A PROJECT REPORT

ON

"ALGAE TO BIOFUEL"

Submitted by

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In partial fulfillment for the award of the Degree

Of

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UNDER THE GUIDANCE

Of

Prof. SHAKIL TADVI

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To the Kalsekar Technical Campus, New Panvel is a record of bonafide work carried out by him under our supervision and guidance, for partial fulfillment of the requirements for the award of the Degree of Bachelor of Engineering in Mechanical Engineering as prescribed by **University Of Mumbai**, is approved.

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APPROVAL OF DISSERTATION

This is to certify that the thesis entitled **"ALGAE TO BIOFUEL"**

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Declaration

We declare that this project report represents our ideas in our own words and where others ideas or words have been included, we have adequately cited and referenced the original sources. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any data/fact in our submission. We understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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ABSTRACT:

Biodiesel is biodegradable, less NOx CO and C02 emissions. Continued use of petroleum sourced fuels is now widely recognized as unsustainable because of depleting supplies and the contribution of these fuels to the accumulation of carbon dioxide in the environment. Renewable, carbon neutral, transport fuels are necessary for environmental and economic sustainability. Sustainable production of renewable energy is being hotly debated globally since it is increasingly understood that first generation biofuels, primarily produced from food crops and mostly oil seeds are limited in their ability to achieve targets for biofuel production, climate change mitigation and economic growth. These concerns have increased the interest in developing second generation biofuels produced from nonfood feed stocks such as microalgae, which potentially offer greatest opportunities in the longer term. Microalgae have emerged as one of the most promising sources for biodiesel production. It can be inferred that microalgae grown in C02-enriched air can be converted to oily substances. Such an approach can contribute to solve major problems of air pollution resulting from C02 evolution and future crisis due to a shortage of energy sources.

Thinking about these elements, exhibit work focused on generation of Biodiesel from the Microalgae by Expeller Method. This project is concerned with the analysis and development of a algae oil extracting machine Further the aim of the project is to increase the understanding of the operation of the machine, and identify and implement methods of improving the performance.

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CHAPTER NO 1: INTRODUCTION

Concerns about shortage of fossil fuels, increasing crude oil price, energy security and accelerated global warming have led to growing worldwide interests in renewable energy sources such as biofuels. An increasing number of developed and rapidly developing nations see biofuels as a key to reducing reliance on foreign oil, lowering emissions of greenhouse gases (GHG), mainly carbon dioxide (CO2) and methane (CH4), and meeting rural development goals . Biofuels are referred to solid, liquid or gaseous fuels derived from organic matter. They are generally divided into primary and secondary biofuels (Fig. 1.1). While primary biofuels such as fuelwood are used in an unprocessed form primarily for heating, cooking or electricity production, secondary biofuels such as bioethanol and biodiesel are produced by processing biomass and are able to be used in vehicles and various industrial processes. The secondary biofuels can be categorized into three generations: first, second and third generation biofuels on the basis of different parameters, such as the type of processing technology, type of feedstock or their level of development .

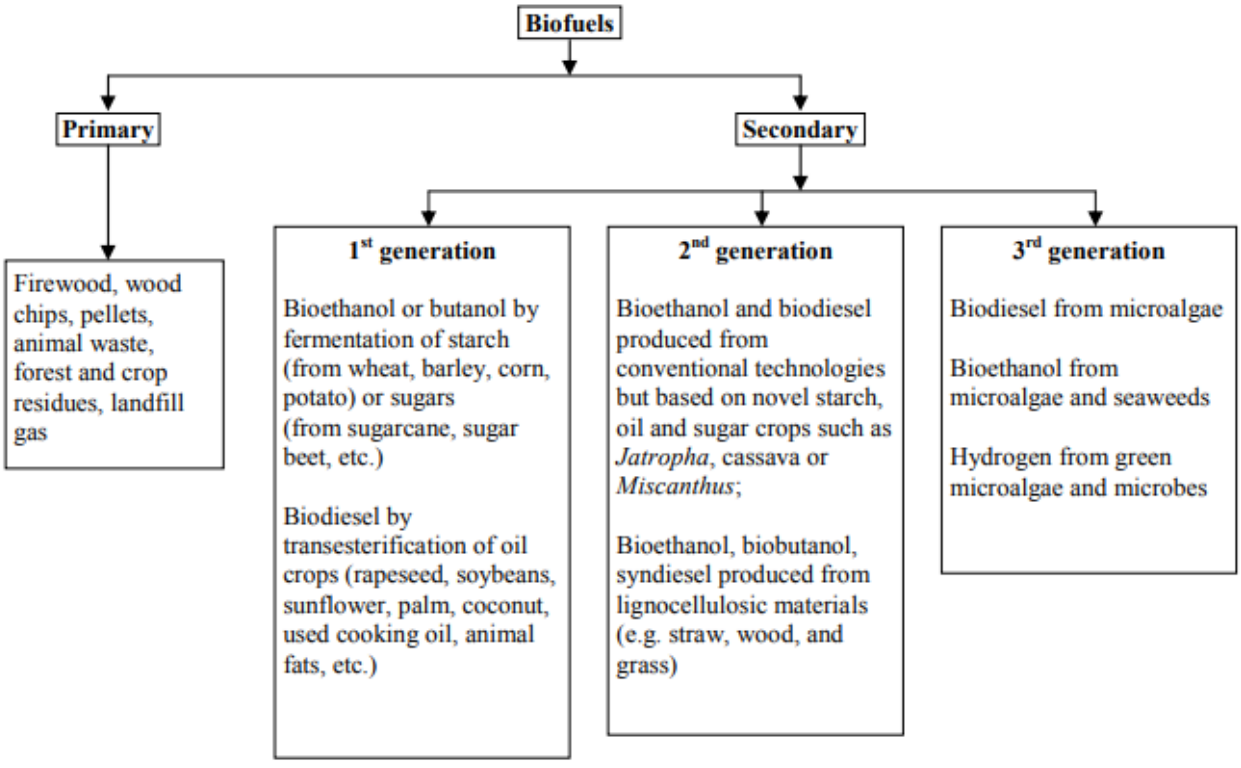


Fig. 1.1 Classification of Biofuels.

Although biofuel processes have a great potential to provide a carbon-neutral route to fuel production, first generation production systems have considerable economic and environmental limitations. The most common concern related to the current first generation biofuels is that as production capacities increase, so does their competition with agriculture for arable land used for food production. The increased pressure on arable land currently used

for food production can lead to severe food shortages, in particular for the developing world where already more than 800 million people suffer from hunger and malnutrition. In addition, the intensive use of land with high fertilizer and pesticide applications and water use can cause significant environmental problems .

The advent of second generation biofuels is intended to produce fuels from lignocellulosic biomass, the woody part of plants that do not compete with food production. Sources include agricultural residues, forest harvesting residues or wood processing waste such as leaves, straw or wood chips as well as the non-edible components of corn or sugarcane. However, converting the woody biomass into fermentable sugars requires costly technologies involving pre-treatment with special enzymes, meaning that second generation biofuels cannot yet be produced economically on a large scale

Therefore, third generation biofuels derived from microalgae are considered to be a viable alternative energy resource that is devoid of the major drawbacks associated with first and second generation biofuels [2, 5, 6]. Microalgae are able to produce 15–300 times more oil for biodiesel production than traditional crops on an area basis. Furthermore compared with conventional crop plants which are usually harvested once or twice a year, microalgae have a very short harvesting cycle (≈1– 10 days depending on the process), allowing multiple or continuous harvests with significantly increased yields.

CHAPTER NO 2: LITERATURE SURVEY

Advantage of using microalgae for biodiesel production has been reported by a number of workers . The interest in microalgae for biodiesel started in 1970s during the first oil crisis due to high oil yields. The average oil yield is reported between 1% and 70% but under certain conditions, some species can yield up to 90% of dry biomass weight . The variation in fatty acid composition of oil from different algae species is reported by several authors. In fact, several studies have reported the use of microalgae for the production of bio- diesel and other by products.

Oil extraction from algae is one of the costly processes that can determine the sustainability of algae-based bio- diesel. In order to produce biodiesel from microalgae lipids, the later must be priory extracted. The main lipid extraction techniques are the use of chemical solvents, supercritical CO2, physicochemical, biochemical and direct transesterification.Chemical solvents extraction Chemical solvents method is by far the most commonly used, but less effective when microalgae are still wet (Samorì et al., 2010). Consequently, for laboratory scale extraction of lipids, freeze-drying (J. Lee et al., 2010) is a popular method, but spray-drying (Koberg et al., 2011), oven-drying (Cooney et al., 2009) or vacuum-evaporation (Umdu et al., 2009) have also been used to dry microalgae. However, drying microalgae prior to lipid extraction could require 2.5 times more energy than a process without drying, which makes a process using a prior drying unprofitable (negative balance) (Lardon et al., 2009).

In laboratory scale studies, even if chloroform-methanol blends have been extensively used with high extraction yields up to 83% (g lipid/g dry weight) (Yaguchi et al., 1997), less polar solvent like hexane are often preferred because of their lower toxicity and affinity for nonlipid contaminants (less polar) (Halim et al., 2010). As an example, hexane was used to obtained lipids content up to 55% (g lipid/g dry weight) from a heterotrophic microalgae, Chlorella protothecoides (Miao & Wu, 2006). For microalgae lipid extraction on an industrial scale, Soxhlet extraction is not recommended due to high energy requirement (Halim et al., 2010). Other less toxic solvents like alcohols (ethanol, octanol) or 1,8-diazabicyclo-[5.4.0]-undec-7- ene (DBU) have been tested but the yield of fatty acid methyl ester (FAME) obtained was up to 5 times lower than with n-hexane extraction (Samorì et al., 2010) even if the hydrocarbon (lipid) yield was more than twice higher.

Supercritical carbon dioxide extraction Supercritical CO2 (Dhepe et al., 2003) has the advantages of being not toxic, easy to recover and usable at low temperatures (less than 40˚C) (Andrich et al., 2005). However, this technique requires expensive equipments (Perrut, 2000) and a huge amount of energy to reach high pressures (Tan & Lee, 2011). Few studies used supercritical CO2 extraction to recover microalgae lipids and transformed them into biodiesel (Halim et al., 2010) even if some studies obtained lipid content up to 26% (g lipid/g dry weight) from Nannocloropsis sp. (Andrich et al., 2005).

Using supercritical CO2 extraction at operating temperature of 60˚C and pressure of 30 MPa to extract lipids from Chlorococcum sp. microalgae, Halim et al. (2010) obtained a higher extraction yield of lipids with supercritical CO2 than hexane Soxhlet extraction (5.8 and 3.2% (g lipid/g dry weight), respectively). Moreover, using supercritical CO2 extraction with wet microalgae, Halim et al. (2010) obtained a maximum yield of lipids of 7.1% (g lipid/g dry weight) for the same experimental conditions, which was a relatively Production of Biodiesel from Microalgae 253 low lipid yield compared to other species such as Botryococcus sp. (28.6% g lipid/g dry weight) (J. Lee et al., 2010). Consequently, in opposition to chemical solvent extraction, supercritical CO2 lipid extraction can be stimulated by the presence of water in the blend of microalgae. Physicochemical extraction Some physicochemical techniques like microwave, autoclaving, osmotic shock, bead-beating, homogenization, freeze-drying, French press, grinding and sonication can be used for microalgae cell disrupting in order to recover lipids (Cooney et al., 2009; J. Lee et al., 2010; S. Lee et al., 1998). Using microwave or bead-beating seems to be the most promising techniques to increase the lipid yield. As an example, J. Lee et al. (2010) increased the lipid extraction yield of Botryococcus sp. microalgae in water phase from 7.7 to 28.6% (g lipid/g dry weight) using a 5 min microwave pretreatment. 3.3.4 Biochemical extraction Few studies have used biochemical extraction to extract lipids from microalgae. Using a 72 h cellulase hydrolysis pretreatment of the Chlorella sp. microalgae, Fu et al. (2010) have obtained a hydrolysis yield of sugars of 70% (concentration reducing sugar/concentration total sugar), although the lipids yield has increased only from 52 to 54% (g lipid/g dry weight).

Direct transesterification is a process that blends the microalgae with an alcohol and a catalyst without prior extraction. Number of acid catalysts have been investigated for heterotrophic microalgae biomass including hydrochloric (HCl) or sulphuric acid (H2SO4) but acetyl chloride (CH3COCl) remains the catalyst producing the higher FAME yield of 56% (g FAME /g dry weight) (Cooney et al., 2009). A less polar solvent, like hexane or chloroform, can be added to increase the yield of biodiesel production (M. B. Johnson & Wen, 2009).

Direct transesterification using a heterogeneous catalyst could be more effective coupled with microwaves heating. As an example, using microwave with direct transesterification of Nannochloropsis in presence of a heterogeneous catalyst (SrO), Koberg et al. (2011) reported an increase in the FAME yield from 7 to 37% (g FAME /g dry weight). However, direct transesterification requires a dry biomass, increasing the cost of harvesting. 3.4 Transesterification The direct use of crude vegetable oils in diesel engines is envisageable, but could lead to numerous technical problems.

For example, their characteristics (high viscosity, high density, difficulty to vaporize in cold conditions) cause deposits in the combustion chamber, with a risk of fouling and an increase in most emissions (Basha et al., 2009). These drawbacks can be mitigated, but not without some modifications of the diesel engine (Altin et al., 2001). To overcome all these inconveniences, the transformation of microalgae lipids in corresponding esters is essential.

CHAPTER NO 3: ALGAE

ALGAE :

Algae have been used in animal and human diets since very early times. Filamentous algae are usually considered as 'macrophytes' since they often form floating masses that can be easily harvested, although many consist of microscopic, individual filaments of algal cells. Algae also form a component of periphyton, which not only provides natural food for fish and other aquatic animals but is actively promoted by fishers and aquaculturists as a means of increasing productivity. This topic is not dealt with in this section, since periphyton is not solely comprised of algae and certainly cannot be regarded as macroalgae. However, some ancillary information on this topic is provided in Annex 2 to assist with further reading. Marine 'seaweeds' are macro-algae that have defined and characteristic structures.

Microalgal biotechnology only really began to develop in the middle of the last century but it has numerous commercial applications. Algal products can be used to enhance the nutritional value of food and animal feed owing to their chemical composition; they play a crucial role in aquaculture. Macroscopic marine algae (seaweeds) for human consumption, especially *nori* (*Porphyra* spp.), *wakame* (*Undaria pinnatifida*), and *kombu (Laminaria japonica)*, are widely cultivated algal crops. The most widespread application of microalgal culture has been in artificial food chains supporting the husbandry of marine animals, including finfish, crustaceans, and molluscs.

The culture of seaweed is a growing worldwide industry, producing 14.5 million tonnes (wet weight) worth US$7.54 billion in 2007 (FAO, 2009). The use of aquatic macrophytes in treating sewage effluents has also shown potential. In recent years, macroalgae have been increasingly used as animal fodder supplements and for the production of alginate, which is used as a binder in feeds for farm animals. Laboratory investigations have also been carried out to evaluate both algae and macroalgae as possible alternative protein sources for farmed fish because of their high protein content and productivity.

Microalgae and macroalgae are also used as components in polyculture systems and in remediation; although these topics are not covered in this paper, information on bioremediation is contained in many publications, including Msuya and Neori (2002), Zhou *et al*. (2006) and Marinho-Soriano (2007). Red seaweed (*Gracilaria* spp.) and green seaweed (*Ulva* spp.) have been found to suitable species for bioremediation. The use of algae in integrated aquaculture has also been recently reviewed by Turan (2009).

3.1 Classification

The classification of algae is complex and somewhat controversial, especially concerning the blue-green algae (Cyanobacteria), which are sometimes known as blue-green bacteria or Cyanophyta and sometimes included in the Chlorophyta. These topics are not covered in detail this document. However, the following provides a taxonomical outline of algae.

- Chlorophyta (green algae)
- Rhodophyta (red algae)
- Glaucophyt
- Rhizaria, Excavata
- Chlorarachniophytes
- Bacillariophyceae (diatoms)
- Axodine
- Bolidomonas
- Eustigmatophyceae
- Phaeophyceae (brown algae)
- Chrysophyceae (golden algae)
- Raphidophyceae
- Synurophyceae
- Xanthophyceae (yellow-green algae)
- Cryptophyta
- Dinoflagellates
- Haptophyta

The following sections discuss the characteristics and use of both 'true' algae and the Cyanophyta, hereinafter referred to as 'blue-green algae').

3.2 Characteristics of microalgae

Microlgae, recognised as one of the oldest living organisms, are thallophytes (plants lacking roots, stems, and leaves) that have chlorophyll *a* as their primary photosynthetic pigment and lack a sterile covering of cells around the reproductive cells . While the mechanism of photosynthesis in these microorganisms is similar to that of higher plants, they are generally more efficient converters of solar energy because of their simple cellular structure. In addition, because the cells grow in aqueous suspension, they have more efficient access to water, CO_2, and other nutrients .

Traditionally microalgae have been classified according to their colour and this characteristic continues to be of a certain importance. The current systems of classification of microalgae are based on the following main criteria: kinds of pigments, chemical nature of storage products and cell wall constituents. Additional criteria take into consideration the following cytological and morphological characters: occurrence of flagellate cells, structure of the flagella, scheme and path of nuclear and cell division, presence of an envelope of endoplasmic reticulum around the chloroplast, and possible connection between the endoplasmic reticulum and the nuclear membrane . There are two basic types of cells in the algae, prokaryotic and eukaryotic. Prokaryotic cells lack membrane-bounded organelles (plastids, mitochondria, nuclei, Golgi bodies, and flagella) and occur in the cyanobacteria. The remainder of the algae are eukaryotic and have organelles .

Microalgae can be either autotrophic or heterotrophic. If they are autotrophic, they use inorganic compounds as a source of carbon. Autotrophs can be photoautotrophic, using light as a source of energy, or chemoautotrophic, oxidizing inorganic compounds for energy. If they are heterotrophic, microalgae use organic compounds for growth. Heterotrophs can be photoheterotrophs, using light as a source of energy, or chemoheterotrophs, oxidizing organic compounds for energy. Some photosynthetic microalgae are mixotrophic, combining heterotrophy and autotrophy by photosynthesis . For autotrophic algae, photosynthesis is a key component of their survival, whereby they convert solar radiation and CO_2 absorbed by chloroplasts into adenosine triphosphate (ATP) and O_2, the usable energy currency at cellular level, which is then used in respiration to produce energy to support growth .

Microalgae are able to fix CO_2 efficiently from different sources, including the atmosphere, industrial exhaust gases, and soluble carbonate salts. Fixation of CO_2 from atmosphere is probably the most basic method to sink carbon, and relies on the mass transfer from the air to the microalgae in their aquatic growth environments during photosynthesis. However, because of the relatively small percentage of CO_2 in the atmosphere (approximately 0.036

%), the use of terrestrial plants is not an economically feasible option . On the other hand, industrial exhaust gases such as flue gas contains up to 15 % CO_2, providing a CO_2-rich source for microalgal cultivation and a potentially more efficient route for CO_2 bio-fixation. Many microalgal species have also been able to utilize carbonates such as Na_2CO_3 and $NaHCO_3$ for cell growth. Some of these species typically have high extracellular carboanhydrase activities, which is responsible for the conversion of carbonate to free CO_2 to facilitate CO_2 assimilation. In addition, the direct uptake of bicarbonate by an active transport system has also been found in several species .

