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Design and Development of an Oil Skimmer for the Sugar Industry

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Abstract - *Environmental pollution has been recognized as the major problem of the modern world. In the recent decades, the many oil spillage accidents were occurred in the word, and eventually it harmed to alive and environments. So there is a need of an effective method to skim this oil from the surface of affected water (effluent/wastewater) to maintain the pH of water (2). The sugar factory is one of the major industries which have been incorporated in water polluting industries. Water quality parameters nearby the sugar industry are very high and exceeds the permissible limits. Since oils/grease are used for lubrication purpose in various sector of industry, oil spillage is occurred periodically. As a result, the effluent of industry is contaminated by this spilled oil (1). So that we have developed belt type oil skimmer to recover this oil, this skimmer works along with Effluent Treatment Plant which exists already at sugar industry. We have developed a simple mechanical device 'oil skimmer' which consists of a belt drive arrangement, AC motor and gearbox etc. It offers continuous operation for an efficient, cost effective oil removal process with almost 80 percent rate of oil recovery. This recovered oil can be reused or can be sold. This project aims to extract the oil from wastewater (effluent) of the sugar factory to reduce water pollution.*

Key Words: **oil spillage, oil pollution, water pollution, oil recovery, belt type oil skimmer, pH value, effluent, revenue, economical, environmental responsibility.**

1. INTRODUCTION

1.1. What is the 'Oil' and need of Oil Skimmer?

Oil is one of the valuable crudes and being employed in number of routine application incorporated in human life. As most of the oils are toxic, so it is quite harmful for alive when it comes to straight contact with human.

During the recent decade many oil spillage accidents were happened around the world and there was subsequent damage to both living things and environment. Many countries have formed strict safety norms for waste water disposal comprised with oils typically from petrochemical and process industries so that such industries are provided with suitable oil skimmers to separate the oils from disposal water.

1.2. Oil Skimming

One method of addressing and handling oil spills is oil skimming, a mechanical process of separating the oil from the water (1). Skimming can be performed by variety of techniques and is the only large scale method for actually retrieving the oil. The collection of spilled oil is performed by means of special devices which are called as oil skimmers.

All skimmers are designed to recover the oil in preference to water, but designs may vary considerably according to the intended usage. In our project, we have decided to develop belt type oil skimmer for intended purpose as it is reliable and perfect for permanent installation.

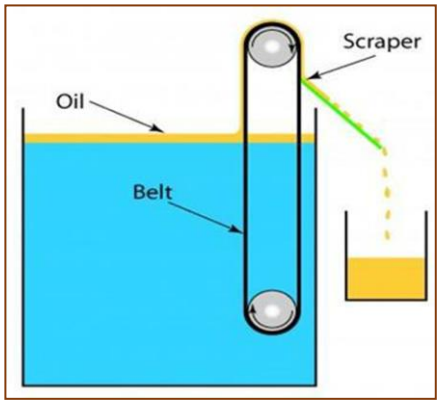


Fig -1: General Layout

1.3. Benefits of Removing Oil from water

- Reduces cost associated with disposal water
- Generates new revenue
- Enhances environmental responsibility.
- Provides a safe environment to work.
- Improves efficiency of overall waste water treatment system, which shortens maintenance and treatment costs.

2. PROBLEM STATEMENT

The wastewater coming out from the sugar factory cannot be used for agriculture purpose or other purpose because it is highly contaminated with impurities and has low pH value. All contaminants are minimized in Effluent Treatment Plant, but the major problem which is much more concerned in the context of growth of industry is that the removal of maximum possible amount of oil and grease from wastewater. The problem statement for the current project is to design and develop the suitable oil skimmer for E.T.P. section at the sugar factory to recover the oil and grease continuously from wastewater to minimize water pollution and promotes the industrial growth.

