ACTA TECHNICA CORVINIENSIS – BULLETIN OF ENGINEERING
TOME XVI [2023] | FASCICULE 3 [JULY – SEPTEMBER]

[1.]Carmen BĂLȚATU, [2.]Sorin–Stefan BIRIȘ, [1.]Eugen MARIN, [1.]Marinela MATEESCU, [1.]Gabriel GHEORGHE, [1.]Dragos MANEA, [3.]Gabriela MATACHE,[4.]Robert BILA, [4.]Oana–Diana MANOLELI–PREDA, [4.]Adrian PANDELE

DESIGN AND STRESS ANALYSIS OF THE SCREW OF THE MECHANICAL PRESS TO OBTAIN GRAPE SEED OIL

[1]INMA Bucharest, ROMANIA
[2]Politechnica University of Bucharest, Faculty of Biotechnical Systems Engineering, ROMANIA
[3]INOE 2000–IHP Bucharest, ROMANIA
[4]ROLIX IMPEX SERIES SRL, ROMANIA

Abstract: The extraction of oil from oilseed material by mechanical pressing is carried out in special machines called mechanical presses. The press's primary component sections are the transmission, press bearings, feed area, press chamber, screw, and barrel output. The screw plays a crucial role in a press's operation. A rotating helical body (screw) inside a cylinder–shaped enclosed space produces the pressing force (pressing chamber) in mechanical presses. In this article, we have designed the screw of an oil press to obtain oil from grape seeds. To make the 3D model, we used SolidWorks software, after which we also simulated the model under stress conditions. In the first phase, the behavior of the 3D model will be simulated for the screw with which a small press is equipped, a model most often used in farms for obtaining oil. Later we also simulated a screw model with a larger pitch to observe the differences in behavior between them. In this paper, we show whether the different pitch of the screw press models influences their degree of erosion and fatigue.
Keywords: grape seeds, Solidworks, screw press, simulation

INTRODUCTION

The extraction of oil from oilseed material by mechanical pressing is carried out in special machines called mechanical presses. These machines fall into two main categories: hydraulic presses and auger presses.

Hydraulic presses, so called because they are operated by liquid pressure, were first made in England and patented by Joseph Bromah in 1795. The working pressure, in these presses, is applied to a stationary mass by means of levers, jacks or hydraulic cylinders, and the oil removed from the compressed oily material is collected by rings at the bottom, (*Bargale, 1997*).

V. D. Anderson created the first screw press in the United States in 1900. In contrast to hydraulic presses, this press allowed operations to be carried out continuously, processing higher capacity with less equipment and less work, (*P. Evon et. al, 2009; C.N. Okoye et. al, 2008*). Thus, screw presses have gradually replaced hydraulic presses in oil extraction units, (*R.P. Hutchins et. Al, 1949*).

Mechanical presses are grouped into the following categories based on the degree of oil separation (more specifically, the amount of oil still in the broken), (*Milea D., et. al, 2018*):

- pre– or ante–press presses that guarantee the separation of 75–85% of the oil; these presses are made for moderate pre–press (with 18–22% oil in the broken) or advanced ante–press (with 12–14% oil in the broken); the latter kind may process 50% more seed while operating in moderate pressing mode;
- presses used for final pressing, which eject shattered objects with 3–5% oil;
- double action presses combine two pressing chambers in one machine to perform the final pressing and the pre–pressing.

The press's primary component sections are the transmission, press bearings, feed area, press chamber, screw, and barrel output. The press drive's main function is to transfer power from the press auger to the electric drive motor. Because it needs to be situated in the coolest, cleanest, and most effective region feasible for the best performance, the transmission is placed before the press feed area, where the pressure is the lowest, (*Choi, Y. et. al, 2009*).

The feed area is compounded from the food connection, horizontal feed zone, and vertical feed zone. A conveyor auger is located between the two zones, and the horizontal zone's screw speed variation allows the press's material feed rate to change, (*M.O. Faborode et. al, 1993*).