Growth medium must provide the inorganic elements that constitute the algal cell. Essential elements include nitrogen (N) and phosphorus (P). Minimal nutritional requirements can be estimated using[4] the approximate molecular formula of the microalgal biomass, which is $CO_{0.48}H_{2.83}N_{0.11}P_{0.01}$. Nitrogen is mostly supplied as nitrate (NO^-), but often ammonia (NH^+) and urea are also used. Urea is most favourable as the nitrogen source because, for an equivalent nitrogen concentration, it gives higher yields and causes smaller pH fluctuations in the medium during algal growth . On the other hand, nutrients such as P must be supplied in significant excess because the phosphates added complex with metal ions, therefore, not all the added P is bio-available . Furthermore, microalgae growth depends not only on an adequate supply of essential macronutrient elements (carbon, nitrogen, phosphorus, silicon) and major ions (Mg^+, Ca^+, Cl^-, and SO^{2-}) but also on a number of micronutrient metals such as iron, manganese, zinc, cobalt, copper, and molybdenum .

3.2.1 Filamentous algae

Filamentous algae are commonly referred to as ‘pond scum’ or ‘pond moss’ and form greenish mats upon the water surface. These stringy, fast-growing algae can cover a pond with slimy, lime-green clumps or mats in a short period of time, usually beginning their growth along the edges or bottom of the pond and ‘mushrooming’ to the surface. Individual filaments are a series of cells joined end to end which give the thread-like appearance. They also form fur-like growths on submerged logs, rocks and even on animals. Some forms of filamentous algae are commonly referred to as ‘frog spittle’ or ‘water net’.

Spirulina, which is a genus of cyanobacteria that is also considered to be a filamentous blue-green algae, is cultivated around the world and used as a human dietary supplement, as well as a whole food. It is also used as a feed supplement in the aquaculture, aquarium, and poultry industries (Figure 3.1)

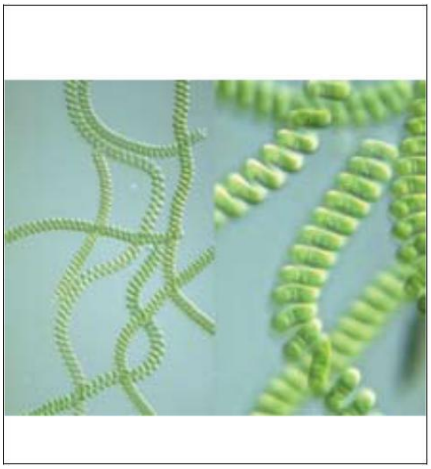


Figure 3.1
Spirulina sp.

Figure 3.2
Spirogyra sp.

Spirogyra, one of the commonest green filamentous algae (Figure 3.2), is named because of the helical or spiral arrangement of the chloroplasts. There are more than 400 species of *Spirogyra* in the world. This genus is photosynthetic, with long bright grass-green filaments having spiral-shaped chloroplasts. It is bright green in the spring, when it is most abundant, but deteriorates to yellow. In nature, *Spirogyra* grows in running streams of cool freshwater, and secretes a coating of mucous that makes it feel slippery. This freshwater alga is found in shallow ponds, ditches and amongst vegetation at the edges of large lakes. Under favourable conditions, *Spirogyra* forms dense mats that float on or just beneath the surface of the water. Blooms cause a grassy odour and clog filters, especially at water treatment facilities.

Cladophora (Figure 3.3) is a green filamentous algae that is a member of the Ulvophyceae and is thus related to the sea lettuce (*Ulva* spp.). The genus *Cladophora* has one of the largest number of species within the macroscopic green algae and is also among the most difficult to classify taxonomically. This is mainly due to the great variations in appearance, which are significantly affected by habitat, age and environmental conditions.

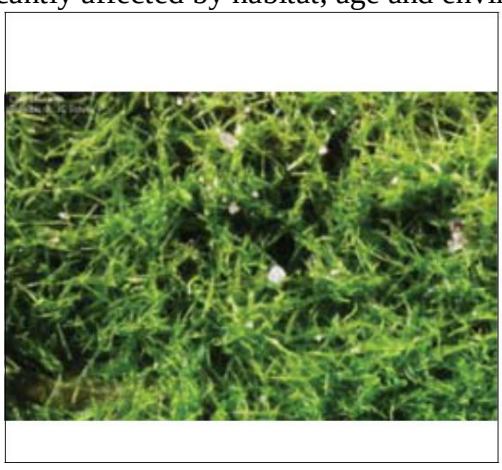


Figure 3.3
Cladophora sp.

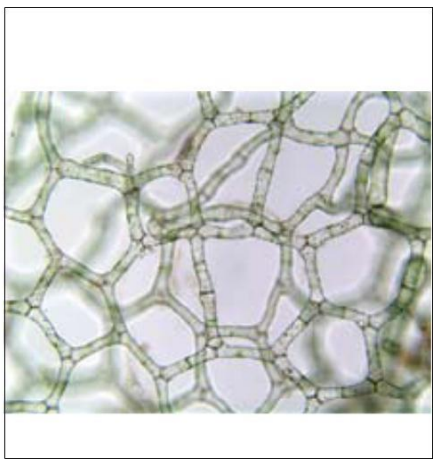


Figure 3.4
Water net (Hydrodictyon sp.)

Another green filamentous alga, *Hydrodictyon*, commonly known as 'water net', belongs to the family Hydrodictyaceae and prefers clean, eutrophic water. Its name refers to its shape, which looks like a netlike hollow sack (Figure 3.4) and can grow up to several decimetres.

3.2.2 Seaweeds

Ulva are thin flat green algae growing from a discoid holdfast that may reach 18 cm or more in length, though generally much less, and up to 30 cm across. The membrane is two cells thick, soft and translucent and grows attached (without a stipe) to rocks by a small disc-shaped holdfast. The water lettuce (*Ulva lactuca*) is green to dark green in colour (Figure 3.5). There are other species of *Ulva* that are similar and difficult to differentiate.

Figure 3.5
Sea lettuce (Ulva lactuca)

Figure 3.6
Eucheuma cottonii

It is important to recognize that the genera *Eucheuma* and *Kappaphycus* are normally grouped together; their taxonomical classification is contentious. These are red seaweeds and are often very large macroalgae that grow rapidly. The systematics and taxonomy of *Kappaphycus* and *Eucheuma* (Figure 3.6) is confused and difficult, due to morphological plasticity, lack of adequate characters to identify species and the use of commercial names of convenience. These taxa are geographically widely dispersed through cultivation (Zuccarello *et al.*, 2006). These red seaweeds are widely cultivated, particularly to provide a source of carageenan, which is used in the manufacture of food, both for humans and other animals.

Gracilaria is another genus of red algae (Figure 3.7), most well-known for its economic importance as a source of agar, as well as its use as a food for humans.

Figure 3.7
Gracilaria sp.

Figure 3.8
Porphyra tenera

The red seaweed *Porphyra* (Figure 3.8) is known by many local names, such as laver or *nori*, and there are about 100 species. This genus has been cultivated extensively in many Asian countries and is used to wrap the rice and fish that compose the Japanese food *sushi*, and the Korean food *gimbap*. It is also used to make the traditional Welsh delicacy, laverbread.

3.2.3 Production

As in the case of their environmental conditions, the methods for culturing filamentous algae and seaweeds vary widely, according to species and location. This topic is not covered in this review but there are many publications available on algal culture generally, such as the FAO manual on the production of live food for aquaculture by Lavens and Sorgeloos (1996). Concerning seaweed culture, the following summary of the techniques used has been has been extracted from another FAO publication (McHugh, 2003) and further reading on seaweed culture can also be found in McHugh (2002).

Some seaweeds can be cultivated vegetatively, others only by going through a separate reproductive cycle, involving alternation of generations.

In vegetative cultivation, small pieces of seaweed are taken and placed in an environment that will sustain their growth. When they have grown to a suitable size they are harvested, either by removing the entire plant or by removing most of it but leaving a small piece that will grow again. When the whole plant is removed, small pieces are cut from it and used as seedstock for further cultivation. The suitable environment varies among species, but must meet requirements for salinity of the water, nutrients, water movement, water temperature and light. The seaweed can be held in this environment in several ways: pieces of seaweed

may be tied to long ropes suspended in the water between wooden stakes, or tied to ropes on

a floating wooden framework (a raft); sometimes netting is used instead of ropes; in some cases the seaweed is simply placed on the bottom of a pond and not fixed in any way; in more open waters, one kind of seaweed is either forced into the soft sediment on the sea bottom with a fork-like tool, or held in place on a sandy bottom by attaching it to sand-filled plastic tubes.

Cultivation involving a reproductive cycle, with alternation of generations, is necessary for many seaweeds; for these, new plants cannot be grown by taking cuttings from mature ones. This is typical for many of the brown seaweeds, and *Laminaria* species are a good example; their life cycle involves alternation between a large sporophyte and a microscopic gametophyte-two generations with quite different forms. The sporophyte is what is harvested as seaweed, and to grow a new sporophyte it is necessary to go through a sexual phase involving the gametophytes. The mature sporophyte releases spores that germinate and grow into microscopic gametophytes. The gametophytes become fertile, release sperm and eggs that join to form embryonic sporophytes. These slowly develop into the large sporophytes that we harvest. The principal difficulties in this kind of cultivation lie in the management of the transitions from spore to gametophyte to embryonic sporophyte; these transitions are usually carried out in land-based facilities with careful control of water temperature, nutrients and light. The high costs involved in this can be absorbed if the seaweed is sold as food, but the cost is normally too high for production of raw material for alginate production.

Where cultivation is used to produce seaweeds for the hydrocolloid industry (agar and carrageenan), the vegetative method is mostly used, while the principal seaweeds used as food must be taken through the alternation of generations for their cultivation.

3.3 Chemical composition

A summary of the chemical composition of various filamentous algae and seaweeds is presented in Table 3.2. Algae are receiving increasing attention as possible alternative protein sources for farmed fish, particularly in tropical developing countries, because of their high protein content (especially the filamentous blue-green algae).

The dry matter basis (DM) analyses reviewed in Table 3.1 show that the protein levels of filamentous blue green algae ranged from 60–74 percent. Those for filamentous green algae were much lower (16–32 percent). The protein contents of green and red seaweeds were quite variable, ranging from 6–26 percent and 3–29 percent respectively. The levels reported for *Eucheuma*/ *Kappaphycus* were very low, ranging from 3–10 percent, but the results for *Gracilaria*, with one exception, were much higher (16–20 percent). The one analysis for

Porphyra indicated that it had a protein level (29 percent) comparable to filamentous green algae. Some information on the amino acid content of various aquatic macrophytes is contained in Annex 1.

The lipid levels reported for *Spirulina* (Table 3.1), with one exception (Olvera-Novoa *et al.* (1998), were between and 4 and 7 percent. Those for filamentous green algae varied more widely (2–7 percent). The lipid contents of both green (0.3–3.2 percent) and red seaweeds (0.1–1.8 percent) were generally much lower than those of filamentous algae. The ash content of filamentous blue-green algae ranged from 3–11 percent but those of filamentous green algae were generally much higher, ranging from just under 12 percent to one sample of *Cladophora* that had over 44 percent. The ash contents of green seaweeds ranged from 12–31 percent. Red seaweeds had an extremely wide range of ash contents (4 to nearly 47 percent) and generally had higher levels than the other algae shown in Table 3.1.

3.4.Microalgae as a potential source of biofuel:

There are several ways to convert microalgal biomass to energy sources, which can be classified into biochemical conversion, chemical reaction, direct combustion, and thermochemical conversion (Fig. 3.9). Thus, microalgae can provide feedstock for renewable liquid fuels such as biodiesel and bioethanol .

The idea of using microalgae as a source of biofuel is not new, but it is now being taken seriously because of the rising price of petroleum and, more significantly, the emerging concern about global warming that is associated with burning of fossil fuels. The utilization of microalgae for biofuels production offers the following advantages over higher plants:

(1) microalgae synthesize and accumulate large quantities of neutral lipids (20–50 % dry weight of biomass) and grow at high rates; [3] [4]

(2) microalgae are capable of all year round production, therefore, oil yield per area of microalgae cultures could greatly exceed the yield of best oilseed crops;

(3) microalgae need less water than terrestrial crops therefore reducing the load on freshwater sources;

(4) microalgae cultivation does not require herbicides or pesticides application;

(5) microalgae sequester CO_2 from flue gases emitted from fossil fuel-fired power plants and other sources, thereby reducing emissions of a major greenhouse gas (1 kg of dry algal biomass utilise about 1.83 kg of CO2);

(6) wastewater bioremediation by removal of NH_4^+, NO^-, PO^{3-} from a variety of wastewater

sources (e.g.

agricultural run-off, concentrated animal feed operations, and industrial and municipal wastewaters);

(7) combined with their ability to grow under harsher conditions and their reduced needs for nutrients, microalgae can be cultivated in saline/brackish water/coastal seawater on non-arable land, and do not compete for resources with conventional agriculture; (8) depending on the microalgae species other compounds may also be extracted, with valuable applications in different industrial sectors, including a large range of fine chemicals and bulk products,

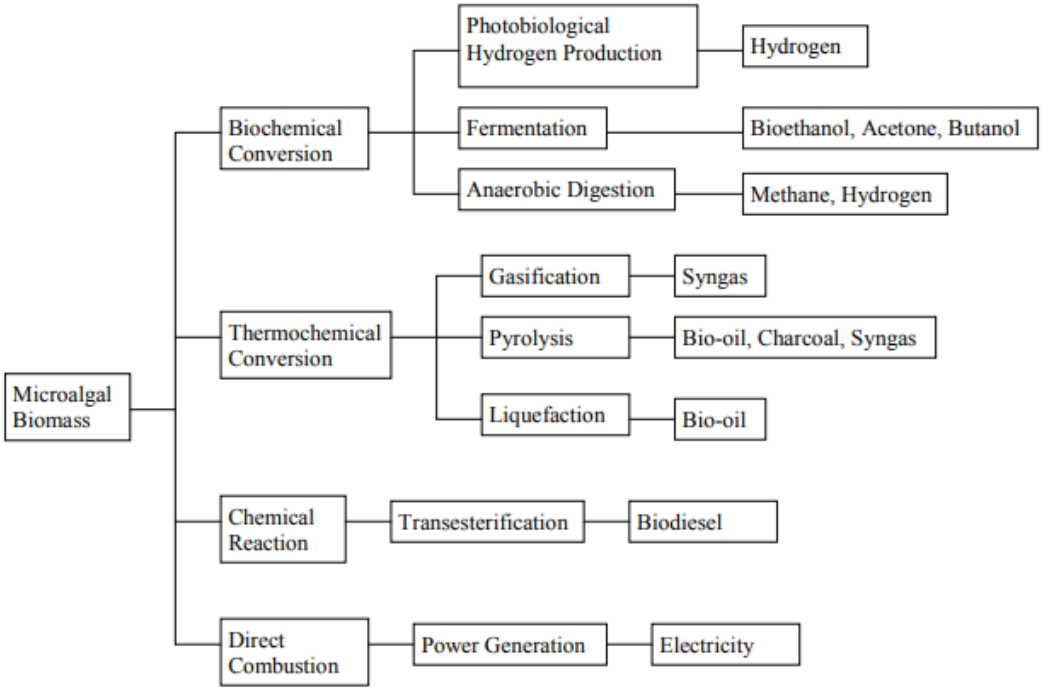


Fig.3 9 Conversion processes for biofuel production from microalgal biomass

such as polyunsaturated fatty acids, natural dyes, polysaccharides, pigments, antioxidants, high-value bioactive compounds, and proteins.

3.5. Biodiesel and bioethanol production from microalgae

Recent studies have shown that microalgal biomass is one of the most promising sources of renewable biodiesel that is capable of meeting the global demand for transport fuels. Biodiesel production by microalgae will not compromise production of food, fodder and other products derived from crops . Microalgal biomass contains three main components: proteins, carbohydrates, and lipids (oil) . The biomass composition of various microalgae in terms of those main components is shown.

Much of the on-going research work is focused on a small number of fast-growing microalgal species which have been found to accumulate substantial quantities of lipids, though under specific conditions. Within the green algae, typical species include *Chlamydomonas reinhardtii*, *Dunaliella salina*, and various *Chlorella* species, as well as *Botryococcus braunii*, which although slow growing can accumulate large quantities of lipids . While many microalgae strains naturally have high lipid content, it is possible to increase that concentration by optimising growth- determining factors such as the control of nitrogen level, light intensity, temperature, salinity, CO_2 concentration and harvesting procedure.

Table 3.1 Biomass composition of microalgae expressed on a dry matter basis .

Strain	Protein	Carbohydrates	Lipid
Anabaena cylindrical	43–56	25–30	4–7
Botryococcus braunii	40	2	33
Chlamydomonas rheinhardii	48	17	21
Chlorella pyrenoidosa	57	26	2
Chlorella vulgaris	41–58	12–17	10–22
Dunaliella bioculata	49	4	8
Dunaliella salina	57	32	6
Dunaliella tertiolecta	29	14	11
Euglena gracilis	39–61	14–18	14–20
Porphyridium cruentum	28–39	40–57	9–14
Prymnesium parvum	28–45	25–33	22–39
Scenedesmus dimorphus	8–18	21–52	16–40
Scenedesmus obliquus	50–56	10–17	12–14

Scenedesmus quadricauda	47	–	1.9
Spirogyra sp.	6–20	33–64	11–21
Spirulina maxima	60–71	13–16	6–7
Spirulina platensis	42–63	8–14	4–11

However, increasing lipid accumulation will not result in increased lipid productivity as biomass productivity and lipid accumulation are not necessarily correlated. Lipid accumulation refers to increased concentration of lipids within the microalgae cells without consideration of the overall biomass production. Lipid productivity takes into account both the lipid concentration within cells and the biomass produced by these cells and is therefore a more useful indicator of the potential costs of liquid biofuel production .

An integrated production of biofuels from microalgae (Fig. 3.10) includes a microalgal cultivation step, followed by the separation of the cells from the growth medium and subsequent lipid extraction for biodiesel production through transesterification.

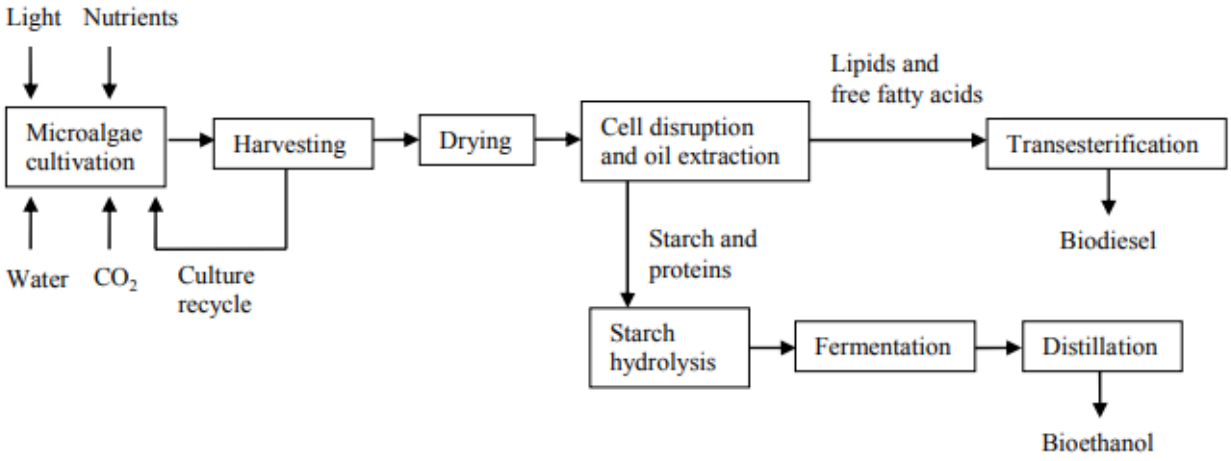


Fig. 3.10 Integrated process for biodiesel and bioethanol production from microalgae.