Fig -2: Effluent Treatment Plant

3. PROPOSED LAYOUT OF BELT OIL SKIMMER

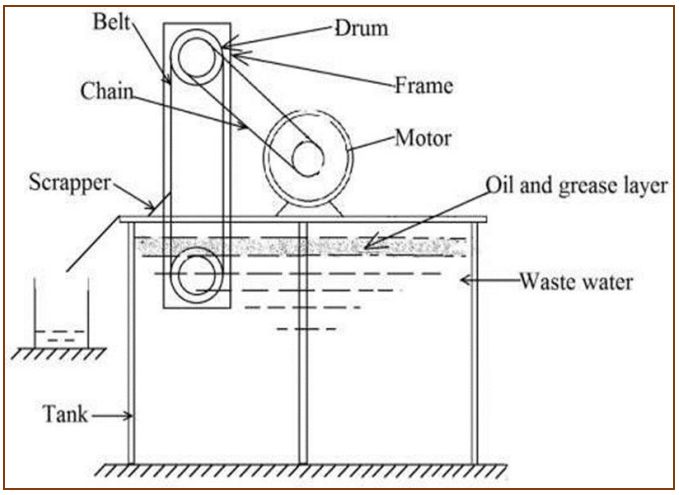


Fig -3: Proposed layout

4. DESIGN AND SELECTION OF PARTS

In the current scenario, there are various types of oil skimmers are readily available in market, but they may not be suited for certain conditions at concerned industry. Here we have made the design and selection of parts for our tailor made oil skimmer as follows.

4.1. Selection of Motor

Power requirement = 656 watt.

Oil skimming to be done continuously, so that we have selected 1 hp, 1500 rpm. 230 v, AC Motor.

4.2. Selection and Design of gearbox (9)

A conveyor for oil skimming is supposed to run 8 to 10 hours per day with minimum shock loading. The motor to be used have a nominal speed of 1500 rpm. The conveyor speed need to be 40 rpm. This requirement of lowering speed is fully accomplished by the one type of gearbox, which is known as worm gear box. Thus, **Worm Gear box** is used for large reduction of speed from input speed of around 1500 rpm to 40 rpm which is required output speed for operation of oil skimmer.

Considering all the given data and specification table, "WGA-50M-030-H1" worm gearbox found suitable for intended application. It was manufactured by 'Minraj Gears, Gokul Shirgaon Kolhapur'.

4.3. Design of Chain drive (4)

All the final specifications of chain drive after designing are as follows:

Type and No. of chain: - simple bush roller chain with single strand, Chain No. 16 A

Number of teeth on smaller sprocket: - 27

Number of teeth on larger sprocket: - 33

Pitch: - 25.40 mm

Centre distance between sprockets: - 758 mm

Length of chain: - 2.27 m

Result Checking:

Speed of Conveyor = ((O/P Speed of Gearbox × T_1))/T_2

Where, T_1 = No. of teeth on GB shaft sprocket = 27

T_2 = No. of teeth on Roller Shaft sprocket = 39

Therefore,

Speed of Conveyor = 40.15 rpm ≈ 40 rpm (as required)

4.4. Design of Conveyor system

Length of conveyor from center to center- 2 m

Orientation – Vertical

Maximum capacity per hour - 20 Kg oil sludge / hour

Nature of material to be transfer – Oily and Grease type

The volumetric capacity of belt conveyor s given by,

$Q = Cb^2 v = C (0.9B-0.05) v$

Where, C= Surcharge factor = 1 (Flat belt drive),

B= width of belt = 300 mm (std. value)

$Q = 0.25327 m^3/s$

4.5. Design of Belt and Rollers

Belt material – Canvas, tensile strength 700 N/mm^2

$$\text{Velocity of belt} = \frac{\pi D N}{60} = \frac{\pi \times 0.250 \times 40}{60} = 0.523 \text{ m/s}$$

Where D = Diameter of rollers = 250 mm (Std. value)

For the sake of operation of oil skimmer, we have selected center to center distance between drum as,

C =2 m = 2000 mm

Length of belt = 2C + π.D = (2×2000) + (π ×250) = 5.41 m

4.6. Design of Shaft and Key

Material selected for shaft is EN24 as its having excellent machinability.

Considering torsional moment and bending stress, we get the value of diameter of shaft as 25 mm for safe design.

For this application sunk key is used of grade 30C8 with designed dimensions as 6 × 6 × 35, which are b, h and l respectively.

4.7. Selection of Bearing

The proposed oil skimmer is supposed to be used for continuous operation per day. So that bearing should work properly for 5 years. And therefore, bearing life is calculated as 43800 hours.

For this life of bearing, after design calculations, we have selected single row deep groove ball bearing from SKF bearing catalogue of designation “61804”.

