Design and Stress Analysis of Screw Press Oil Expeller

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Abstract- The main aims of this paper design and stress analysis of screw press oil expeller. There are several processes to extract oil from these e.g. chemical, centrifuge and mechanical. A mechanical oil expeller press was designed and analyzed with simulation software (ANSYS) in this paper. This expeller can be used in small scale oil extraction. ASME shaft design code was used in designing the screw shaft of the press. Locally available material (mild steel) was used in manufacturing of the expeller. A 20 hp, 3-phase electric motor was used for running the machine and the rpm of the screw was maintained 140 rpm. A screw rotates inside the barrel of the press which creates pressure for the extraction of oil. Raw material is feeded through hopper and compressed inside the barrel for oil extraction and the cake is discharged through a choke mechanism outside. The pressure on screw was determined and applied in the created meshed design withANSYS software. From the achieved stress analysis it can be concluded that the screw used in this project is within safety limit of stress.

Indexed Terms- ASME shaft design, Screw, Mechanical Oil extraction, expeller, Stress analysis, Efficiency

I. INTRODUCTION

Oil expeller is a device which can produce pressure by rotating feed to expeller screw manually or automatically. Screw press method for oil extraction is a mechanical method for extracting oil from raw materials. Oil extracted by screw pressing is used either as a food product or as an industrial product. Food products include raw oil in dressings and made up to corn oil, peanut oil, rice bran oil etc.

One of the disadvantage of screw pressing is the low oil recovery when processing untreated seeds. But major concern is on it because it requires less capital & it can be used for low production. In screw press method seed is confined in barrel through hopper and extraction of the oil is accomplished by exerting sufficient force on confined seed. The residue of the material from which oil has been expressed exits from the unit and is known as the cake. The seeds are continuously fed to the expeller screw which grinds, crushes and presses the oil out as it passes through the machine.

By analyzing through simulating software design verification of parts used in screw presser can be modified and increase performance efficiency [5]. Limitation of our research is it will only discuss about the screw press extraction method yet there is another oil extraction method the solvent extraction. Solvent extraction is quite efficient method for this purpose hence it discharges press cake having less than 1% oil content. In spite of having high efficiency it possess some drawbacks. Firstly, solvent extraction process isn't suitable for small scale production. Secondly, it requires a costly plant and equipment. Thirdly, the commercially available hexane used in this process reacts with air to yield explosive mixture. In this research is introduced the simulation in purpose of stress and displacement analysis of the installed worm shaft. Worm shaft is the heart of screw press as it supplies the pressure required for extracting oil from the raw materials. It is found from observation that the failure of screw causes extra costs which is undesirable. In addition, excess stress, bending, displacement may cause major overhaul of the press. So to increase the life of screw press and efficient oil extraction it is necessary to find exact stress and bending of the screw blades. This research design and simulation is introduced which is performed by FEA (Finite Element Analysis) with ANSYS software.

II. MATERIAL AND METHOD

Locally available material mild steel was used in construction of the oil expeller. In the oil expeller firstly it was designed and validity of stress checked in ANSYSsoftware.

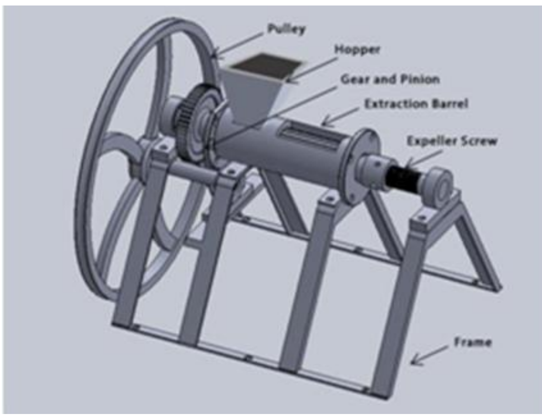

Fig.1 Main Component of the Oil Expeller [3]