Following oil extraction, amylolytic enzymes are used to promote starch hydrolysis and formation of fermentable sugars. These sugars are fermented and distilled into bioethanol using conventional ethanol distillation technology.

3.6 Cultivation systems

After selecting the microalgae strain to obtain the product of interest, it becomes necessary to develop a whole range of bioprocesses that make viable its commercialization. Thus, the design and optimization of adequate bioreactors to cultivate these microorganisms is a major step in the strategy that aims at transforming scientific findings into a marketable product. Despite of many possible applications, only a few species of algae are cultured commercially because of poorly developed microalgal bioreactor technology. From a commercial point of view, a microalgae culture system must have as many of the following characteristics as possible: high area productivity; high volumetric

productivity; inexpensiveness (both in terms of investment and maintenance costs); easiness of control of the culture parameters (temperature, pH, O2, turbulence); and reliability . Cultivation systems of different designs attempt to achieve these characteristics differently. Although the term "photobioreactor" (PBR) has been applied to open ponds and channels, applied phycologists have generally distinguished between open-air systems and PBRs (devices that allow monoseptic culture). Thus in this chapter the term PBR is used only for closed systems.

3.6.1 Open-air systems

Fig. 3.11 Open-air systems

Open-air systems were extensively studied in the past few years [17-19], but these algae cultivation systems have been used since the 1950s. The classical open-air cultivation systems comprise lakes and natural ponds, circular ponds, raceway ponds and inclined systems. Open-air systems are the most widespread growth systems and all very large commercial systems used today are of this type. The reasons for this relate to economic and operational issues, since these systems are easier and less expensive to build, operate more durably and have a

larger production capacity than most closed systems; further, they can utilize sunlight and the nutrients can be provided through runoff water from nearby land areas or by channeling the water from sewage/water treatment plants making it the cheapest method of large-scale algal biomass production. Although these systems are the most widely used at industrial level, open-air systems still present significant technical challenges. Generally ponds are susceptive to weather conditions, not allowing control of water temperature, evaporation and lighting, which make these systems dependent on the prevailing regional climate conditions (daily and annual temperature range, annual rainfall and rainfall pattern, number of sunny days, and degree of cloud cover). Furthermore, contamination by predators and other fast growing

heterotrophs have restricted the commercial production of algae in open culture systems to fast growing, naturally occurring or extremophilic species. Consequently, this strictly limits the species of algae that can be grown in such systems. As a result, only Dunaliella (adaptable to very high salinity), Spirulina (adaptable to high alkalinity) and Chlorella (adaptable to nutrient-rich media) have been successfully grown in commercial open pond systems . Natural and artificial ponds are only viable when a series of conditions are met. The existence of favorable climatic conditions and sufficient nutrients in order to the microalgae grow is profusely unavoidable and it also requires that the water presents selective characteristics (e.g. high salinity, high pH, high nutrients concentration) to ensure the existence of a monoculture. Successful examples of this type of cultivation are the Arthrospira production in Lake Kossorom (soda lake at the irregular northeast fringe of Lake Chad) where the Kanembu people harvest about 40 t/year of Arthrospira (Spirulina), to use it as food [21] and in Myanmar, where four old volcanic craters, full of alkaline water are used as cultivation system for the production of around 30 t/year of Arthrospira that are sold on the local market . The Australian producer of D. salina (extremely halophilic and highly light-tolerant green alga) Betatene Ltd, uses very large ponds (up to 250 ha with an average depth of 0.2 to 0.3 m) at the extremely halophilic waters of HuttLagoon, Western Australia which are unmixed other than by wind and convection . The inclined system (cascade system) is the only open-air system which achieves high sustainable cell densities (up to 10 g l-1). This system is very well suited for algae such as Chlorella and Scenedesmus, which can tolerate repeated pumping . In inclined systems turbulence is created by gravity, the culture suspension flowing from the top to the bottom of a sloping surface, thus achieving highly turbulent flow and allowing the adoption of very thin culture layers (< 2 cm), facilitating higher cell concentrations and a higher surface-to-volume ratio (s/v) compared to raceway ponds. Circular ponds with a centrally pivoted rotating agitator are widely used in Indonesia, Japan and Taiwan for the production of Chlorella. Depth is about 0.3 m. The design of these systems, however, limits

pond size to about 10,000 m2 , because mixing by the rotating arm is no longer possible in larger ponds. Circular ponds are not favored in commercial plants since they require expensive concrete construction and high energy input for mixing . Raceway ponds are the most commonly used artificial system. They are typically made of a closed loop, oval shaped recirculation channels, generally between 0.2 and 0.5 m deep, with mixing and circulation required to stabilize algae growth and productivity (Table 2). In a continuous production cycle, algae broth and nutrients are introduced in front of the paddlewheel and circulated through the loop to the harvest extraction point. The paddlewheel is in continuous operation to prevent sedimentation. At water depths of 0.15-0.20 m, biomass concentrations of up to 1 g and productivities of 10-25 g m-2 d-1, are possible . The largest raceway-based biomass production facility located in Calipatria, CA (USA) occupies an area of 440,000 m2 to grow Spirulina .

3.6.2 Photobioreactors

Fig. 3.12 Photobioreactors

(PBRs) are characterized by the regulation and control of nearly all the biotechnologically important parameters as well as by a reduced contamination risk, no CO2 losses, reproducible cultivation conditions, controllable hydrodynamics and temperature, and flexible technical design . These systems receive sunlight either directly through the transparent container walls or via light fibres or tubes that channel it from sunlight collectors. Despite the relative success

of open systems, recent advances in microalgal mass culture require closed systems, as many of the new algae and algal high-value products for use in the pharmaceutical and cosmetics industry must be grown free of pollution and potential contaminants such as heavy metals and microorganisms.

3.6.3 Photobioreactors versus open-air systems

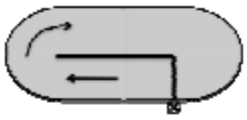
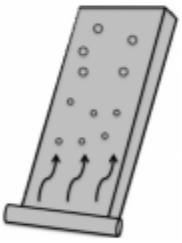
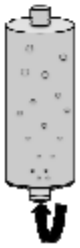
Culture Systems	Advantages	Limitations
Open systems 	Relatively economical Easy to clean up Easy maintenance Utilization of non-agricultural land Low energy inputs	Little control of culture conditions Poor mixing, light and CO_2 utilization Difficult to grow algal cultures for long periods Poor productivity Limited to few strains Cultures are easily contaminated
Tubular PBR 	Relatively cheap Large illumination surface area Suitable for outdoor cultures Good biomass productivities	Gradients of pH, dissolved oxygen and CO_2 along the tubes Fouling Some degree of wall growth Requires large land space Photoinhibition
Flat PBR 	Relatively cheap Easy to clean up Large illumination surface area Suitable for outdoor cultures Low power consumption Good biomass productivities Good light path Readily tempered Low oxygen build-up Shortest oxygen path	Difficult scale-up Difficult temperature control Some degree of wall growth Hydrodynamic stress to some algal strains Low photosynthetic efficiency
Column PBR 	Low energy consumption Readily tempered High mass transfer Good mixing Best exposure to light-dark cycles Low shear stress Easy to sterilize Reduced photoinhibition Reduced photo-oxidation High photosynthetic efficiency	Small illumination surface area Sophisticated construction materials Shear stress to algal cultures Decrease of illumination surface area upon scale-up Expensive compared to open ponds Support costs Modest scalability

Table 3.2- Shows a comparison between PBR (tubular, flat and column) and open systems for several culture conditions and growth parameters.

3.7 Harvesting methods

Given the relatively low biomass concentration obtainable in microalgal cultivation systems due to the limit of light penetration (typically in the range of 1-5 g l-1) and the small size of microalgal cells (typically in the range of 2-20 μm in diameter), costs and energy consumption for biomass harvesting are a significant concern that needs to be addressed properly . In this sense, harvesting of microalgal cultures has been considered as a major bottleneck towards the industrial-scale processing of microalgae for biofuel production.

The cost of biomass recovery from the broth can make up to 20–30% of the total cost of producing the biomass . Microalgal biomass harvesting can be achieved in several physical, chemical or biological ways: flocculation, centrifugation, filtration, ultrafiltration, air-flotation, autoflotation, etc. Generally, microalgae harvesting is a two stage process, involving:

(1) Bulk harvesting: aimed at separation of biomass from the bulk suspension. The concentration factors for this operation are generally 100–800 times to reach 2– 7 % total solid matter. This will depend on the initial biomass concentration and technologies employed, including flocculation, flotation or gravity sedimentation;

(2) Thickening: the aim is to concentrate the slurry through techniques such as centrifugation, filtration and ultrasonic aggregation, hence, it is generally a more energy intensive step than bulk harvesting .

3.7.1 Flocculation

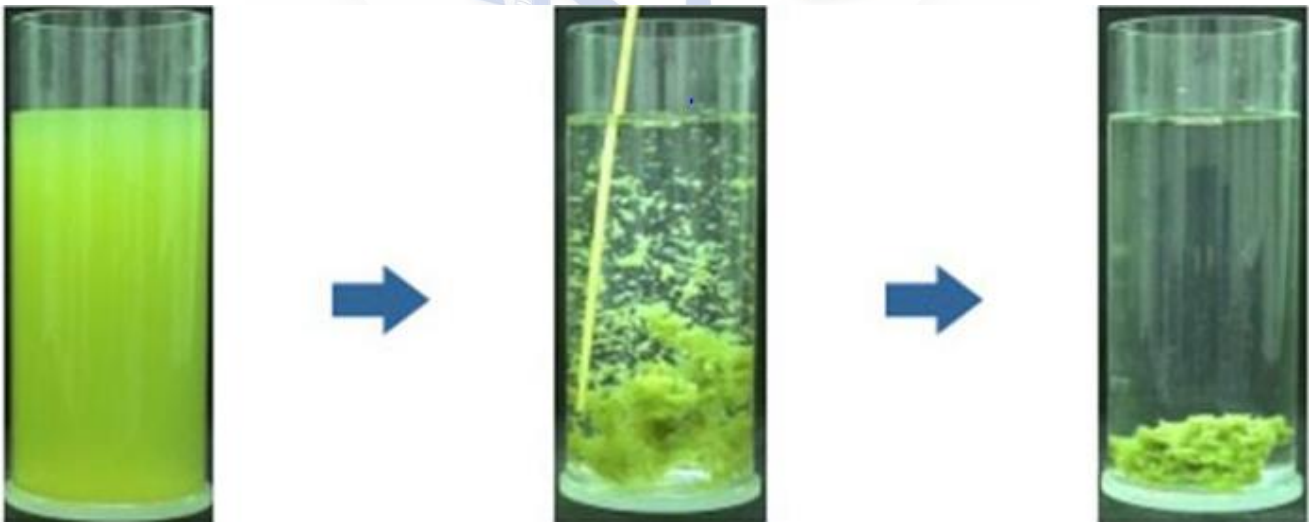


Figure 3.13 Flocculation

Flocculation can be used as an initial dewatering step in the bulk harvesting process that will significantly enhance the ease of further processing. This stage is intended to aggregate

microalgal cells from the broth in order to increase the effective ‘‘particle’’ size . Since microalgae cells carry a negative charge that prevents them from self-aggregation in suspension, addition of chemicals known as flocculants neutralises or reduces the negative surface charge. These chemicals coagulate the algae without affecting the composition and toxicity of the product . Multivalent metal salts like ferric chloride (FeCl3), aluminium sulphate (Al2(SO4)3) and ferric sulphate (Fe2(SO4)3) are commonly used .

3.7.2 Flotation

Some strains naturally float at the surface of the water as the microalgal lipid content increase. Although flotation has been mentioned as a potential harvesting method, there is very limited evidence of its technical or economic viability .

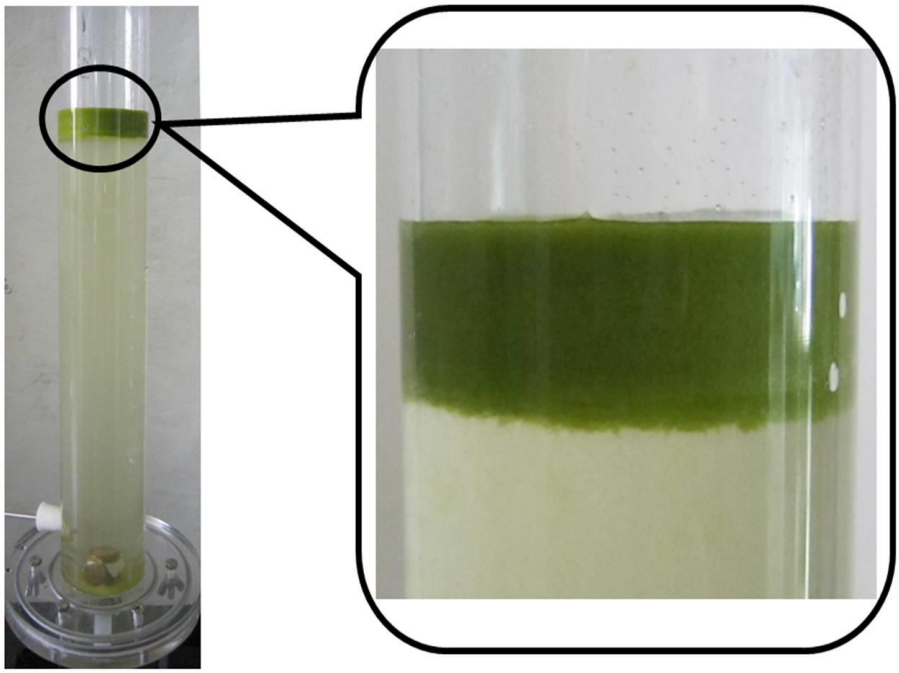


Figure 3.14 Flotation

3.7.3 Centrifugation

Centrifugation involves the application of centrifugal forces to separate microalgal biomass from growth medium. Once separated, microalgae can be removed from the culture by simply draining the excess medium . Centrifugal recovery is a rapid method of recovering algal cells, especially for producing extended shelf-life concentrates for aquaculture hatcheries and nurseries . However, high gravitational and shear forces during the centrifugation process can damage cell structure. Additionally, it is not cost effective due to high power consumption especially when considering large volumes .

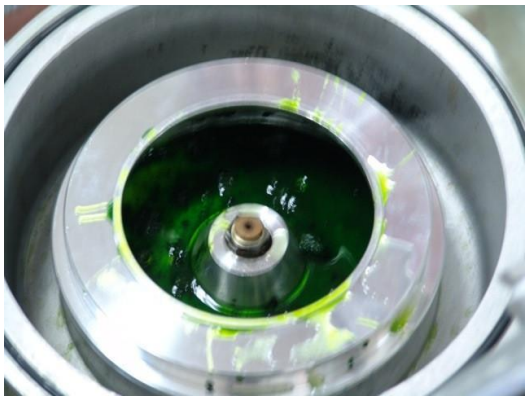


Figure 3.15 Centrifugation

3.7.4 Filtration

Filtration is the method of harvesting that has proved to be the most competitive compared to other harvesting options. There are many different forms of filtration, such as dead end filtration, microfiltration, ultra filtration, pressure filtration, vacuum filtration and tangential flow filtration (TFF). Generally, filtration involves running the broth with algae through filters on which the algae accumulate and allow the medium to pass through the filter. The broth continually run through the microfilters until the filter contains a thick algae paste. Although filtration methods appear to be an attractive dewatering option, they are associated with extensive running costs and hidden pre-concentration requirements .

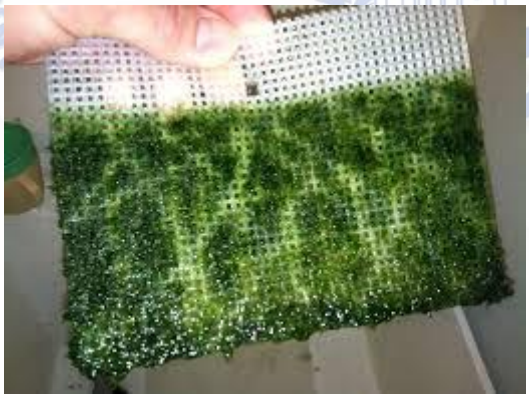


Figure 3.16 Filtration

3.8 Biodiesel production

After the extraction processes, the resulting microalgal oil can be converted into biodiesel through a process called transesterification. The transesterification reaction consists of transforming triglycerides into fatty acid alkyl esters, in the presence of an alcohol, such as methanol or ethanol, and a catalyst, such as an alkali or acid, with glycerol as a byproduct . For user acceptance, microalgal biodiesel needs to comply with existing standards, such as ASTM Biodiesel Standard D 6751 (United States) or Standard EN 14214

(European Union). Microalgal oil contains a high degree of polyunsaturated fatty acids (with four or more double bonds) when compared to vegetable oils, which makes it susceptible to oxidation in storage and therefore reduces its acceptability for use in biodiesel. However, the extent of unsaturation of microalgal oil and its content of fatty acids with more than four double bonds can be reduced easily by partial catalytic hydrogenation of the oil, the same technology that is commonly used in making margarine from vegetable oils . Nevertheless, microalgal biodiesel has similar physical and chemical properties to petroleum diesel, first generation biodiesel from oil crops and compares favourably with the international standard EN14214 .

3.9 Bioethanol production

The current interests in producing bioethanol are focusing on microalgae as a feedstock for fermentation process. Microalgae provide carbohydrates (in the form of glucose, starch and other polysaccharides) and proteins that can be used as carbon sources for fermentation by bacteria, yeast or fungi . For instance, Chlorella vulgaris has been considered as a potential raw material for bioethanol production because it can accumulate high levels of starch . Chlorococum sp. was also used as a substrate for bioethanol production under different fermentation conditions. Results showed a maximum bioethanol concentration of 3.83 g l-1 obtained from 10 g l-1 of lipid-extracted microalgae debris . Production of bioethanol by using microalgae can also be performed via self-fermentation. Previous studies reported that dark fermentation in the marine green algae Chlorococcum littorale was able to produce 450 µmol ethanol g-1 at 30 ºC . Even though limited reports on microalgal fermentation were observed, a number of advantages were observed in order to produce bioethanol from microalgae. Fermentation process requires less consumption of energy and simplified process compared to biodiesel production system. Besides, CO2 produced as by-product from fermentation process can be recycled as carbon sources to microalgae in cultivation process thus reduce the greenhouse gases emissions. However, the production of bioethanol from microalgae is still under investigation and this technology has not yet been commercialized .

CHAPTER NO 4: EXPELLER

EXPELLERS

4.1 Introduction

Expelling operations have come a long way since its inception many centuries ago. From the simple rural 'Ohanis' (Figure 4.1)that were time-intensive and low in capacity, expelling equipment manufactured today, including in India, boasts of high capacity, high workmanship and operational efficiency, and low power consumption. India has always been blessed with a richness of agricultural produce and the same has inspired industrious individuals to design expellers that are employed today in crushing a wide array of oilseeds 0*.