5. CAD MODELLING AND FEA OF DRIVE SHAFT

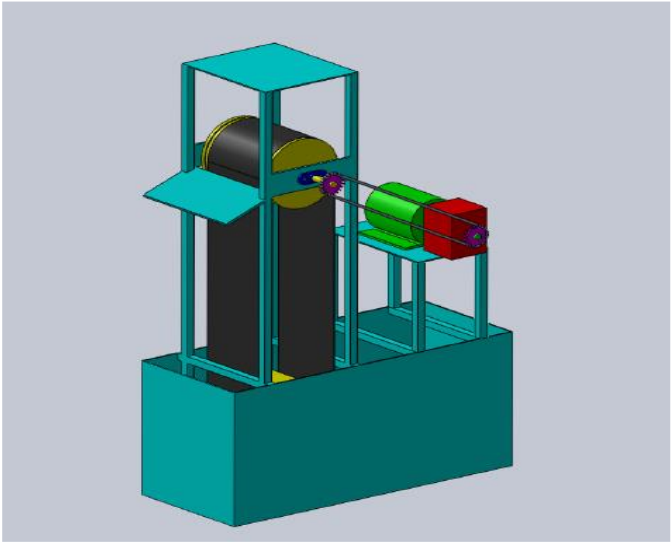


Fig -4: Assembly model of belt oil Skimmer

5.1. F.E.A. of Drive Shaft of Conveyor

In our project, belt oil skimmer has one important part i.e. drive shaft of belt drive which supports first roller of conveyor for skimming. Here, we have assumed that this drive cum roller shaft of system undergoes certain loading condition due to linkage with chain drive, even though the loading values are not having high value due to minor loading, we have performed static and dynamic analysis of the drive shaft in the ‘ANSYS Workbench’ software.

Apart from this, we have checked for optimization of shaft to reduce diameter of it.

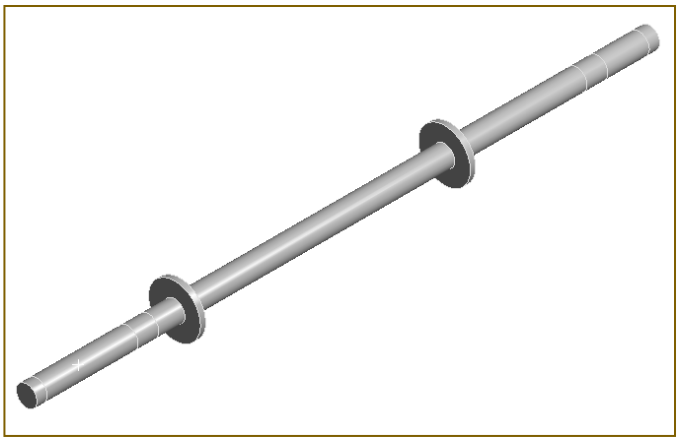


Fig -5: Geometry of drive shaft to be analyzed

Fig. 5 shows geometry of shaft to be analyzed. Diameter of shaft is 25 mm as per design calculation made previously