III. DESIGN OF SCREW PRESS OIL EXPELLER

If the design pressure is increased, the length of the screw flight pitch in the direction of the axial movement is reduced. 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.

a. Torque on Rotating Shaft

$$T = \frac{63000\ hp}{N}$$

Where,
hp = horsepower of motor(20hp), N = motor (1500 rpm)

b. Diameter of the Screw Shaft

$$D^3 = \frac{\sqrt{(K_b \times M_b)^2 + (K_t \times M_t)^2}}{\pi S_s}$$

Where,
D = Shaft Diameter
M_b = Bending Load
M_t = Torsional Load
K_t = Combined shock and Fatigue factor applied to Bending Moment (1.5~2), (used 1.5)
K_t = Combined shock and Fatigue factorapplied to Torsional Moment (1~1.5), (used 1)
S_s = Allowable Shear Stress in Shaft (400Mpa)
Permissible Stress=$\frac{0.5 \times S_s}{f_s}$
Where, fs = factor of safety = 3 (Assuming)
Assuming, Belt drive maximum tension,P_1= 2.5 kN, μ = 0.24,
$\theta = 180°$
Now, $\frac{P_1}{P_2} = e^{\mu\theta}$
P_2= 1176.47 N
Torque, M_t= (P_1- P_2) × radius
Or, Mt = 330882.5 Nmm
Bending Moment, (P3-P4) ×R2=Mt
Or, (P_3-P_4) ×125 = 330882.5
So, P_3= 5000 N
P_4= 2352.94 N
From, Bending Moment Diagram, M_b= 1185625.45 Nmm

c. Load Lifted by Screw

$$W_e = \frac{\frac{D_m}{2}\tan\theta + \frac{\mu}{\cos\alpha}}{1 - \mu\tan\theta\cos\alpha}$$

Where,
D_m = Mean Thread Diameter
μ = Coefficient of friction (0.15)
α = Tapering angle (15°)
θ = Tapering Angle (3°)

d. Pressure Lifted by Screw Thread

$$P_r = \frac{W_e}{A_p}$$

$$A_p = \pi D_m nh$$

Where
P_r = Pressure lifted
A_p = Pressing Area
h = Screw depth at maximum pressure end (0.85m)
n = No. of Threads (4)
It can also be determined from Solidworks Mass propertiestools was found to be 0.064 accurately.

e. Oil Capacity

$$Q_e = 60\frac{\pi}{4}{D_s}^2 \times {d_s}^2 P_s N_s \varphi\rho$$

Were,
Q_e= oil capacity

D_s= diameter of the screw thread (0.07493)
d_s = base diameter of the screw thread (0.034)
P_s = Screw pitch (1.6)
N_s = rotational speed of the screw shaft (137 rpm)
φ = filling factor (0.8)
ρ = bulk density (0.415 kg/m^3)

f. Power and Torque on the Screw Shaft

$P = T_s \times \omega_s$

$$T_s = Fr_m \frac{\tan\theta + \frac{f}{\cos\theta_n}}{1 - \frac{f\tan\theta}{\cos\theta_n}}$$

Where,
P= Power
T_s= Torque
ω_s=14.66 rad/sec
F = Axial Load
f = friction coefficient (0.3)
r_m= Mean Thread Diameter
θ = 180°

g. Longitudinal and Hoop Stress

Since hoop stress is double than longitudinal stress. Design is based on hoop stress.
Assuming, σ_H = 40 Mpa, P = 15 Mpa
Given, D_m= 64.7 mm
Hence, we get reasonable value of extraction chamber thickness, t = 24 mm

$$\sigma_l = \frac{PD_m}{4t}$$

$$\sigma_H = \frac{PD_m}{2t}$$

Where
σ_l= Longitudinal Stress
σ_H= Hoop Stress
P = Pressure
D_m= Mean Diameter

Table.1.The Design Result Data ofScrew Press Oil Expeller

No.	Name	Result Data	Unit
1	Torque	94.465	Nm
2	Shaft Diameter	52	mm
3	Load Lifted by screw	15	kN
4	Pressing Area	0.064	m^2
5	Pressure Lifted by screw	2.34×10^5	Mpa
6	Oil capacity	22.25	Kg/min
7	Power required	5.931	kW

IV. STRESS ANALYSIS SCREW EXPELLER

Screw expeller is widely used for oil extraction in which the screw is the main part. The extraction of oil, its 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. Solid works and ANSYS. The result of this outcome may be used for the further improvement of the screw.