The expelling industry in India therefore is yet to design an expeller that could be put to use exclusively for expelling various oilseeds with high expelling efficiency and minimal power consumption. Expelling of Jatropha and Pongamia in the country has begun only recently and therefore the experience and knowledge specifically for expelling these is comparatively meagre and perhaps not enough. It appears that by and large scientific input has not gone into the design of expellers. Also, scientific understanding of the parameters and process of expelling is not uniformly understood.

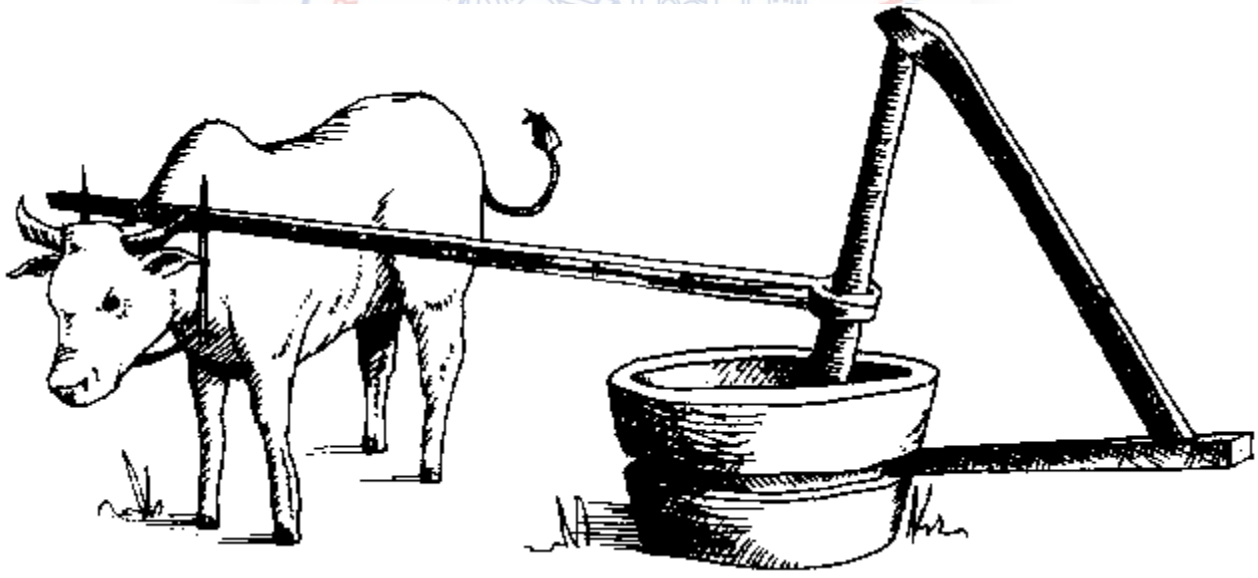


Figure 4.1 Traditional Indian Ghani used for oil expelling

Most manufacturers go by their "experience" in this matter and seem to be satisfied about it. The interaction with various sectors of this activity leads us to believe that there are considerable variations in the understanding of the exact process of expelling which lead to an inexact understanding of the expelling and extraction efficiencies. Mechanical pressing is the most common method for oil extraction which includes different types of presses such as

hydraulic press, screw press and rolling press. This project mainly aims at developing new concepts for redesigning the screw press .

4.2 Screw Press Expeller

The seed crushing industry is one of the oldest industries in the world. The Chinese were the first people to express oil seeds. As far as the year 3000BC, the Egyptians knew how to obtain oil using a press composed of a sausage-shaped rush bag slug between vertical posts of a strong wooden frame. In the 19th century, the ruins of Pompeii dated back to 79AD were excavated. A large pestle and mortar was found, a long pole acted as a grinding pestle and hollowed trunk of a tree held the seeds. An ass or an ox walked around the press, dragging the top end of the pole and thus grinding the seeds in the hollowed tree trunk. Centuries later other seeds such as linseed, rapeseed, cottonseed, groundnut, soya bean and palm kernel which required greater pressure for oil expressing, were available. This was done by a press employing a windlass and then by using water mill or windmill to apply the pressure. The first mechanical press was successfully used back in 1906. The manufacturers have come a long way since then with improved material of construction, manufacturing methods, research and development and have increased the efficiency of the screw press. As a result, various types of improved expellers were developed to meet the requirement of the processes .

Continuous Pressing by means of expellers (also known as screw press) is a widely applied process for the extraction of oil from oil seeds and nuts. It replaces the historical method for the batch wise extraction of oil by mechanical or hydraulic pressing (Figure 4.2)

Figure 4.2 Screw press Expeller

4.3 Principle

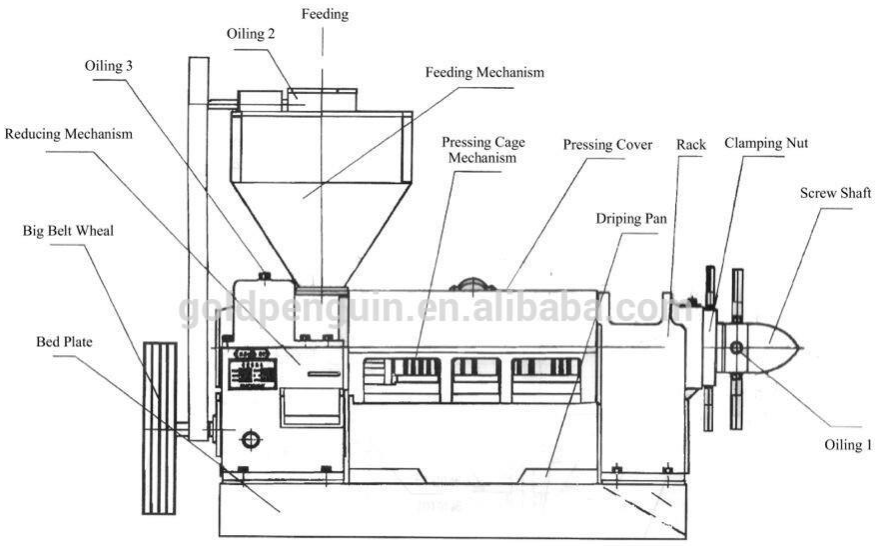
The functional parts of the machine include barrel (a cylindrical cage), auger (worm shaft), gear reduction box, prime mover, oil outlet, cake outlet, hopper, pulley, transmission belts and bearings. The compression effect can be increased by decreasing the clearance between the screw shaft and the cage or by reducing the length of the screw flight in the direction of the axial movement. The gradually increasing pressure releases the oil which flows out of the press through the slots provided on the periphery of the barrel, while the press cake continues to move in the direction of the shaft, towards a discharge gate installed at the other extremity of the machine.

4.4 Types of screw press

Nearly all the mechanized presses that can be found on the market use a continuous pressing process. Usually this involves an endless screw that rotates in a cage and continuously kneads and transports the seed material from the entry funnel to a nozzle where pressure is built up. Over the length of the screw the oil is expelled from the seeds and flows from the side of the screw to a reservoir. All expellers can be categorized as either 'cylinder-hole' type or 'strainer' type.

4.4.1 Cylinder-hole type

In the 'cylinder-hole' type, the oil outlet is in the form of holes at the end of the cylindrical press cage (Figure 4.3). The seed gets a rising compression in the direction of the press head. The oil is pressed out of the seeds near the outlet holes and drained from them.



Structure Chart Of Screw Oil Press

Fig 4.3 Structure Chart

Special cavities near the nozzle prevent the cake and seed-mix from sticking to the screw. Otherwise, there would be no forward movement. The press cake is pressed through changeable nozzles and formed to pellets.

4.4.2 Strainer Type

The strainer type press has an oil outlet over the full length of the press cage that serves as a strainer. The strainer is actually a cylindrical cage built-up of separate horizontal bars or vertical rings arranged at a small interspacing. The spacing between the strainer bars can be either fixed or adjustable. Strainer presses come with various screw design although the principle of all screws is similar.

The screw diameter increases towards the nozzle thereby increasing the compression of the solid material. A screw with multiple compression section can be used to create multiple compression stages to increase oil outlet .

4.5 Existing system

The existing oil expeller machine is of cylinder type which mainly consists of the following three sections:

1. Control feeding section (seed kettle)
2. Crushing chamber and
3. Drive assembly

Figure 4.4 Existing oil expeller

4.5.1 Control feeding section

The seed kettle allows the mixing and feeding of seeds into the pushing chamber of the expeller. The kettle bas a feed control system and a horizontal mixing and feeding blades. The kettle is round in shape with a short central vertical shaft. The agitator blades are mounted on one end of the central shaft The other end of the short central shaft is connected to a bevel pinion assembly. This bevel pinion assembly is driven by a horizontal shaft. The kettle central shaft and horizontal shaft are mounted on bearings. They are:

1. Bevel resting ball bearing (central shaft)
2. Horizontal shaft resting ball bearing
3. Horizontal end shaft ball bearing

4.5.2 Crushing chamber

Crushing chamber is a combination of pushing and crushing chamber. The seed from hopper enters the pushing chamber, comes in contact with of worm shaft and gets pushed forward to crushing chamber continuously.

The crushing chamber is cylindrical in shape and is formed by placing hardened cage bars (24 in numbers) next to each other in shape of perforated cylinder. The hardened cage bars are fitted in such a way that it allows for crushing of seed as well as for the crushed oil to come out of the crushing chamber. These crushing bars are grounded in a systematic angle so as to facilitate the flow of oil and sludge. The thickness of the cake can be adjusted by moving the worm shaft forward and backward. This can be done by adjusting the screw and lock nut. Lock nut fixes the position of the worm shaft.

Worm shaft bolt: It helps to remove the worm shaft outside the crushing chamber. It should be tightly fitted to the shaft. It should rotate with the shaft freely.

4.5.3 Drive Assembly

It consists of a motor, an rpm reduction pulley and a gear assembly system.

RPM reduction system: The motor pulley is connected to the drive pulley through 'B' section belt drive. The speed of the Motor being 960 rpm is stepped down to 480 rpm using drive pulley. This drive pulley shaft is connected to smaller gear wheel of the gear assembly. The

gear meshes with another gear of larger diameter that is mounted on screw conveyor through key way system and hence reduces the speed to 100 rpm.

Drive pulley is supported by two tapered roller bearings. The worm shaft gear wheel is supported either side by two heavy duty ball bearings. Larger gear wheel and the bearing are fitted on gear sleeve supported by adjustable chuck nuts on either side to keep gear wheel in its position.

4.6 Operation of the oil expeller

The machine is powered by an electric motor or Ie engine via pulley arrangement connected to the main shaft that turns the screw conveyor. The hopper, into which the oil seed is fed, is located at the top of the housing. During the pressing process the seeds are fed into the seed hopper. The seed hopper then conveys the oil seed into a barrel inside which a screw shaft rotates. The operation is mainly based on the axial movement of the screw press. Inside the barrel, the seeds are simultaneously crushed and transported in the direction of restriction (also referred as 'die' or 'nozzle') by the rotating screw (often called 'worm').

As the feeding section of the expeller is loosely filled with seed material, the frrst step of the process consists of rolling, breaking, displacement and the removal of air from inter-material voids. As soon as the voids diminish the seeds start to resist the applied force through mutual contact and deformation.

The compression is achieved by decreasing pitch of the auger, designed to act as a screw press. The continuous transport of new material from the hopper causes pressure to increase to a level needed to overcome the nozzle. At this point the press is 'inoperation' .

The built-up pressure causes the oil to be removed from the solid material inside the expeller.

The oil extracted is drained though the oil channel into the oil tray where it is collected. The cake outlet is located at the end of the expelling housing where the conditioned seeds are compressed and the oil content forced out through the oil outlet slots on the oil tray.

4.7 Factors affecting the oil recovery

The amount of oil that can be recovered from the seeds is affected by:

- Throughput: The amount of material that is processed per unit of time (kg/hr). Higher throughput gives lower oil recovery per kg of algae, due to shorter residence time in the press. Throughput can be affected by changing the rotational speed of the screw.
- Oil point pressure: The pressure at which the oil starts to flow from the algae. If seeds can, for example, be manipulated so that the oil point pressure is reduced, it becomes easier to extract the oil.
- Pressure: At higher pressure more oil is recovered from the algae. However, the higher pressure forces more solid particles through the oil outlet of the press. This makes cleaning more difficult. Typical operating pressures for engine-driven presses are in a range of 50-150 bar.
- Nozzle size: Smaller nozzle size leads to higher pressure and therefore higher oil yield. An optimum should be found for each individual press.
- Moisture content of the seeds: An optimal moisture content of 2-6% was identified. Moisture content of 8% (minimum) should be considered too humid and needs more drying.

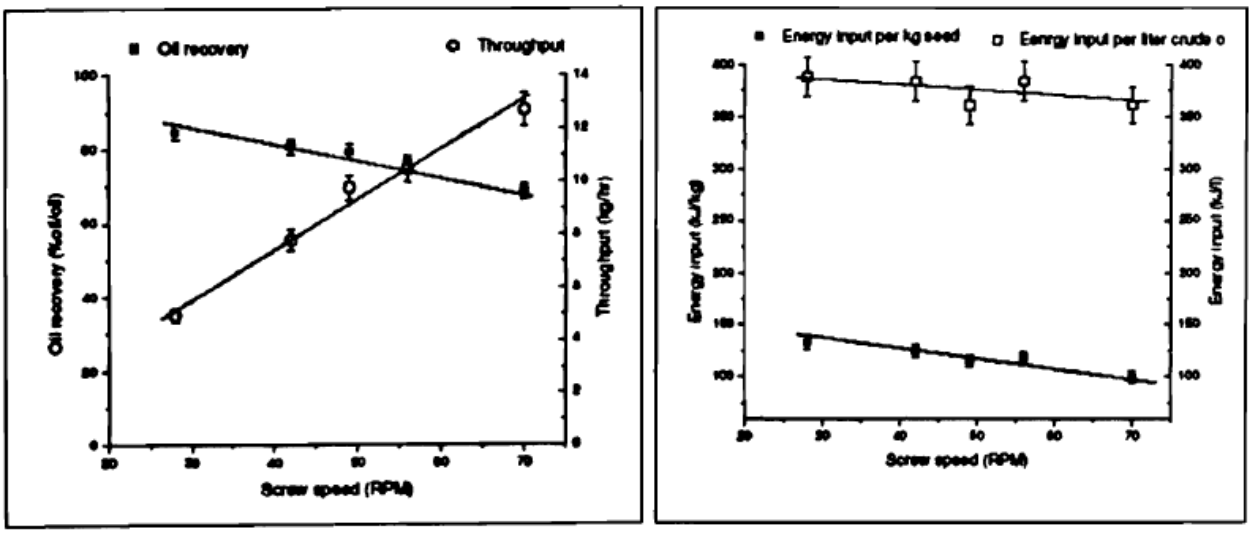
4.8 Effect of Press parameters on Process Parameters

When designing a machine to press seeds, it is useful to know the main variables affecting the oil recovery and oil quality. The information pertains to expelling process in general and may not apply to specific cases.

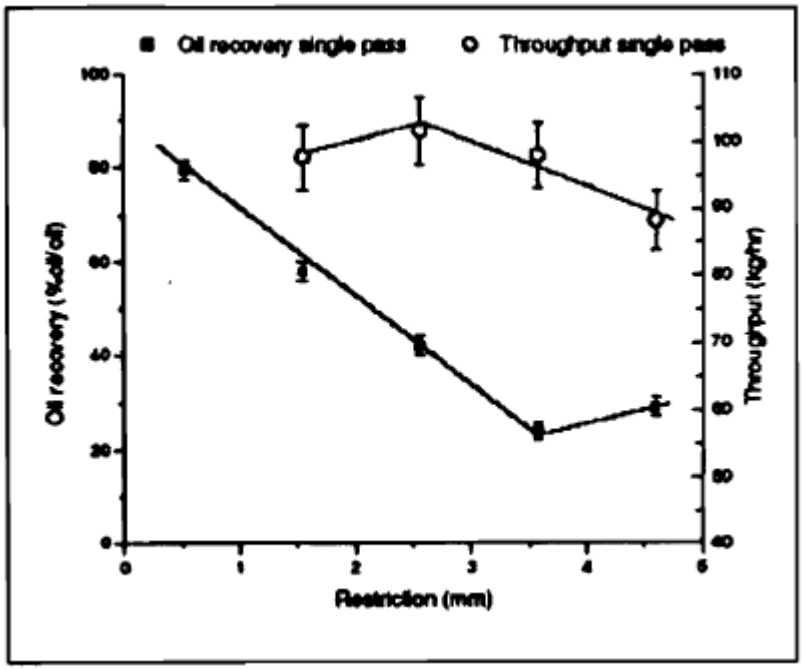
4.8.1 Influence of Revolutions per minute (RPM)

There will be reduction in oil recovery with increased rotational speed .This effect is largely explained by the increasing throughput which implies reduced residence time and thus less chance for the oil to flow from between the solid material. The higher residual oil content in the material ensures that the viscosity of the paste remains relatively low and therefore pressure build-up is also lower at higher speed which again leads to less oil recovery.

Higher rotational speed requires more power and at the same time reduces processing time.



Figures 4.5(a) and 4.5(b) shows that the energy requirement is most strongly affected by the reduction in processing time 0.



4.6. Influence of Restriction Size

Higher Oil recovery was observed for smaller restriction size. This can be attributed to increased pressure and friction. Obviously when decreasing the restriction size the mixture inside the press experiences more resistance when exiting the press cake outlet. Assuming the supply of input material to stay more or less constant, increased compression close to the press cake outlet is expected.

The increase in throughput with decreasing restriction size can appear conflicting at fIrst sight. It might be contributed to better fIlling of the voids inside the wonn channel at higher pressure

therefore enhancing the press perfonnance .Although oil recovery is highest at smaller restriction size there is an operational limit after which it results in jamming 0.

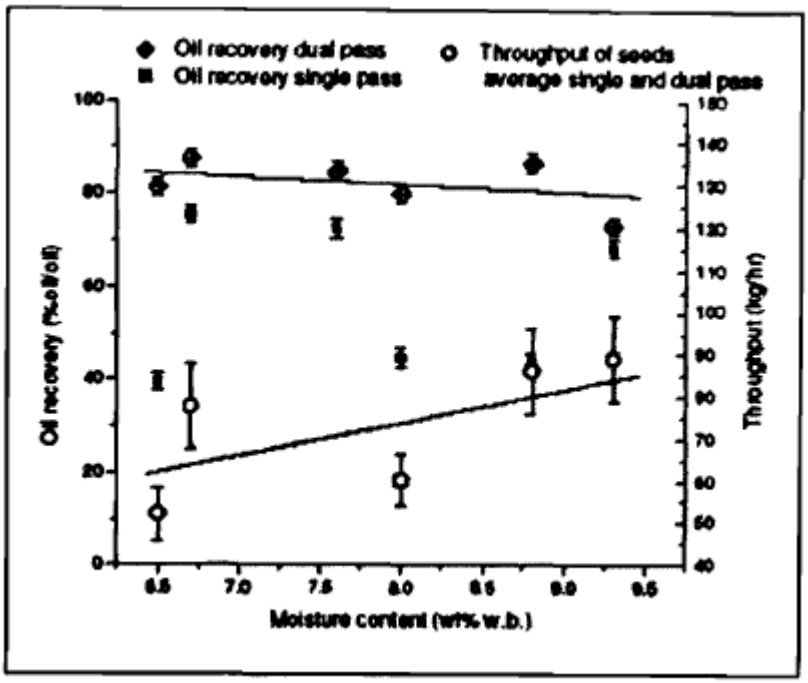


Figure 4.7 Influence of restriction size on oil recovery and throughput

4.8.3 Influence of Moisture Content

Higher moisture content might cause increased defonnability and reduced rupture force. In addition emulsifIcation or plasticizing effects occurring in the pressed material at higher moisture levels reduce the viscosity and thereby decrease pressure build-up. This pressure drop seems an appropriate explanation for the rapid decline in oil recovery with increase in moisture content as shown in the fIgure 4.8.