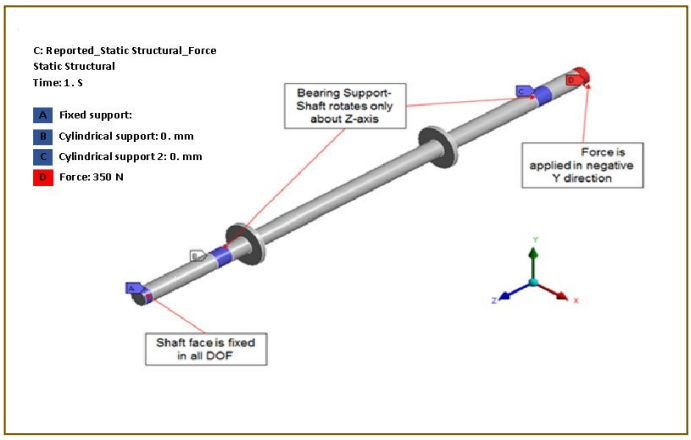


Fig -6: loading & boundary conditions for static analysis

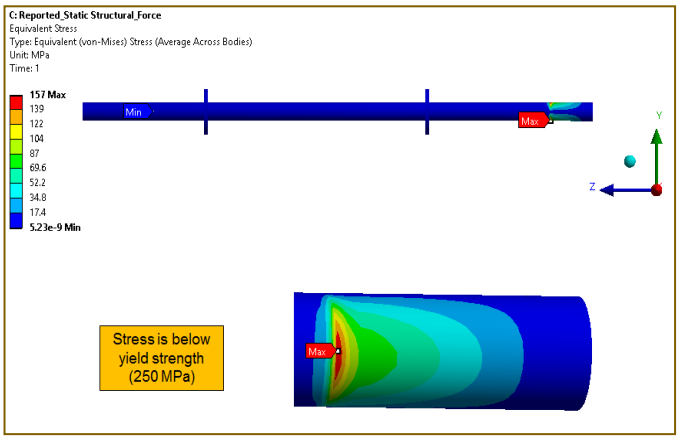


Fig -9: Von Mises Stress Plot

- **Deformation and Stress plots for static analysis**

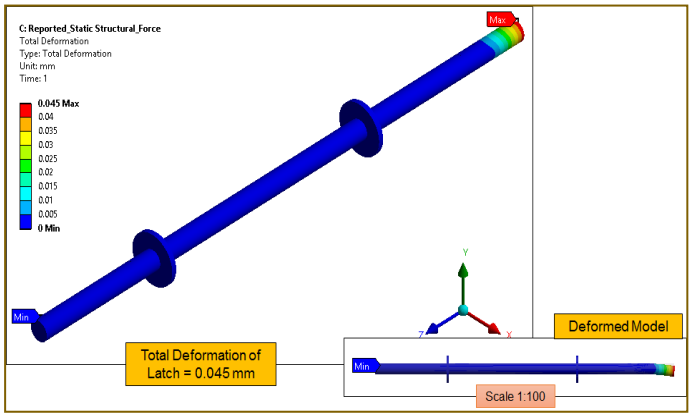


Fig -7: Total deformation plot

Figure 7 shows the total deformation value of support roller shaft. Red zone shows the prime area where deformation occurs most. Deformation is occurring at the end of shaft where chain drive is coupled with conveyor assembly. The plot is taken at exaggerated scale for visualization purpose only but in actual case the deformation is too small i.e. **0.045 mm**, so that it is neglected.

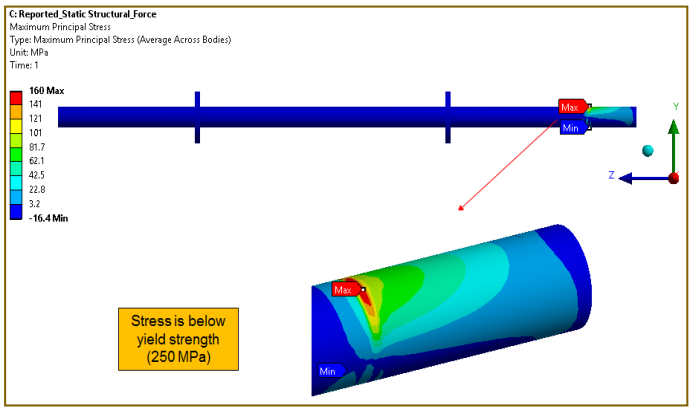


Fig -8: Maximum Principal Stress

5.2. Conclusion and Recommendation

Conclusion -

- Maximum value of deformation obtained is 0.045 mm, which is negligible
- The Equivalent von-Misses stress in shaft is equal to 157 Mpa, which is below the yield strength (250 MPa).
- The Maximum Principal Stress in shaft is 160 Mpa, which isbelow the yield strength (250 MPa).

Recommendation-

The diameter of shaft can be reduced by near about 20 % for optimization of geometry and cost as far as the skimming is to be done in multiple stages. Although, we have developed single stage oil skimmer, the shaft diameter is reduced to 20 mm and it is found that geometry optimization is safe in current scenario.

6. FABRICATION AND INSTALLATION OF SKIMMER

Fabrication is the process of constructing a product by combining typically standard parts together by using one or more processes. Here in our project, standard parts are such as drums, belt drive conveyor, chain drive, motor and gearbox etc. all the parts are designed or selected as discussed in design chapter before commencement of actual fabrication. The processes in fabrications include bending, cutting and assembling.

Fabrication of belt oil skimmer is generally all about the assembly of all selected and standard parts to form a product called as 'belt oil skimmer' to be used in the skimming operation at E.T.P plant at Sugar Factory.

Fig -10: Assembly cum installation of full-fledged skimmer

Fig. 8 shows the assembly of entire set up, which took place at desired location at E.T.P. of sugar factory. This include fabrication of frame and many sub-assemblies or mountings such as conveyor assembly, scraper mounting, chain drive mounting and mounting of gearbox and motor.