The pressing chamber for industrial press models is of the slotted drum type (Figure1). This type of pressing chamber consists of metal bars arranged side by side and separated by spacers to create oil discharge slots. The perforated cylinder press chamber (Figure 1), a different type of press chamber, consists of a cylinder with oil discharge ports in the form of milling holes placed in a certain location of the cylinder. As one gets closer to the discharge end, the compressive forces generated in the press chamber increase. Oil is driven through the perforations in the cylinder and discharged from the seed close to them. The oil is released from the press as pellets through the discharge end, which is made of replaceable nozzles. To prevent clogging of the barrel at the outflow, the nozzles are typically heated, (*M.O. Faborode et. al, 1993*).

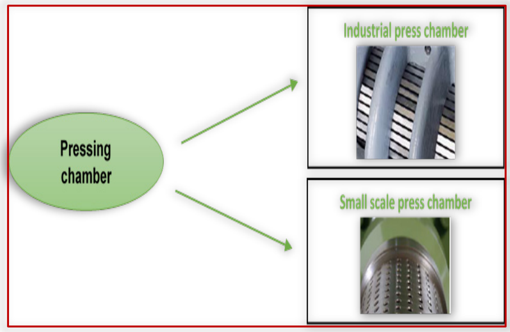


Figure 1 – Tow models of pressing champers (E. Ferchau, 2000, J.B. Xiao et. al,2007)

The screw plays a crucial role in a press's operation. A rotating helical body (screw) inside a cylinder–shaped enclosed space produces the pressing force (pressing chamber) in mechanical presses. The helical coil can be produced separately and welded to a tubular shaft or a solid shaft, or the screw can be created by spinning a cylindrical bar (the material matching the helical groove is removed). The design of the screw assembly is crucial for a successful press since it must consider how to produce high–quality oil and barrels with the least amount of energy. Different screw configurations are possible; some fundamental auger configurations are listed here, Figure 2. The screw variations with a diameter of and perhaps with variable pitch are thought to be inexpensive, (*V.V. Jinescu, 2007*), as variable diameter design variants are pricey.

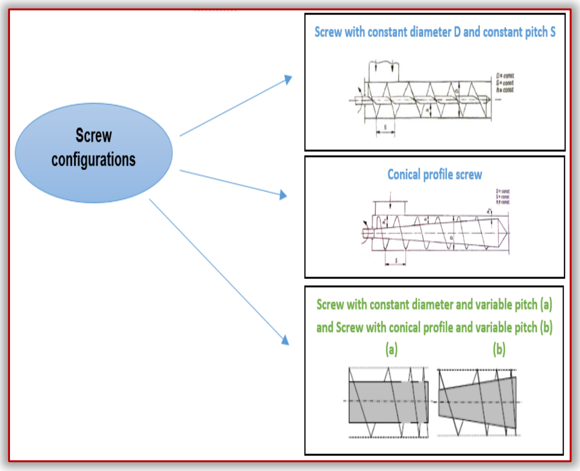


Figure 2 – Multiple models of the screw (*V.V. Jinescu, 2007, P. Sari, 2006*)

For this paper, we used the screw from a small press with a continuous pitch and a conical profile as a model. The screw has been 3d modeled and subjected to a simulation. The screw press's design has a significant impact on the amount and calibre of oil produced, (*Yaolin, 1981*). The pressing screw is a component of an assembly, and it is the most crucial component. It functions under the influence of friction forces from oil–based materials and various types of resistance forces, with surface wear and screw tooth fracture serving as the primary failure modes, (*Xuege Zhang et al. 2012; Yanan Pi et. al, 1996*).

MATERIALS AND METHOD

The oil press used as a model in these papers is presented in Figure3. Is a press whit a small working capacity, suitable for farms that want to obtain cold–pressed oil from various oilseeds.

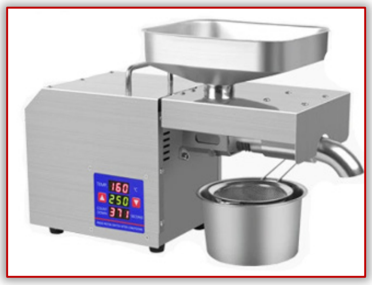


Figure 3 – Small screw press

For this screw press, we have two screws with different pitches, Figure4, which have been 3D designed in the SolidWorks program.