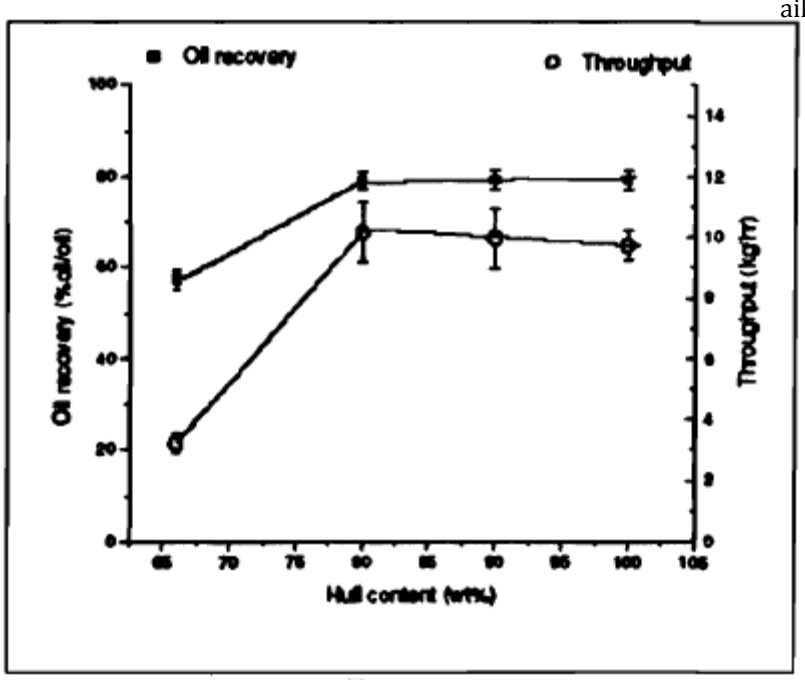


Figure 4.8 Influence of Moisture Content on Oil recovery and throughput

An explanation on the importance of parts involved in the oil expeller and the respective design calculations of the screw press are performed .The main components of the oil expeller are frame, cake outlet, expeller housing, heating compartment, auger (worm shaft), hopper, and auger pulley. The cake outlet is located at the end of the expelling housing where the conditioned seeds are compressed and the oil content forced out through oil outlet slots on the housing. The machine is powered by an electric motor or Ie engine via pulley arrangement connected to the main shaft that turns the screw conveyor. The operation is based on the axial movement of the material in the screw press. The electric motor was used to power the machine. Then the oil seeds are fed from the hopper to the screw conveyor which rotates in an expeller housing. When the electric motor is switch on, the main shaft and the auger, which moves and packs the seed being heated along the passage to the far side, will start to rotate. The compression is achieved by decreasing pitch of the auger, designed to act as a screw press. However, improvement in the design of the auger and the heating device is expected to greatly improve the performance efficiency of the machine.

The important configurations of the worm shaft are explained . The worm shaft is at an increasing diameter while the screw system is at a decreasing pitch - a combination that is essential for obtaining maximum pressure for oil extraction and cake extrusion process. It is essentially a tapered screw conveyor with the volumetric displacement being decreased from the feed end of the barrel to the discharge end. In this way, the seeds are subjected to pressure which expels oil from them as they are propelled forward by the screwing process. The screw threading system was designed as a step up shaft diameter and decreasing screw depth. The residual cake from where the oil is extracted is extruded out of the cake outlet in form of flakes. While designing the machine, the following considerations are made: high oil yield,

high extraction efficiency, low extraction loss, quality of oil, availability and cost of construction materials.

An explanation about the influence of pressure, temperature and moisture content on the oil yield and rate of conventional hydraulic expression of sesame and linseed is discussed as well as the influence of pressure and temperature for rapeseed, palm kernel and jatropha . Yield increased with increase in pressure and with increase in temperature. Rate of expression increased with an increase in temperature and a decrease in moisture content.

Information is available on the processing factors affecting yield and quality of mechanically expressed groundnut oil . The oil yields from coarsely ground groundnut were higher than those from finely ground samples, but the free fatty acid values were lower.

Increasing the temperature did not improve the oil yield after 25 minutes of heating. Oil yield increased with pressures of up to 20 MPa beyond which the yield either leveled off or decreased. The rate of oil expression was increased by an increase in temperature, time of heating, and particle size.

4.9 Problem Statement

> Expeller manufacturers in the country have honed their equipment to stellar levels of output, but, little or no research appears to have been carried out in this area of equipment design and the knowledge base is a bare minimum.

> A higher efficiency of expelling is clearly desirable to maximize the availability of the feedstock for biodiesel production.

4.10 Literature Gap

> In order to extract oil in a single pass, a seed chopping mechanism similar to flour mill is adopted in the design of the present oil expeller.

> There is a scope to change the design of the screw conveyor incorporating a reverse wonn teeth which increases the residence time in extraction process.

> There is also a scope to increase the depth in the screw thread in order to increase the pressure inside the barrel.

4.11 Objectives

- To study the theory behind oil expelling process and analyze the problems associated with existing oil expeller.
- To obtain design parameters and to develop a detailed design of the expeller using Solidworks and Ansys.
- To Extract Oil From Algae So that it can be Used as BioDiesel.

4.12 Methodology

In order to achieve the above mentioned objectives the following methodology is planned.

- Understanding the drawbacks of the present oil expeller. The Technical and the Performance parameters affecting the process are studied. Research papers, journals on the various experiments and studies carried out in the field of oil expelling are referred.
- After understanding the process of oil expelling, new concepts are generated along with the drawings. Each concept is then evaluated for its technical, economical and production feasibility. Depending on the various deciding factors, the concept is screened for the further development. By incorporating the adopted concept, the oil expeller is taken up for conceptual design.
- By considering various factors such as throughput, power requirements and material selection, the detailed design of machine is started. It includes belt drive design, Gear design, Torque Calculations, base frame design and part modeling followed by assembly of the machine using Solidworks and Ansys.
- The screw conveyor along incorporation of adopted concept is fabricated and introduced in the existing machine for testing and results are compared with the present machine.

The detailed methodology is been depicted in the flowchart (Figure 4.9).

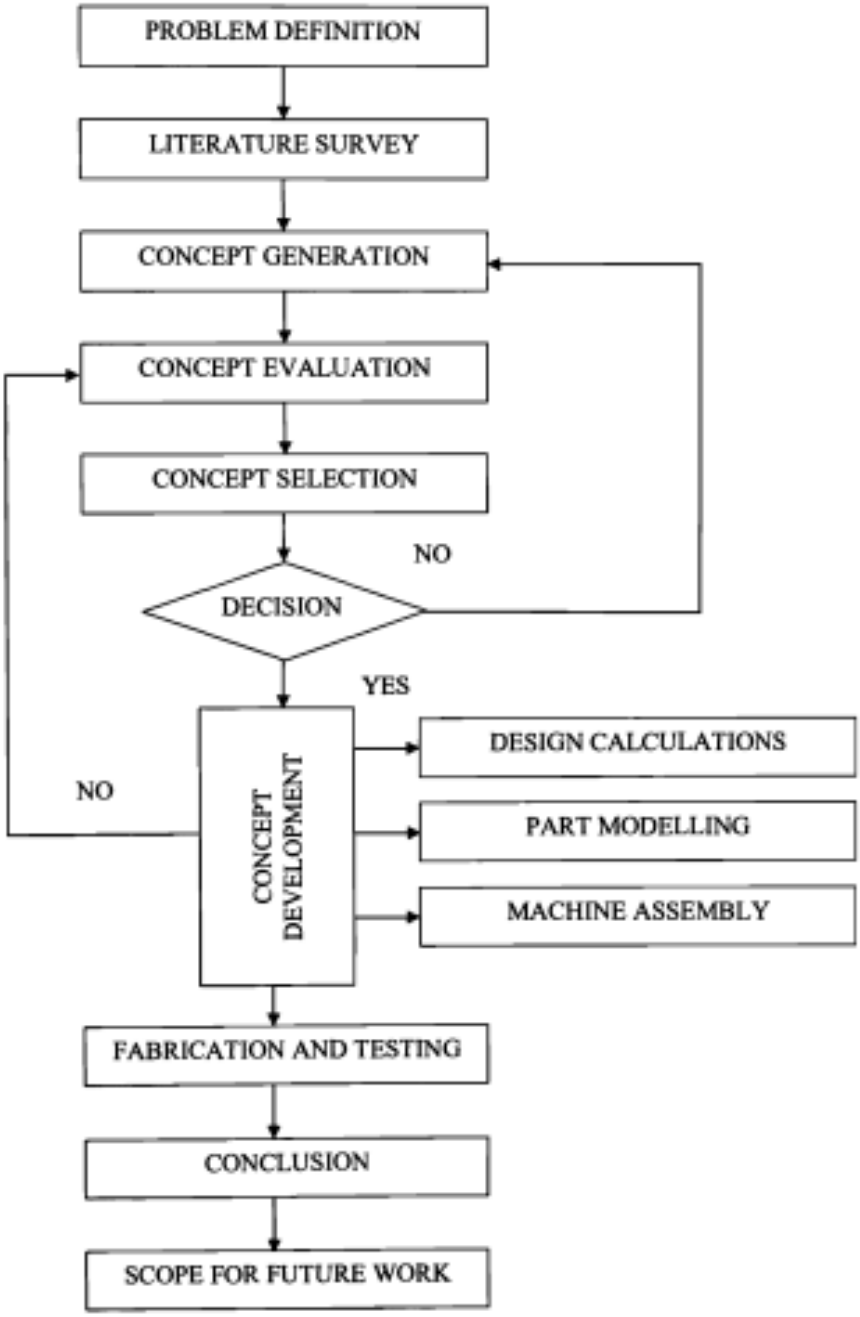


Figure.4.9 Methodology

4.13 Design Methodology

1) Studying the Failure causes of Expeller.
2) Selection of three different materials.
3) Preparation of 3D model using SOLIDWORKS software.
4) Analyzing the expeller using ANSYS software.
5) Comparing the Analytical results with Theoretical results to validate the model.

CHAPTER NO 5:
DESIGN CALCULATIONS

Machine Description and Working Principles

The screw press oil expeller consists of the following components: worm shaft, cylindrical barrel, cylindrical barrel cover, feeding hopper, geared motor, cake outlet, oil outlet, plates, pulleys, belt, and main frame. The cylindrical barrel was made from a pipe of length 320 mm, inside diameter of 65 mm and thickness 8 mm. The worm shaft was made from a mild steel solid rod of diameter 58 mm and length 320 mm, which was machined on the lathe at a decreasing screw pitch and decreasing screw depth. The worm shaft is housed in the cylindrical barrel at a clearance of 2 mm between the screw diameter and inside diameter of the barrel. In operation, the oilseed is introduced into the machine through the feeding hopper; the machine conveys, crushes, grinds and presses the oilseed inside the cylindrical barrel with the aid of the worm shaft and the plate until oil is squeezed out of the seed. The oil extracted is drained though the oil outlet and the residual cake is discharged at the cake outlet. The machine is powered by a 1.hp Single-phase electric geared motor.

5.Design Considerations and Calculation Procedures :

5.1. Design Considerations

While designing the machine, consideration included: high oil yield, high extraction efficiency, low extraction loss, quality of oil, availability and cost of construction materials. Other considerations included the desire to design the cylindrical barrel to accommodate the require quantity of raw materials (Algae). Also considered is to design the worm shaft to ensure maximum conveyance, crushing, grinding and pressing of the Algae. Consideration was also given for hopper and strong main frame to ensure structural stability and strong support for the machine.

5.2 Design of the oil expeller components

The relevant physical and mechanical properties of *Algae* as basic design data were obtained. Basic considerations were given to the design for the size/dimension and capacity of the machine**,** The design of the hopper is based on flow characteristics of the Algae, and we found out the flow characteristics such as Sphericity (70.58 %) and Moisture Content(5.56 %).

5.3 Determination of Power Required To Drive the Expeller

The power required to drive the expeller was calculated using a modified from (Anirudha L. Katkar*1, Dr.C. N. Sakhale2, S. K. Undirwade3 2015) as:

$PT = PD + PE$

$PD = TD + \omega D$

$TD = WD + RD$

PT, $Total\ power$

PD ,$power\ to\ drive\ the\ process\ unit$

PE ,$power\ to\ extract\ the\ oil$

WD, weight of the pressing screw = 3.5 ×9.81 =343 N

RD, radius of the pressing screw = 0.029 m

TD= 0.995 Nm =1 Nm

$\omega D = 2 \times \pi \times N/60 = 1.9\ rad/s$

PD=1.9 w =2 w

$\tau = F/A$

$PE = Ts \times Wn$

$TS = \pi \times D3 \times \boldsymbol{\tau}$

D, major diameter of screw = 0.058m

F, rupture force for algae = 113.99 N

τ=234113.78$Nm2$

Ts=143.5 Nm

PE=287.1 w
PT=289 w=0.289 Kw =0.39 Hp ×2.5(safety factor) =0.975 Hp

5.4 Selection Motor Required

As long as the total capacity needed to move the worm shaft is 0.975 hp In terms of safety we used 1. Hp geared motor at 1440rpm (after gearbox reduction 100 rpm) was adopted.

5.5 Design of Worm Shaft of the Expeller

The worm shaft is the main component of the expeller and is acted upon by weights of material being processed, pulley and screw thread. In operation, the worm shaft conveys, crushes, presses and squeezes the material (*Algae*) for oil extraction. Therefore, in order to safeguard against bending and tensional stresses, the diameter of the shaft was determined from the equation given by (Shigley and Mischke 2001) and (Khurmi and Gupta 2008) as:

ds= 16 T/0.27π δ0
ds= 50mm
where, ds= is diameter of the screw shaft,
T= is the Torque transmitted by the shaft (143.5Nm), and
δo = is the yield stress for mild steel. (340 Mpa)
n = safety factor (2).

5.6 Design of the Screw Thread

The worm shaft is essentially a tapered screw conveyor with the volumetric displacement being decreased from the feed end of the barrel to the discharge end. In this way, the seeds are subjected to pressure which expels oil from them as they are propelled forward by the screwing process (Sivakumaran et al., 1985). The screw threading system was designed as a step up shaft diameter and decreasing screw depth using the expression in Eqn. 5 below as:
Un= a+ (n−1) ……(2)
where, Un is the screw depth at the discharge end,
a= is the screw depth at the feed end(10mm),
n= is the number of screw turns (10), and
d= is the common difference between next successive screw depths (zero).
Therefore, Un=a=10

5.7 Determination of Load that can be lifted by the Screw

The load that can be lifted by the screw was determined from the equations given by Hall et al. (1961) as:
We = T x ((Dm/2tanθ+μcosα)/(1−μ tanθcosα))
α = tan−1($tan\theta n\ Cos\theta$)
θ= tan−1(L /π Ds)……(5)
where, We= is the load that can be lifted by the screw,
T= is the Torque transmitted by the screw shaft (143.5Nm),
Dm= is the mean thread diameter(38mm)
μ= is the coefficient of friction(0.15),
$\boldsymbol{\theta}$= 50.2
α=32.1
We= 3.9 KN

5.8 Determination of Pressure to be developed by the Screw Thread

The pressing area (Hall et al., 1961) and the pressure developed by the screw thread were determined by Eqn. 9 and 10 respectively as

$Ap = \pi Dm\ n\ h$ …… (6)

$pr = We/Ap$ …… (7)

where, Pr= is the pressure developed by the screw thread,
Ap= is the pressing area, and
Dm= is the mean thread diameter, (38mm)
h = is the screw depth at the maximum pressure (10mm),
n = number of screw turns (flights) (10)
Ap= 11938 $mm2$, Pr= 3.265 N/$mm2$

5.10 Determination of Expeller Capacity

The theoretical capacity of the expeller was determined using a modified form of the equation given by Onwualu *et al.* (2006) as:

Qe= 60 x(π/ 4) ($Ds2 - ds2$)$Ps\ N$s φ …….. (13)

where, Qe is the theoretical capacity of the expeller,
Ds= is the diameter of the screw thread(58mm),
ds= is the base diameter of the screw shaft(38mm),
Ps= is the screw pitch(24mm),
Ns= is the rotational speed of the screw (worm) shaft(18rpm),
φ = is filling factor(0.9), and
ρ = is the bulk density of jatropha seed(450kg/m3).
Qe=15.83 kg/h

5.11 Design for the Pressure of the Barrel

This is the cylindrical member which fits tightly around the rotating extruder screw. The pressure that can be withstood by the barrel was determined by the equation given by Ryder (1985) and Khurmi and Gupta (2008) as:

$Pb = 2t\delta a/Di$…… (14)

Where, Pb is the pressure to be withstood by the barrel,
t is thickness of the barrel(8mm),
δo is the yield stress of mild steel (340/2 = 170 MPa),
δa is allowable stress = 0.27δo = 45.9 MPa,
and Di is the inside diameter of the barrel (56 mm).
Pb = 11.29 N/mm2 or 11.3 MPa. This means that the pressure that the barrel can withstand (11.3 MPa) is greater than the pressure developed by the screw thread for oil extraction (3.256MPa). Therefore, the barrel will withstand the extraction pressure without bursting.

5.12 Casing Stress

The thickness of the barrel wall =4 mm
The clearance = 2mm
Calculated diameter of casing barrel = thickness +clearance + Di is the inside diameter of the barrel =8+65 = 73mm

$\sigma = Pb \times Db2t$…… *(15)*

σ= *103.11 N/mm2*

5.13 Determination of Hopper Design

The hopper has a shape, which facilitates loading, maximum volume utilization and reliable and complete gravity discharge through its outlet.

Volume of hopper = ($1^3 - b2^3$ /$b1 - b2$)h ……..(16)

b1, length of larger part =150 mm
b2, length of smaller part = 35 mm
h = height = 200 mm
by equation the volume of hopper =2897500 m m^3 = 0.0028975 m3

5.14 Screw Press

Expellers use a horizontally rotating metal screw, which feeds the products into a barrel shaped outer casing. The products are continuously fed to the expeller through the hopper to the pressing unit through the screw which grinds, crushes and carry the products to be pressed through the pressure applied by the screw feeding movement and press the product between the plate and the sharp end of the screw. The residue of the material from which oil has been expressed exits from the nozzle in the front of the machine, and is known as the cake.

Most expellers are power-driven, and are able to process between 8 and 45 kg per hour of product depending upon the type of expeller used. Bigger units processing greater quantities of oil are available for use in larger mills. The percentage of oil expressed by expellers is as high as 90% depending upon the type and kind of products as well as the expeller being employed (Gate, 1979). The percentages of oil yield decreased with increasing of nozzle sizes, diameter screw, speed and temperatures (Deli, S.Farah Masturah, M., 1*Tajul Aris, Y. and 2Wan Nadiah, W. A. 2011)

The screw shaft was made of mild steel with dimensions of 50 mm for diameter of the screw flights and 38mm for the diameter of the mean shaft and 24mm for the pitch and 19mm the width of flights and length

5.15 Cylindrical Barrel

It is the screw casing and the place where the seeds have been crushed grind and pressed.