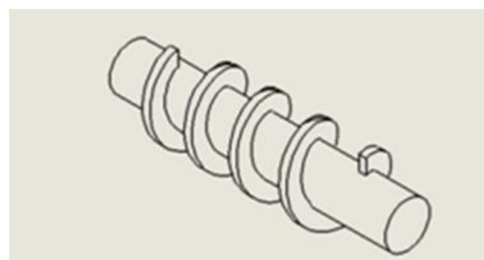

Fig.2 Structural Analysis of Screw Expeller

The 3-D model of the screw was developed in Solid works and saved as x_t 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. The minimum edge length was 7.62 mm. There was 145,370 nodes and 94794 elements in the mesh. Volume 5.1272e+005 mm³ and mass 4.0248 kg.

Structural Steel is used as the material of the screw. Different parameters of structural steel are: Density ρ = 7,850 kgm-3, Tensile yield strength = 250 MPa, Compressive yield strength = 250 MPa, Tensile ultimate strength = 460 MPa. Rotational velocity of the screw is 140 rpm which is around X-axis in clockwise direction. The other two ends are bearing support assumed as frictionless support. These conditions defines the full conditions of the constraints.

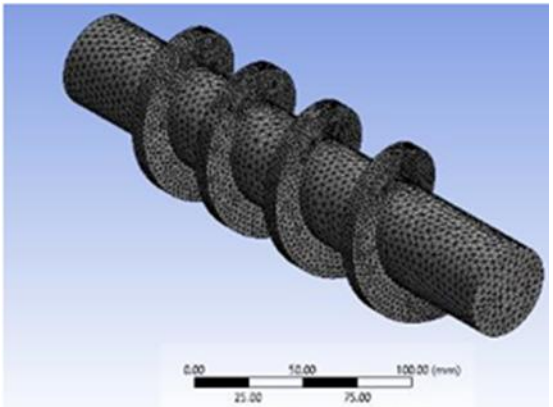

Fig.3Mesh Design of Screw Expeller

The stress acting in each screw thread as determined previously now applied in the thread as per direction satisfied. After defining the analysis setting simulation is carried on for maximum shear stress. By putting the pressure consecutively 0.938 Mpa, 0.469 Mpa, 0.312 Mpa, 0.234 Mpa on each screw thread, this paper stress was analyzed in ANSYS as Fig. 9 From the stress analysis it is found that the maximum stress developed in the screw shaft is 1.40 MPa maximum and 0.00115 MPa minimum. The maximum stress occurs at the discharged end and the minimum stress at the beginning or front of the screw.

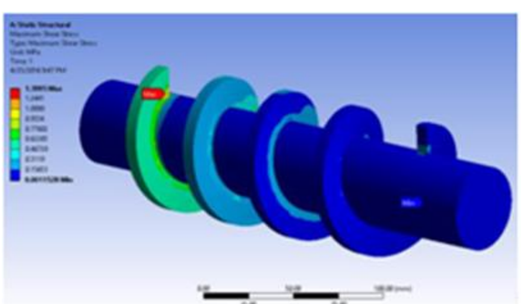

Fig.4Stress Analysis of Screw Expeller

V. CONCLUSION

From the above graphs it had been obtained that for each of the raw materials variation of extracted oil with respect feed of raw approaches to a constant value and variation of extracted oil with respect to time increases almost proportionally.

From the stress analysis the perfect clearance between the screw and barrel can be determined of the machine. The safe functioning of the screw was also checked in ANSYS by applying the pressure on thread.

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