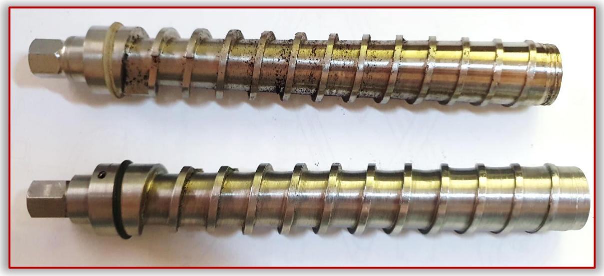
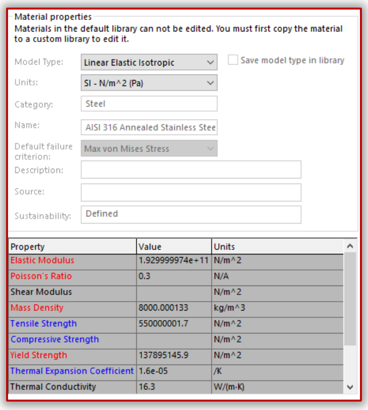


Figure 4 – Two screws with different pitches

After the 3D design of the two screw models, we prepared the part for its torsion simulation. We selected the material from which the screw is made, namely AISI 316 – Stainless Steel. This is steel that can be used for equipment in the food industry and has the properties shown in Figure 5.



Material properties

Materials in the default library can not be edited. You must first copy the material to a custom library to edit it.

Model Type: Linear Elastic Isotropic — Save model type in library
Units: SI - N/m^2 (Pa)
Category: Steel
Name: AISI 316 Annealed Stainless Stee
Default failure criterion: Max von Mises Stress
Description:
Source:
Sustainability: Defined

Property	Value	Units
Elastic Modulus	1.929999974e+11	N/m^2
Poisson's Ratio	0.3	N/A
Shear Modulus		N/m^2
Mass Density	8000.000133	kg/m^3
Tensile Strength	550000001.7	N/m^2
Compressive Strength		N/m^2
Yield Strength	137895145.9	N/m^2
Thermal Expansion Coefficient	1.6e-05	/K
Thermal Conductivity	16.3	W/(m·K)

Figure 5a – Material properties AISI 316 – Stainless Steel

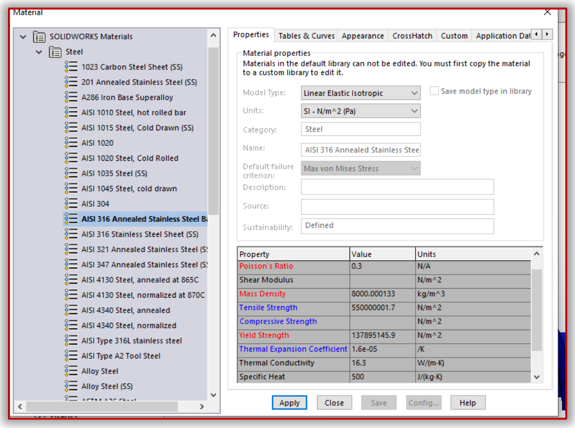


Figure 5b – Material properties AISI 316 – Stainless Steel

The next step was to fix the screw and apply 5Nm torque on all its surface, like in Figure 6.

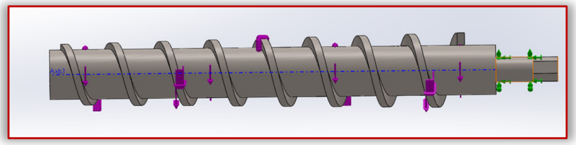


Figure 6 – 3D model of screw

A very important stage of design analysis is meshing. The software's automatic mesher creates a mesh based on the specifications for the global element size, tolerance, and local mesh control.