5.16 The Motor

It supplies the machine with the required power. The selected motor was a geared three phase motor that gives 100 rpm.

5.17 Oil Outlet

It is the unit that discharges the oil using perforations on the casing barrel of the machine through the nut at the front of the expeller. The diameter of the holes are 3mm.

5.18 Nozzle

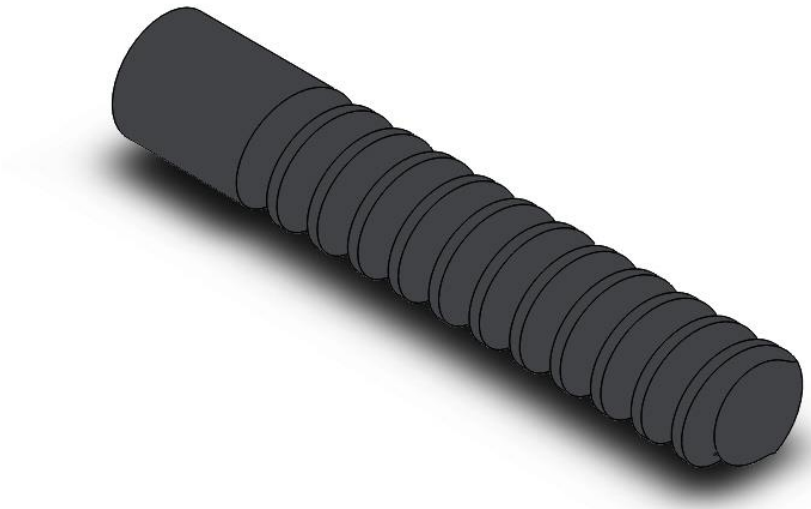
It is the short tube in the end of the casing barrel that controls the direction and the flow of the seed cake. It's a small hole with 17 mm diameter.

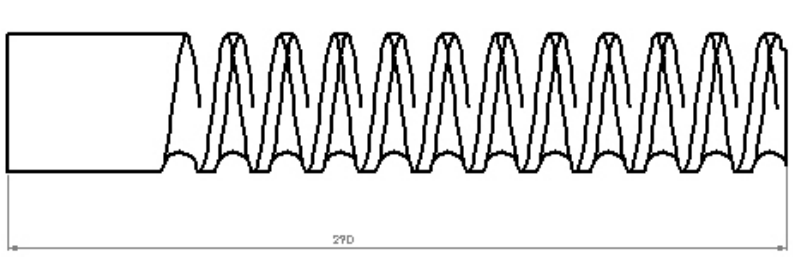
5.19 Oil Tray

It is the unit used to control the oil that comes out of the bottom of the nozzle and facilitate the oil flow of sheet metal.

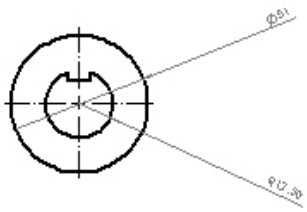
CHAPTER NO 6:
CAD DRAWINGS AND 3D MODELS