6.1. Working of belt oil skimmer

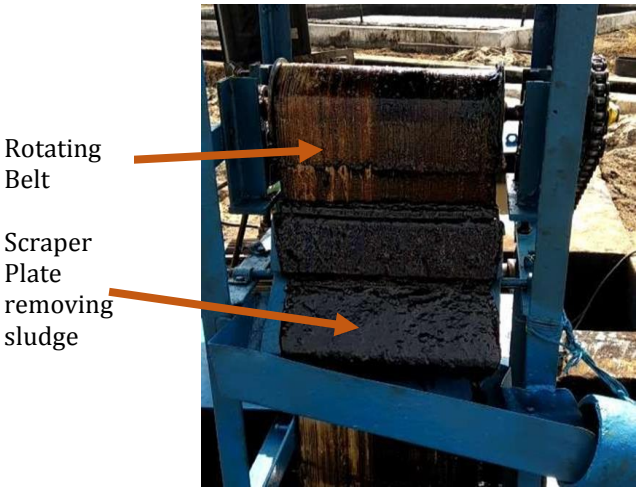


Fig -11: Demonstrative image of oil skimmer

As the belt which is dipped in effluent gets rotated the layer of impurities floating over effluent get attracted towards belt of conveyor. This conveyor belt with adhered impurities like oil and sludge etc. will move forward towards scraper plate during rotation. This scraper plate performs assigned function which is to remove that layer of oil from belt. The removed oil with some other impurities is collected in another tank.

This tailor made belt oil skimmer works continuously to remove oil from effluent. As it is continuous operation, the maximum amount or all the impurities can be extracted from wastewater to reduce water pollution.

The retrieved amount of oil after filtration is then undergone for testing to check whether its required properties are changed or not. Then, according to result, this oil is stored for reusing within industry for lubrication or boiler firing process.

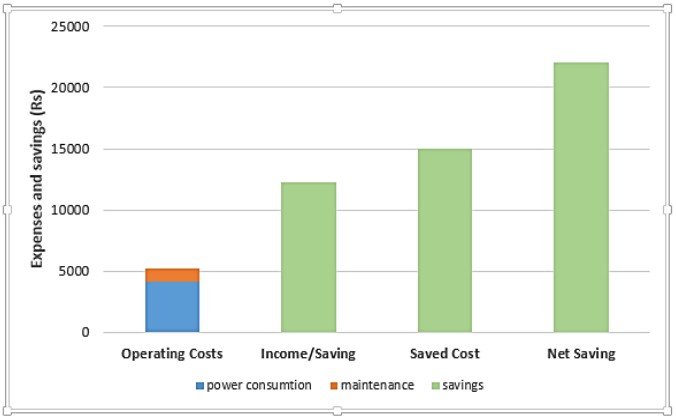
7. RESULTS BY OBSERVATIONS AND TESTING

Oil removal rate of oil skimmer = 0.85 lit/hr. = 612 lit/month.

$$\text{Recovery of oil per month \%} = \frac{recovered\ oil\ (l)}{total\ spilled\ oil\ (l)} \times 100$$

$$= \frac{612}{800} \times 100 = \mathbf{76.5\ \%}$$

Net saving of factory per month by after employing our developed oil skimmer is calculated as equal to **22,060 Rs.**



Graph -1: Expenses vs. Savings (per month)

Net saving of factory per one season (of 6 months) every year is equal to **1, 32,360 Rs.**

7.1. pH and Viscosity measurement

It is necessary to check the pH value of wastewater after removal of oil from it. It is seen that the pH of water is improved by using developed oil skimmer.

Most importantly, it is seen that pH value of wastewater is in the limit as directed by Maharashtra Pollution control Board (MPCB). This was sign of satisfaction to accomplish the motive of this project. The results are as shown in table 1.

Table -1: pH measurement

	Before oil skimmer	After oil skimmer	MPCB limit (standard value)
pH	**2.5 - 4.5**	**6.3**	**6.1 -9.5**

We have used 'Brookfield Viscometer' to measure the viscosity of recovered oil by our oil skimmer from effluent in E.T.P. it is important testing as far as quality of oil is concerned. We have measured viscosity of oil before and after separation as shown in table-2.

Table -2: Oil Viscosity and Efficiency

	Oil viscosity (cP)		Efficiency
	Before Skimming	After skimming	
Oil(mixed)	114.4	104.5	**91.34 %**

8. CONCLUSIONS

The tailor-made oil skimmer made as per requirements of target customer i.e. sugar industry, has been performing successfully and accomplishing all the desired outcomes after separation of oil from sugar factory's waste water. The subsequent trial and testings' conducted shows that, the design and development of oil skimmer satisfies the motive behind the project to reduce water pollution at great extent.

pH value of effluent after separation of oil is in the range as prescribed by Maharashtra Pollution control Board (MPCB), so that wastewater can be reused following oil removal which reduces water consumption by industry.

It is also enhancing the ability to reuse and/or recycle skimmed oil. It is also beneficial from the economical point of view as it generates new revenue and reduces costs associated with wastewater disposal.

The significance of oil skimmer is more than revenue for industry as it enhances the environmental responsibility. It helps to provide safer work environment. It improves overall efficiency of Effluent Treatment Plant.

The tailor-made belt type oil skimmer offers continuous operation for an efficient, cost effective oil removal process.

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