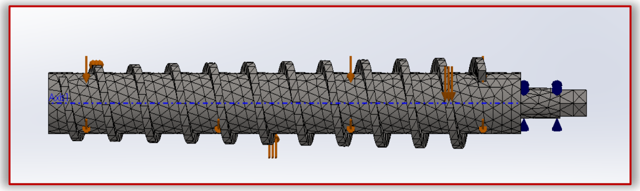
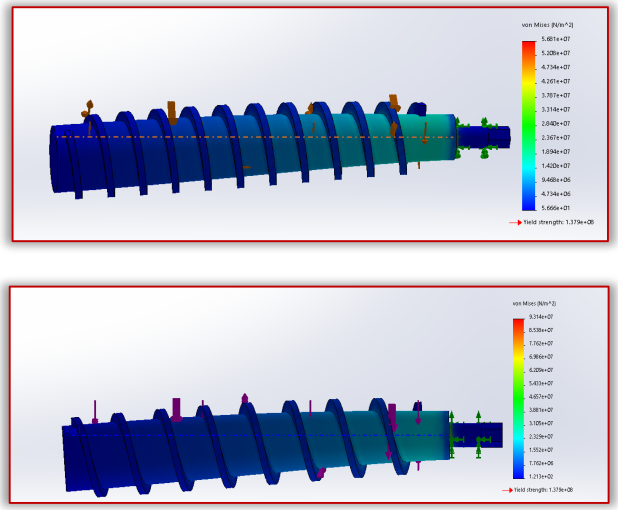


Figure 7 – Mesh of screw

RESULTS

The six components of stress are used to calculate von Mises stresses using the von Mises stress plot. The von Mises stress results are traditionally calculated using only the positive values of the stress components since the results of linear dynamic harmonic studies are generated for the greatest steady–state oscillation amplitude. When one stress component is positive and another is negative, there may be "stress phase offsets." According to the von Mises equation, the square of the difference between the values of a positive and negative stress component may be greater than the difference between the values of a positive and negative stress component.

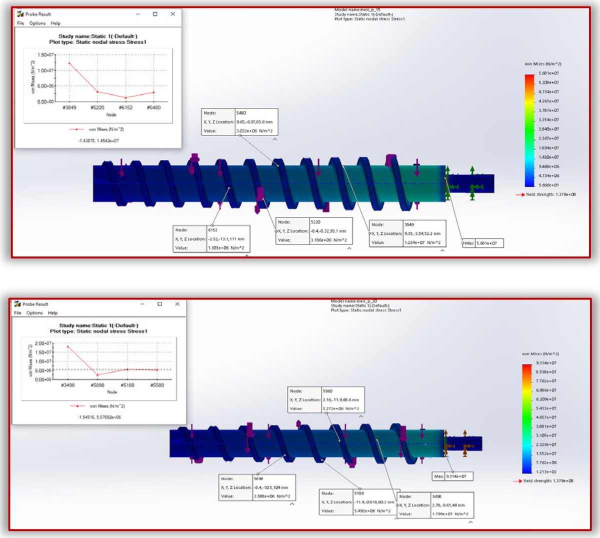
Given that the screw is embedded in the thinnest end, the toque motion makes the screw have the most constricted area in the screw fixing area. According to the von Mises diagram, in the case of the larger pitch screw, the values shown are higher than for the 10mm pitch screw. The difference can also be seen in Figure 9, in which samples are taken along the screw and the maximum point of the screw is shown.



(a)

(b)

Figure 8 – von Mises stresses of screw: a) 10 mm pitch; b) 18 mm pitch.

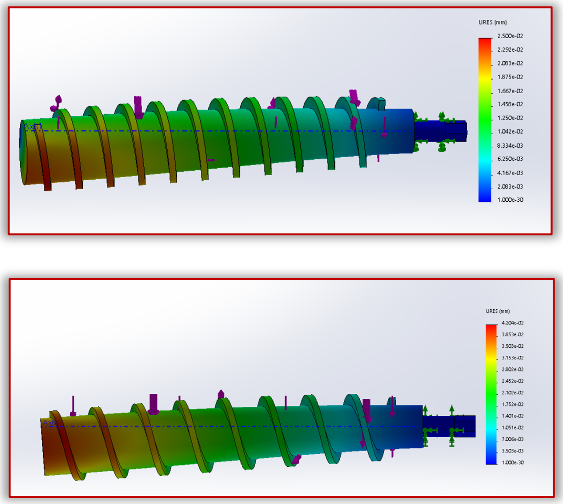


(a)

(b)

Figure 9 – Samples along the screw: a) 10 mm pitch; b) 18 mm pitch

It is clear that the stress is primarily concentrated at the side and root of the screw flight, increases spirally, and peaks at the root position close to the screw end. This pattern closely resembles the results of the strength check calculation and corresponds to the real loading conditions.