1. SCREW

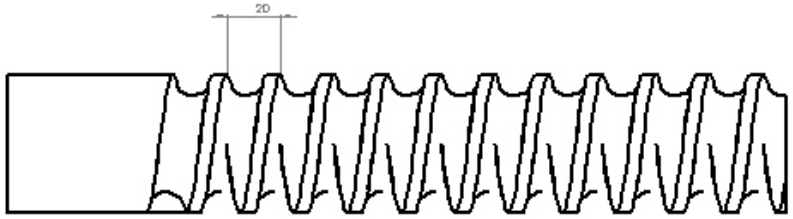




FRONT VIEW

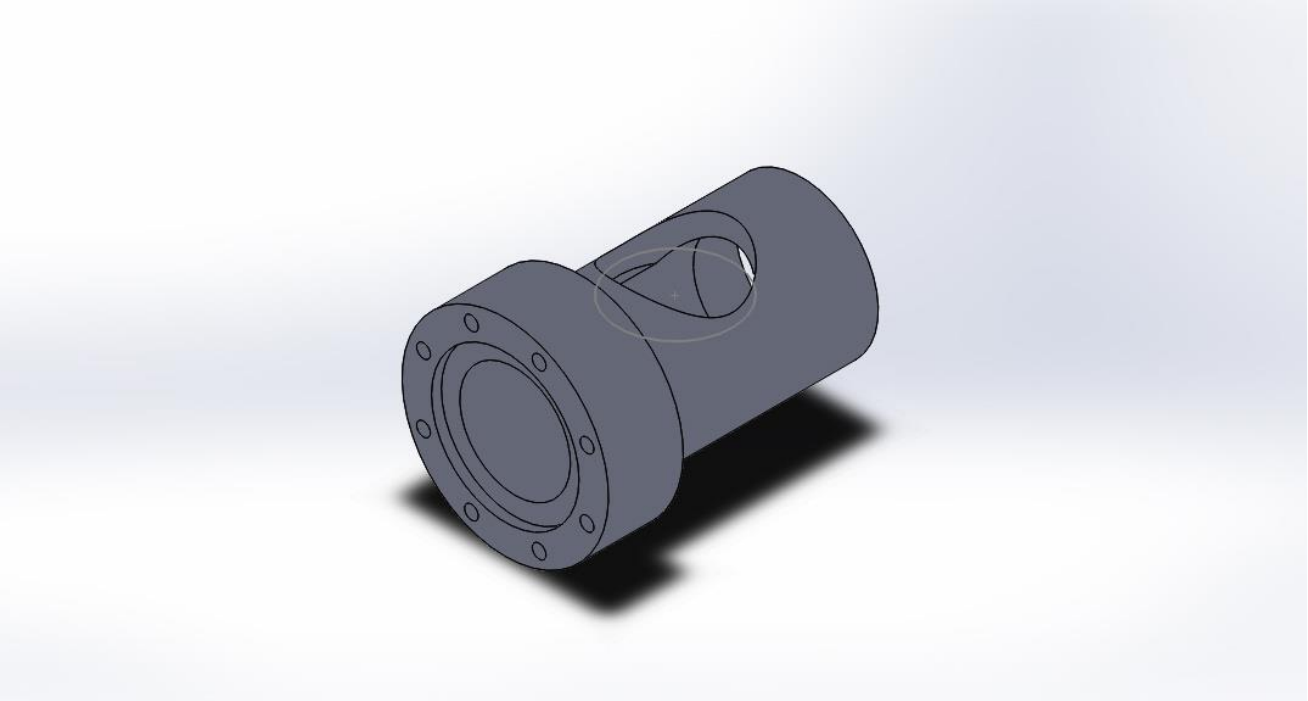


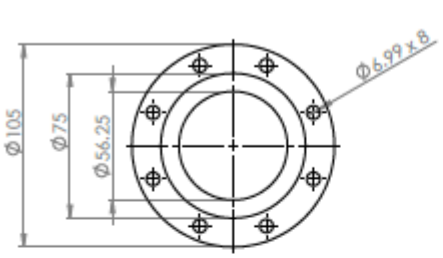
SIDE VIEW



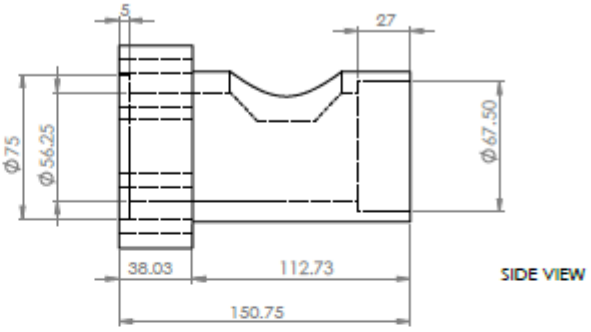
TOP VIEW

2. FEEDER

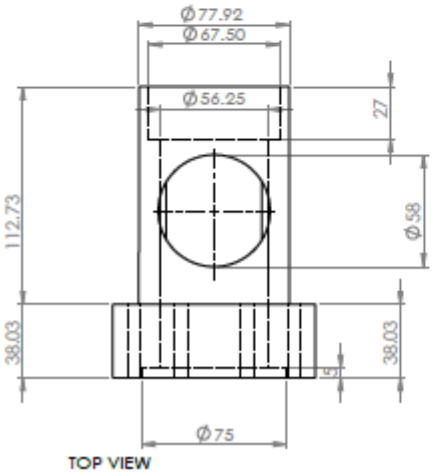




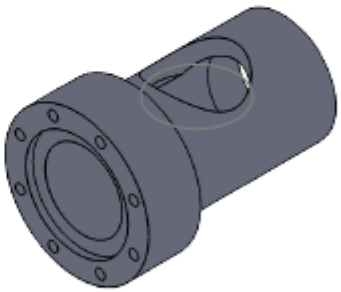
FRONT VIEW



SIDE VIEW

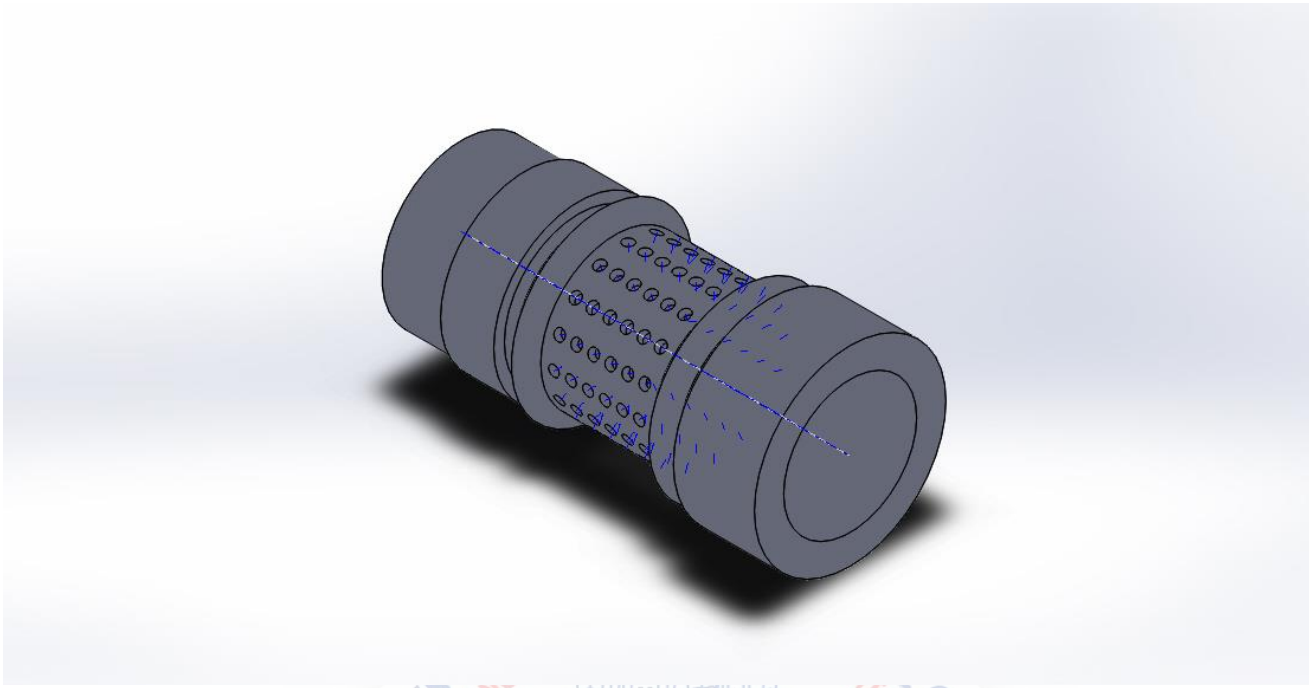


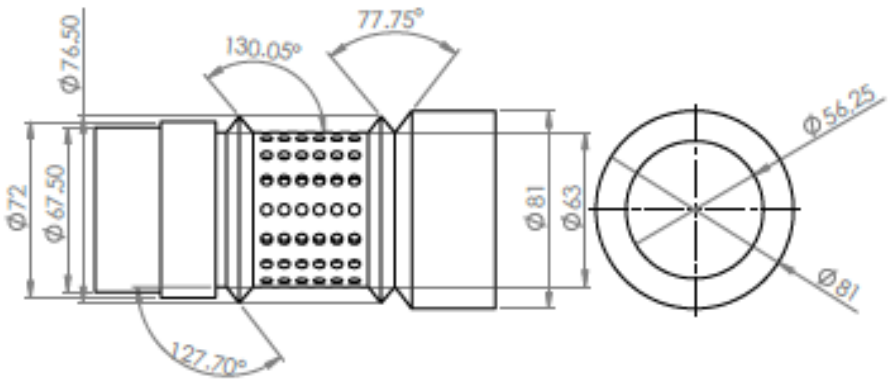
TOP VIEW



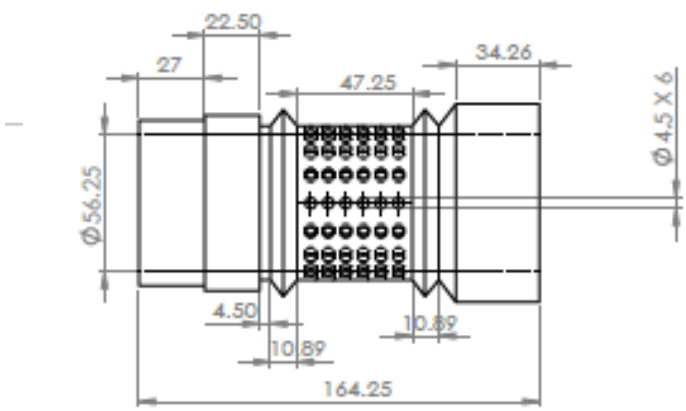
ISOMETRIC VIEW

3. CAGE (BARREL)



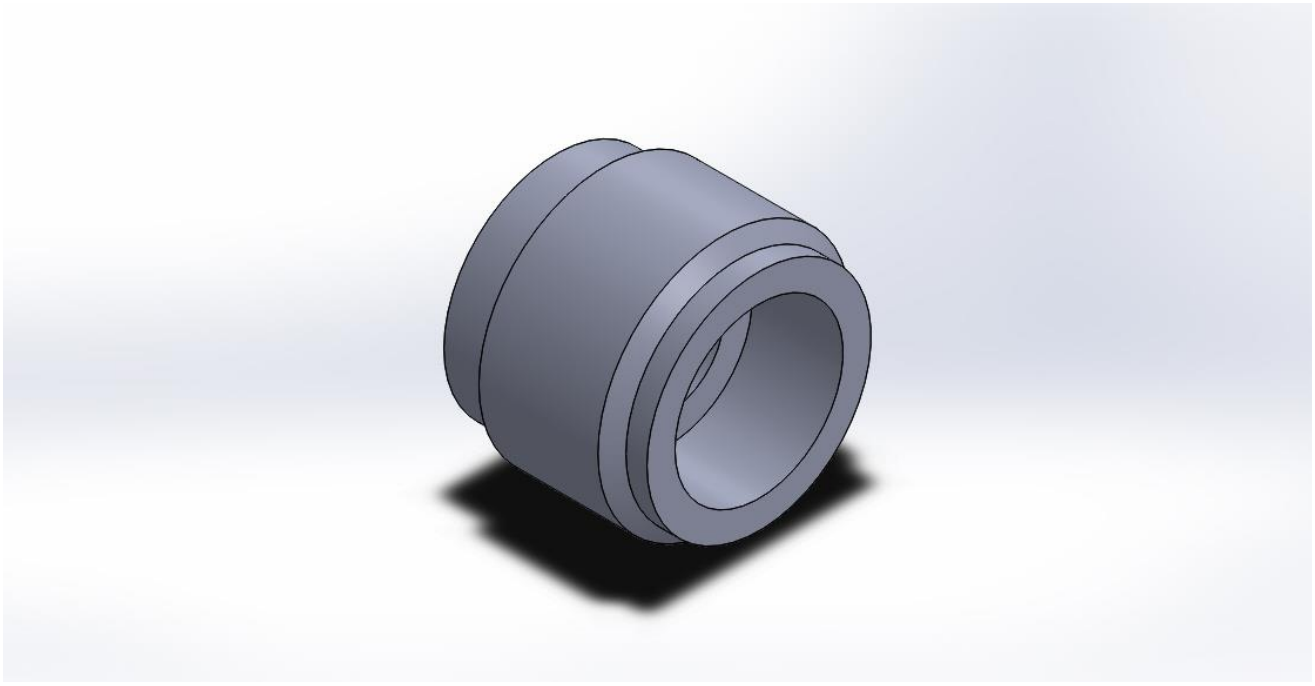


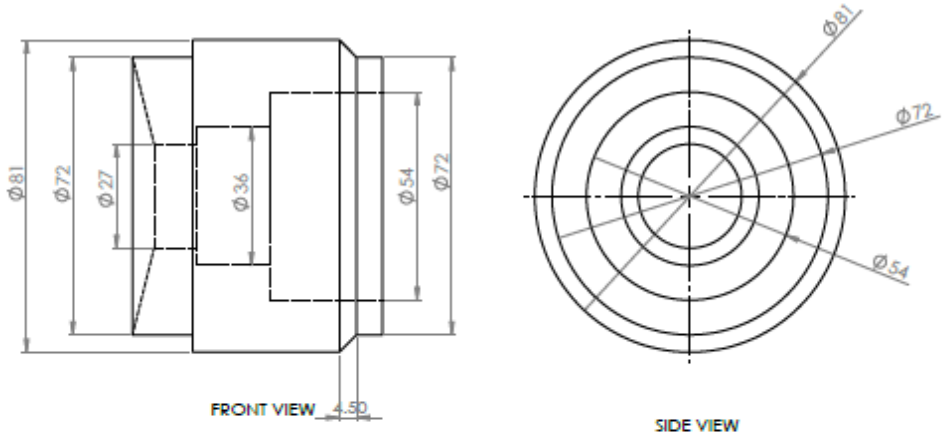
FRONT VIEW SIDE VIEW

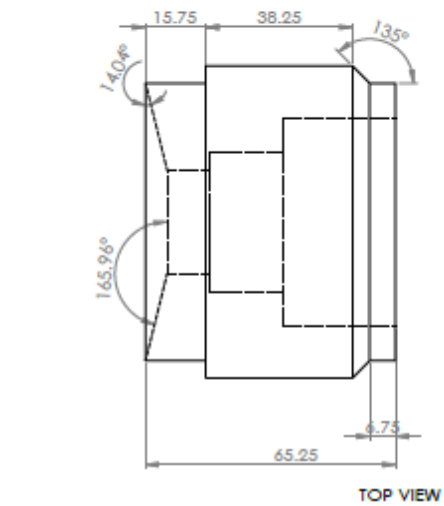


TOP VIEW

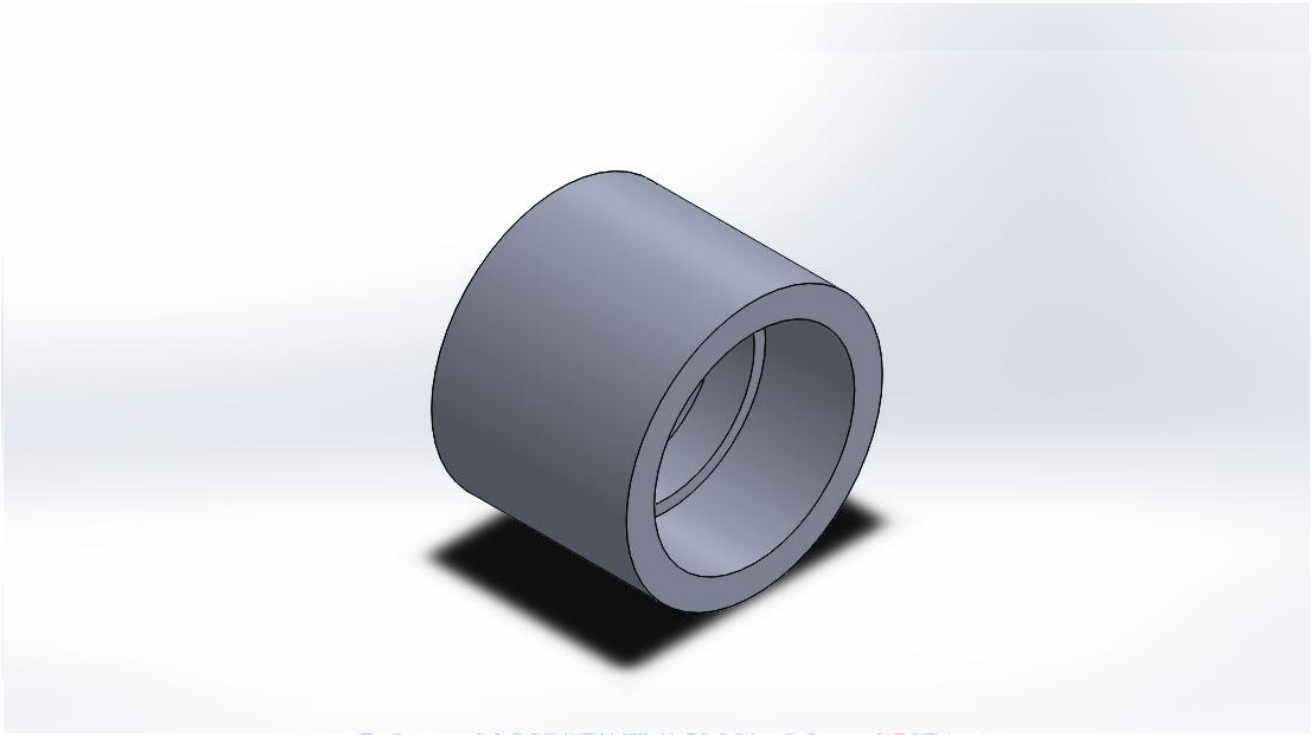
4. PRESS HEAD DIE

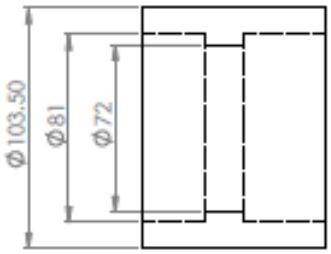




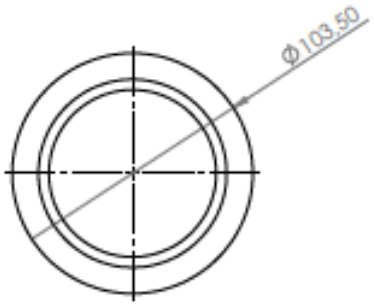


5. PRESS HEAD

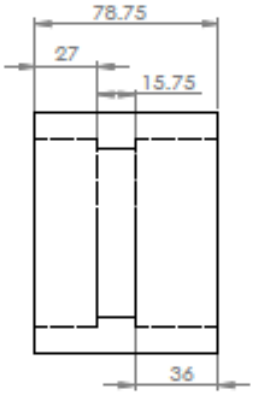




FRONT VIEW

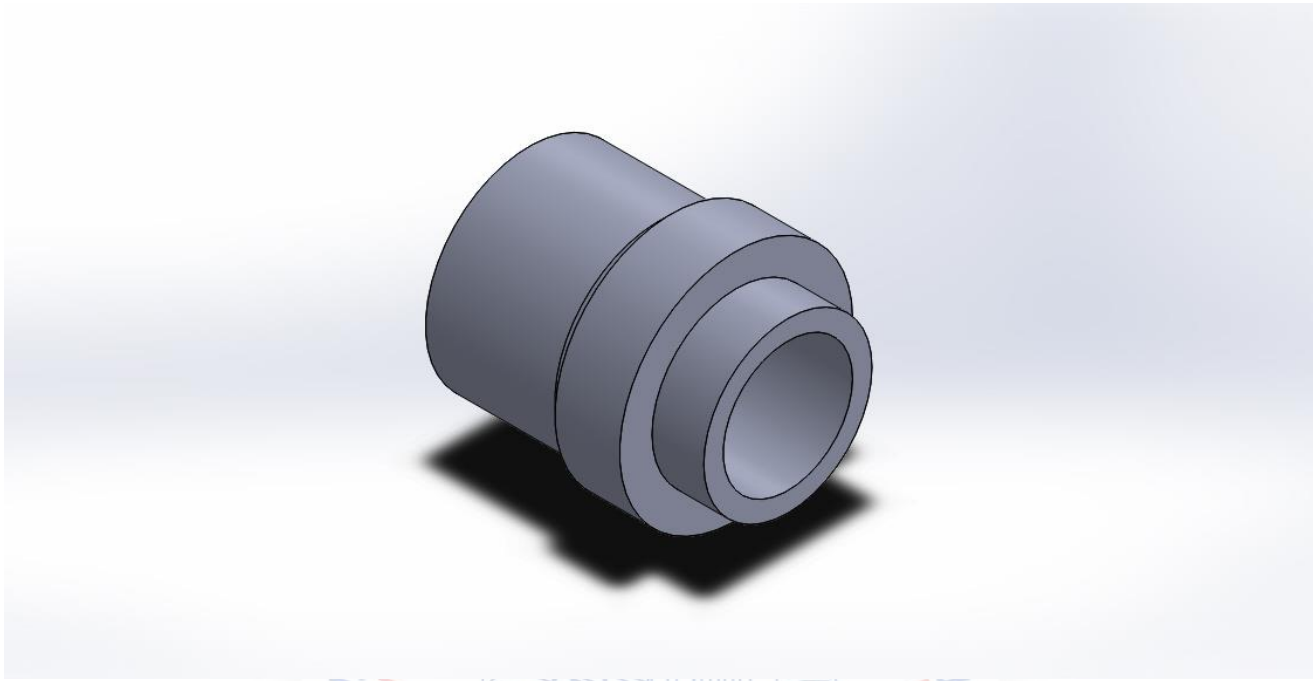


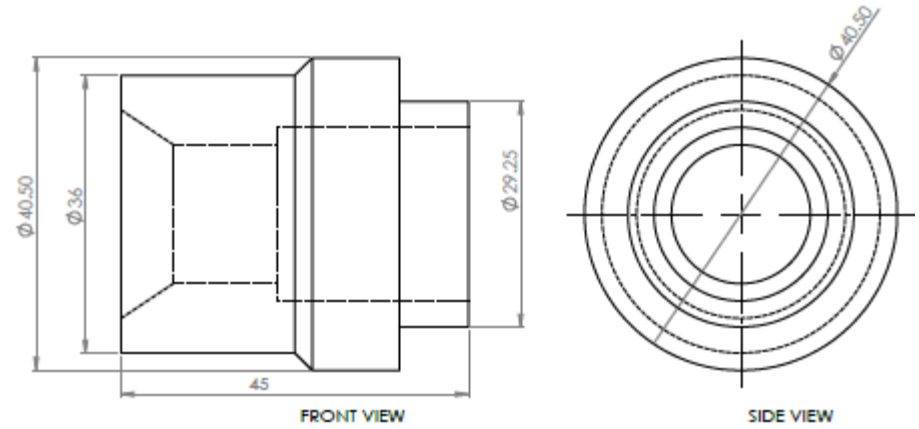
SIDE VIEW

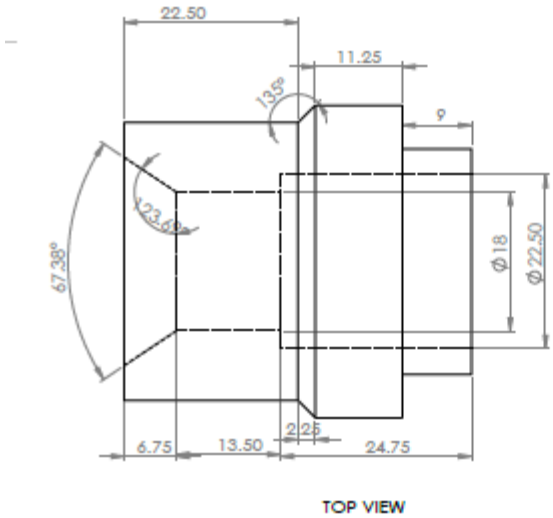


TOP VIEW

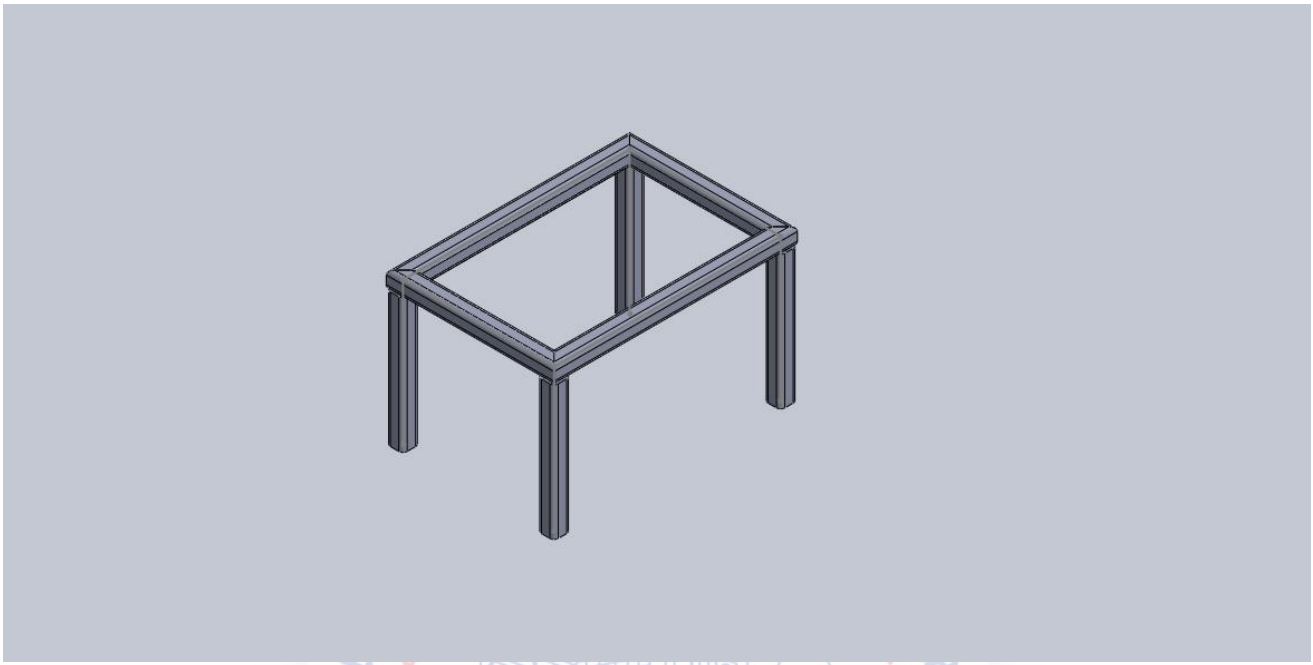
6. NOZZLE



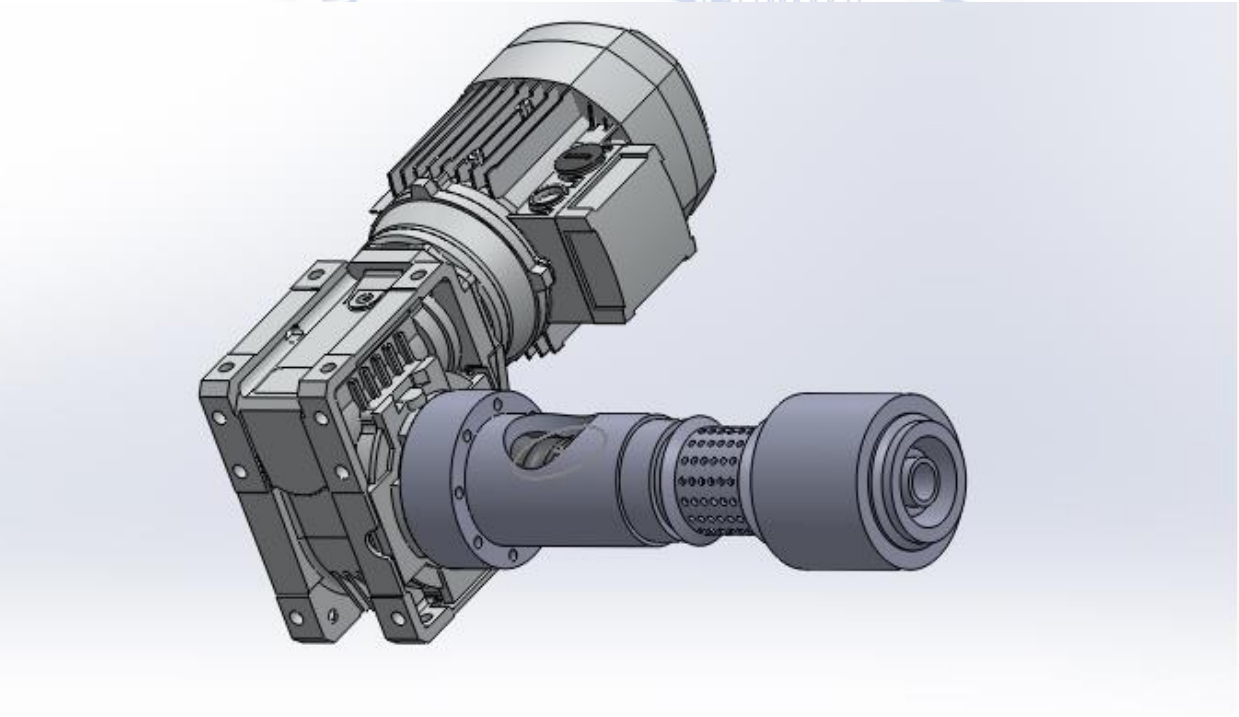

Ø40.50
Ø36
Ø29.25
45
FRONT VIEW
Ø40.50
SIDE VIEW


22.50
11.25
135°
9
23.69°
67.38°
Ø18
Ø22.50
6.75
13.50
2.25
24.75
TOP VIEW

7. FRAME



8. ASSEMBLY



CHAPTER NO 7: ANALYSIS

7.1 ANALYSIS

ANSYS is general-purpose Finite Element Analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user designed size) called elements. The software implements equations that govern the behavior of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole. The ANSYS Workbench environment is an intuitive up-front finite element analysis tool that is used in conjunction with CAD systems and/or Design Model. ANSYS Workbench is a software environment for performing structural, thermal, and electromagnetic analyses. The Workbench focuses on attaching existing geometry, setting up the finite element model, solving, and reviewing results

7.2 Introduction

ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software implements equations that govern the behaviour of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole. These results then can be presented in tabulated, or graphical forms. This type of analysis is typically used for the design and optimization of a system far too complex to analyze by hand. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations. ANSYS is the standard FEA teaching tool within the Mechanical Engineering Department at many colleges. ANSYS is also used in Civil and Electrical Engineering, as well as the Physics and Chemistry departments.

ANSYS provides a cost-effective way to explore the performance of products or processes in a virtual environment. This type of product development is termed virtual prototyping. With virtual prototyping techniques, users can iterate various scenarios to optimize the product long before the manufacturing is started. This enables a reduction in the level of risk, and in the cost of ineffective designs. The multifaceted nature of ANSYS also provides a means to ensure that users are able to see the effect of a design on the whole behavior of the product, be it electromagnetic, thermal, mechanical etc.

7.3 STATIC STRUCTURE:

A **static structural** analysis determines the displacements, stresses, strains, and forces in **structures** or components caused by loads that do not induce significant inertia and damping effect.

It is Used to determine displacements, Stresses, Strain, Deformation etc. under static loading conditions in both linear and nonlinear static analysis. Nonlinearities include plasticity, stress stiffening, large deflection, large strain, hyper elasticity, contact surfaces, and creep.

7.4 STRUCTURAL ANALYSIS:

Screw expeller is widely used for oil extraction in which the screw is the main part. The extraction of oil, it's characteristics depends on this part. So a detailed analysis of it is necessary for making the design effective & for achieving better quality of oil. As finite element method is cheap, most effective & very accurate it is used for the detailed analysis for this research work. In this research work the following software have been used e.g. Solidworks & ANSYS. A 3-D model of the screw was developed in Solidworks & saved as xt format for exporting in ANSYS. Static structural analysis system was used for the analysis of the design. The model was imported using command import external geometry file. Then the model was meshed using advanced sizing function.

7.5 VON-MISES STRESSES:

Von-Mises stress is very much preferred yield/ failure criterion for relative ductile metals like steel.

1. In an elastic body that is subjected to a system of loads in 3-dimensions, a complex 3-dimensional system of stresses is developed. That is, at any point within the body there are stresses acting in different directions, and the directions and magnitude of stresses changes from point to point.
2. The Von-Mises criterion is a formula for calculating whether the stress combination at a given point will cause failure.
3. There are three ―principle stresses‖ that can be calculated at any point, acting in x, y and z directions.
4. Von-Mises found that, even though none of the principal stresses exceed the yield stress of the material, it is possible for yielding to result from the combination of stresses.
5. The Von-Mises criterion is a formula for combining these three stresses into an equivalent stress, which is then compared to the yield stress of the material.
6. The equivalent stress is often called the ―Von Mises Stress‖ as a shorthand description. It is not really a stress, but a number that is used as an index. If the ―Von-Mises Stress‖ exceeds the yield stress, the material is considered to be at the failure condition.

7.6 GENERIC STEPS TO SOLVING ANY PROBLEM IN ANSYS

The complete analysis was based of the following points

(1) Pre-Processing
(2) Mesh Generation
(3) Results
(4) Post Processing

PREPROCESSING:

In preprocessing the decisions about the solution domain ,physical model was finalised. In preprocessing the following points were finalised to conduct detailed analysis and investigate the results.

The analysis was performed by using the following steps,

solving any problem analytically, you need to define

(1) Definition Of Solution Domain,
(2) The Physical Model,
(3) Boundary Conditions And
(4) The Physical Properties.

Object Name	*ASSEMBLY*
State	Solved
Definition	
Physics Type	Structural
Analysis Type	Static Structural
Solver Target	Mechanical APDL
Options	
Environment Temperature	22. °C
Generate Input Only	No

After finalising the above data the model was solved and different results were tabulated. In numerical methods, the main difference is an extra step called mesh generation. This is the step that divides the complex model into small elements that become solvable in an otherwise too complex situation. Below describes the processes in terminology slightly more attune to the software.

7.6.1. Geometry:

The 3 dimensional representation of the oil expeller was modelled using solid works software and tested using the word coordinate system within ansys. for the software compatibility the modelled assembly was imported in IGES file format into ansys environment. the units used are in metric and the angle in degree. It was imported in step file.

