pollution in a specific area. Oil wastage can also be avoided if the job is completed well.

7. References

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