The total volume of the geometry inported was found to be 7.1109e+006 mm³ and mass of 55.821 kg the other properties are tabulates in the table.

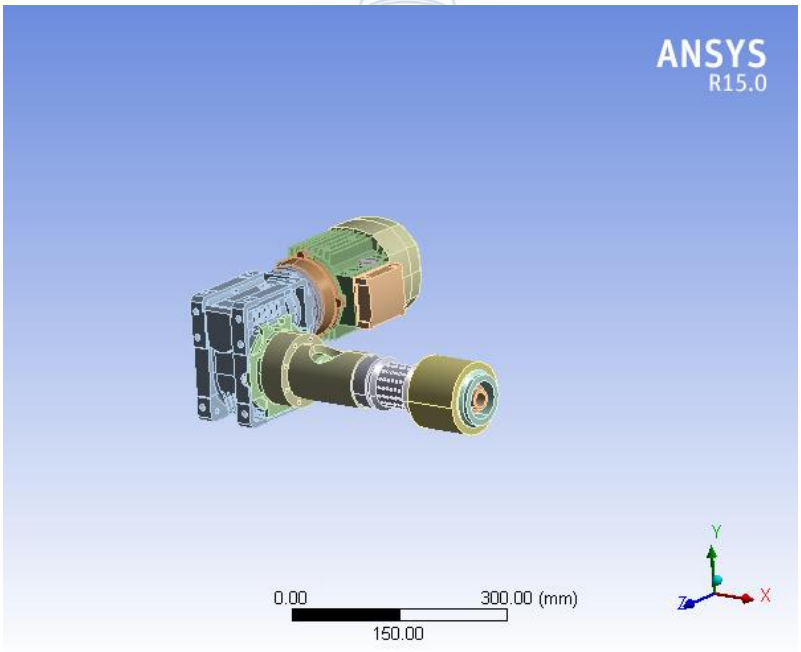


Figure 7.1 Geometry

Bounding Box	
Length X	475.55 mm
Length Y	203.97 mm
Length Z	386. mm
Properties	
Volume	7.1109e+006 mm³
Mass	55.821 kg
Scale Factor Value	1.

Object Name	*KEY*	*COUPLING SHAFT*	*SCREW*	*NOZZLE*	*PRESS HEAD DIE*	*PRESS HEAD*	*CAGE*
Material	EN8	EN8	EN8	EN8	EN8	EN8	EN8
Length X	35. mm	60. mm	290. mm	45. mm	65.25 mm	78.75 mm	164.25 mm
Length Y	7.27 mm	24.386 mm	54.676 mm	56.428 mm	105.7 mm	104.15 mm	97.166 mm
Length Z	8. mm	25.042 mm	54.676 mm	56.428 mm	105.7 mm	104.15 mm	97.166 mm
Volume	**2035.6 mm³**	**27636 mm³**	**4.3775e+005 mm³**	**30035 mm³**	**2.0495e+005 mm³**	**2.7379e+005 mm³**	**2.2473e+005 mm³**
Mass	1.5979e-002 kg	0.21695 kg	3.4363 kg	0.23578 kg	1.6089 kg	2.1492 kg	1.7641 kg
Nodes	261	974	4870	1126	1300	2180	15576
Elements	32	175	2426	580	668	1148	7509

7.6.2. Material Properties:

The material finalised for the analysis is EN8 and static structural .Properties for EN8 is given in the table. entered in engineering data of ansys software so that similar material can be used for assignment during setup modelling

EN8 carbon steel is a common medium carbon and medium tensile steel, with improved strength over mild steel, through-hardening medium carbon steel. EN8 carbon steel is also readily machinable in any condition.

MATERIAL DATA:

Structural Steel	
Density	7.85e-006 kg mm^-3
Compressive Yield Strength	250 MPa
Tensile Yield Strength	250 MPa
Tensile Ultimate Strength	460 MPa
Structural Steel > Isotropic Elasticity	
Young's Modulus	2.e+005 Mpa
Poisson's Ratio	0.3
Bulk Modulus	1.6667e+005 MPa
Shear Modulus	76923 MPa
EN8 > Isotropic Elasticity	
Young's Modulus	1.9e+005 MPa
Poisson's Ratio	0.27
Bulk Modulus	1.3768e+005 MPa
Shear Modulus	74803 MPa
Tensile Yield Strength	550 MPa

7.6.3. Meshing:

At this point meshing performed in the modeled assembly

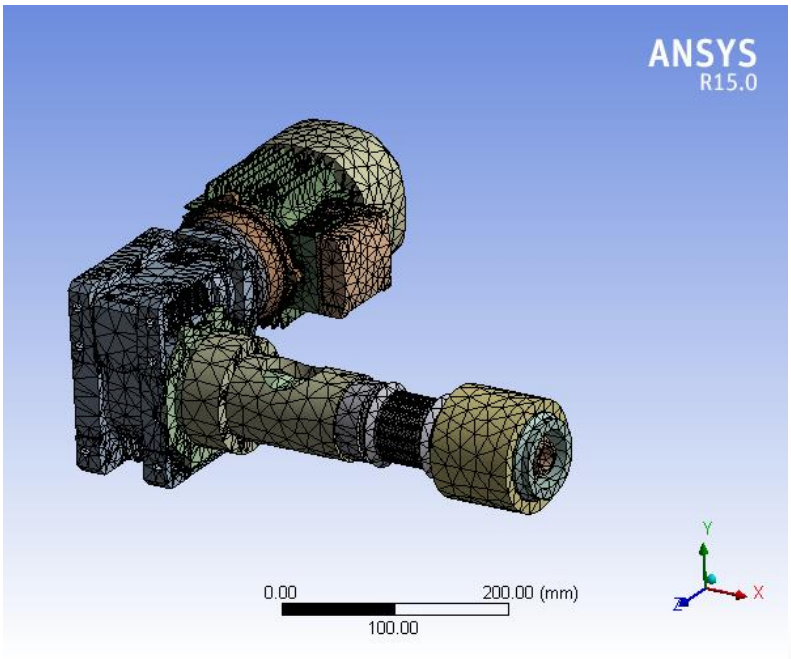


Figure 7.2. Meshing

During mesh we have taken relevance centre as coarse and the elemnt size was taken default the span angle was also taken as coarse and the nodes and elements generated were 225358 & 125901.

Mesh Properties

Object Name	*Mesh*
Sizing	
Relevance Center	Coarse
Element Size	Default
Smoothing	Medium
Transition	Fast
Span Angle Center	Coarse
Minimum Edge Length	1.3595e-005 mm
Statistics	
Nodes	225358
Elements	125901

7.6.4. Loads:

After meshing loads and constraints applied and the model as per the working condition the model which is traced for the cage internal pressure of 11.5Mpa which represents the pressure exerted by the solid algae on the walls of cage,expeller and other connected parts.

Object Name	*Fixed Support*	*Pressure*	*Pressure 2*
State	Fully Defined		
Scope			
Scoping Method	Geometry Selection		
Geometry	6 Faces	2 Faces	
Definition			
Type	Fixed Support	Pressure	
Suppressed	No		
Define By		Normal To	
Magnitude		11.5 MPa (ramped)	11.3 MPa (ramped)

7.6.5. Solution:

This is actually a step, because ANSYS needs to understand within what state (steady state, transient… etc.) the problem must be solved.

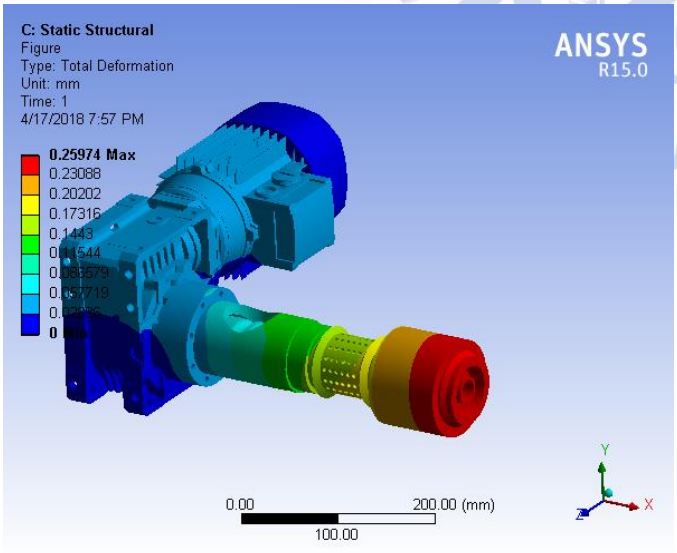


Figure 7.3 Total Deformation Of Assembly

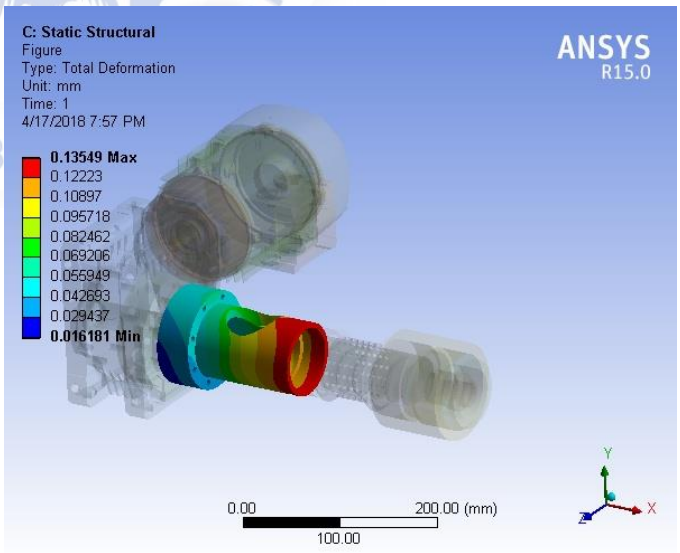


Figure 7.4 Total Deformation Of Feeder

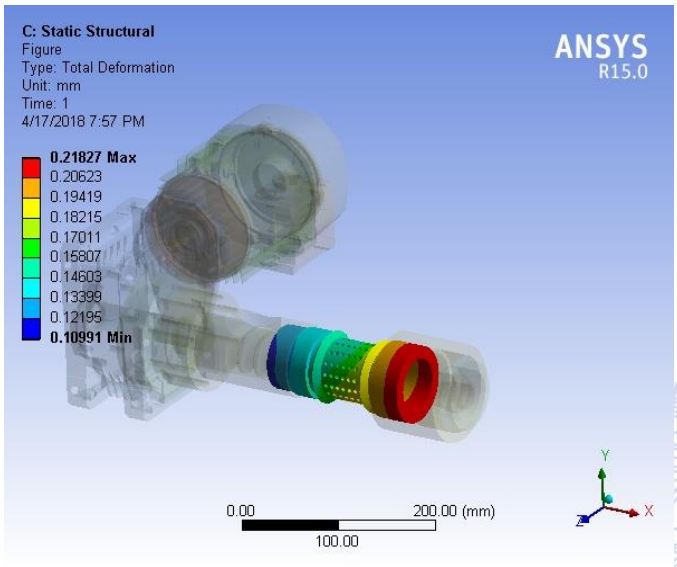


Figure 7.5 Total Deformation Of Cage

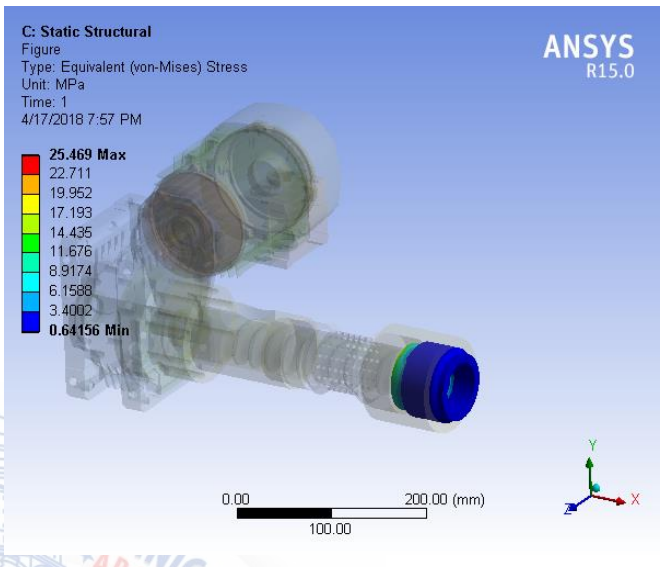


Figure 7.6 Von-Mises Stress Of Press Head Die

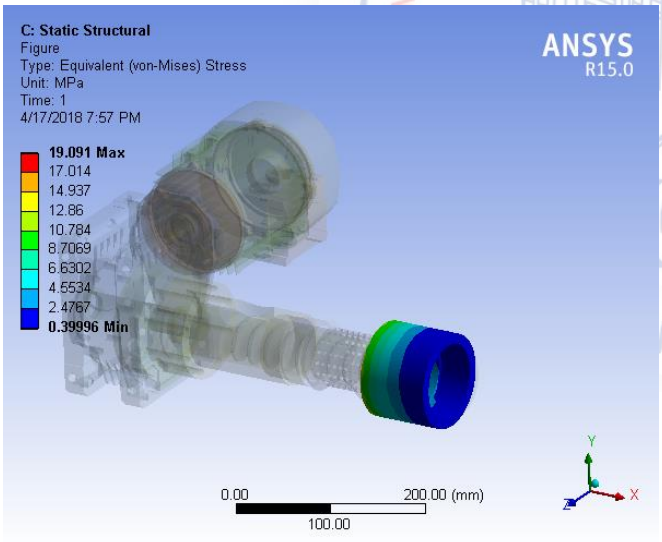


Figure 7.7 Von-Mises Stress Of Press Head

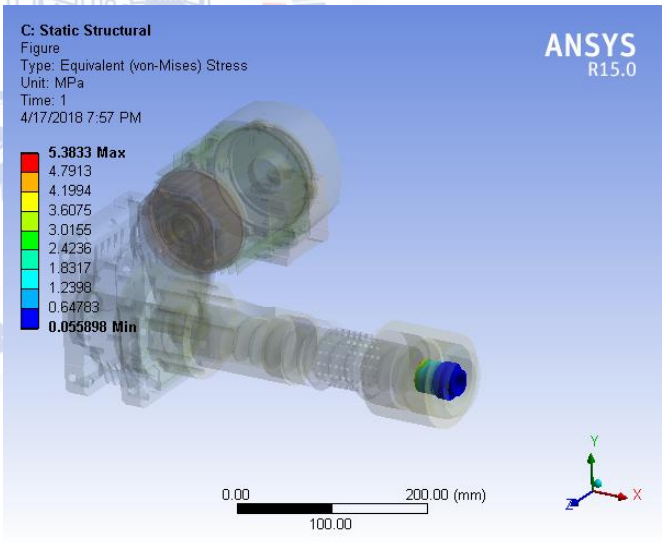


Figure 7.8 Von-Mises Stress Of Nozzle

OBJECT NAME	*EQUIVALENT STRESS*	*EQUIVALENT STRESS 2*	*TOTAL DEFORMATION*	*TOTAL DEFORMATION 2*	*TOTAL DEFORMATION 3*	*EQUIVALENT STRESS 3*	*EQUIVALENT STRESS 4*	*TOTAL DEFORMATION 4*	*EQUIVALENT STRESS 5*	*TOTAL DEFORMATION 5*	*TOTAL DEFORMATION 6*
STATE	Solved										
DEFINITION											
TYPE	Equivalent (von-Mises) Stress		Total Deformation			Equivalent (von-Mises) Stress		Total Deformation	Equivalent (von-Mises) Stress	Total Deformation	
RESULTS											
MIN	0. MPa	3.6516e-002 MPa	0. mm	1.6181e-002 mm	0.10991 mm	0.39996 MPa	0.64156 MPa	0. mm	5.5898e-002 MPa	0. mm	
MAX	261.56 MPa	29.244 MPa	0.25974 mm	0.13549 mm	0.21827 mm	19.091 MPa	25.469 MPa	0.25974 mm	5.3833 MPa	0.25974 mm	
MIN OCCURS ON	REDUTOR		REDUTOR					REDUTOR		REDUTOR	
MAX OCCURS ON	cage		press head die					press head die		press head die	
MINIMUM VALUE OVER TIME											
MIN	0. MPa	3.6516e-002 MPa	0. mm	1.6181e-002 mm	0.10991 mm	0.39996 MPa	0.64156 MPa	0. mm	5.5898e-002 MPa	0. mm	
MAX	0. MPa	3.6516e-002 MPa	0. mm	1.6181e-002 mm	0.10991 mm	0.39996 MPa	0.64156 MPa	0. mm	5.5898e-002 MPa	0. mm	
MAXIMUM VALUE OVER TIME											
MIN	261.56 MPa	29.244 MPa	0.25974 mm	0.13549 mm	0.21827 mm	19.091 MPa	25.469 MPa	0.25974 mm	5.3833 MPa	0.25974 mm	
MAX	261.56 MPa	29.244 MPa	0.25974 mm	0.13549 mm	0.21827 mm	19.091 MPa	25.469 MPa	0.25974 mm	5.3833 MPa	0.25974 mm	

7.6.6. Results:

After the solution has been obtained, there are many ways to present ANSYS' results, choose from many options such as tables, graphs, and contour plots.

7.7. Specific Capabilities Of Ansys:

Structural analysis is probably the most common application of the finite element method as it implies bridges and buildings, naval, aeronautical, and mechanical

7.7.1. Static Analysis

Used to determine displacements, stresses, etc. under static loading conditions. ANSYS can compute both linear and nonlinear static analyses. Nonlinearities can include plasticity, stress stiffening, large deflection, large strain, hyper elasticity, contact surfaces, and creep.

7.7.2. Modal Analysis

A modal analysis is typically used to determine the vibration characteristics (natural frequencies and mode shapes) of a structure or a machine component while it is being designed. It can also serve as a starting point for another, more detailed, dynamic analysis, such as a harmonic response or full transient dynamic analysis. Modal analyses, while being one of the most basic dynamic analysis types available in ANSYS, can also be more computationally time consuming than a typical static analysis. A reduced solver, utilizing automatically or manually selected master degrees of freedom is used to drastically reduce the problem size and solution time.

CHAPTER NO 8:
COSTING OF PROJECT

TOTAL COSTING OF THE PROJECT IN FIGURES

SR NO	ELEMENT	DESCRIPTION	COST
1	GEARED MOTOR	Bonfiglioli Geared Motor Actual Output – 1440rpm Geared Output – 100 rpm	7500
2	SCREW	AVAILABLE IN CAD DRAWINGS	1000
3	FABRICATION OF PARTS	AVAILABLE IN CAD DRAWINGS	10000
4	FRAME	AVAILABLE IN CAD DRAWINGS	1500
5	OTHER MISCILLANEOUS		1000
6	BLACK BOOK		2000
		TOTAL COST	23000

FUTURE SCOPE

Research is the unending activity after every research some issues will definitely come out and these issues are available for coming researchers. These issues provide the wide scope for the future design making that machine more and more efficient. In this oil expeller machine also there is a lot scope for future development such as improvement in design, safety, utility, and use of gear box

- Comprehensive testing of the developed oil extracting machine can be carried out in the actual field condition for rural areas development.
- Heater should be added to the next developed oil extracting machine for higher oil yield.
- Comprehensive testing for the oil been extracted from the machine.
- Automation Can be done Using Electrical Control System and Sensors.

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