(a)

(b)

Figure 10. Displacement along the screw: a) 10 mm pitch; b) 18 mm pitch

CONCLUSIONS

Taking a typical screw press as an example, a simplified three–dimensional model of its pressing screw was established, and then a static calculation was done for this model using the finite element method to obtain its continuous deformation and stress distribution. This was done in consideration of the complexity and drawbacks of the traditional analysis and check method for the pressing screw.

According to this study, the pressing screw's stress mostly develops at the side and root of its screw flight, rises with the spiral, and peaks close to the root end. The interaction of the axial force and circumferential force results in this stress concentration state. It can be efficiently resolved by changing the design of the structure, selecting different materials, upgrading the processing procedures, or employing different heat treatment methods, hence increasing the security and dependability of the entire system.

Using the finite element method can save a significant amount of processing time and allow for direct observation of the object's deformation and stress distribution in comparison to the traditional design, analysis, and check procedure. It significantly increases design efficiency and dependability and serves as a crucial point of reference for structural design.

Acknowledgement

This paper was financed with the support of National Agency for Scientific Research and Innovation, NUCLEU Programme, no. 5N / 07.02.2019, project PN 19/10/01/03 – "Fundamentarea tehnologiei de recoltare şi prelucrare primară a tulpinilor de cânepă în verde".

Note: This paper was presented at ISB–INMA TEH' 2022 – International Symposium on Technologies and Technical Systems in Agriculture, Food Industry and Environment, organized by University "POLITEHNICA" of Bucuresti, Faculty of Biotechnical Systems Engineering, National Institute for Research–Development of Machines and Installations designed for Agriculture and Food Industry (INMA Bucuresti), National Research & Development Institute for Food Bioresources (IBA Bucuresti), University of Agronomic Sciences and Veterinary Medicine of Bucuresti (UASVMB), Research–Development Institute for Plant Protection – (ICDPP Bucuresti), Research and Development Institute for Processing and Marketing of the Horticultural Products (HORTING), Hydraulics and Pneumatics Research Institute (INOE 2000 IHP) and Romanian Agricultural Mechanical Engineers Society (SIMAR), in Bucuresti, ROMANIA, in 6–7 October, 2022.

References

[1] Choi, Y., & Lee, J. (2009). Antioxidant and antiproliferative properties of a tocotrienol–rich fraction from grape seeds. Food Chemistry, 114(4),1386–1390

[2] C.N. Okoye, J. Jiang, L.Y. Hui, „Design and development of secondary controlled industrial palm kernel nut vegetable oil expeller plant for energy saving and recuperation", J Food Eng, 2008; 87:578–90.

[3] E. Ferchau, „Equipment of Decentralized Cold Pressing of Oil Seeds", Webpage of Folkecenter For Renewable Energy, 2000, www.folkecenter.dk.

[4] J.B. Xiao, J.W. Chen, M. Xu, „Supercritical fluid CO2 extraction of essential oil from Marchantia convoluta: global yields and extract chemical composition", Electronic Journal of Biotechnology, vol. 10, no. 1, 2007

[5] Milea D., Vişan A.L., Păun A., Bogdanof C.G., Stroescu Gh. (2018) Performant equipments designed for grape marc seeds separation and calibration for supperior capitalization in food and phytopharmaceutical industry, 853–862, http://isbinmateh.inma.ro/archive.html

[6] Milea D., Vişan A–L., Păun A., Bogdanof C–G., Ciupercă R., Paraschiv G. (2018) Technological and ecological aspects of some wine waste recycling and their capitalization in food industry, Annals of the University of Craiova – Agriculture, Montanology, Cadastre Series, Vol. 48, pg. 320–327, http://anale.agro–craiova.ro/index.php/aamc/article/view/838

[7] M.O. Faborode, J.F. Favier, „Identification and Significance of the Oil–point in Seed–oil Expression", Journal of Agricultural Engineering Research, v. 65, p. 335–345, 1996.

[8] P.C. Bargale, „Mechanical oil expression from selected oilseeds under uniaxial compression", Ph.D. Thesis, University of Saskatchewan, Canada, 1997.

[9] P. Evon, V. Vandenbossche, P.Y. Pontalier, L. Rigal, „Aqueous extraction of residual oil from sunflower press cake using a twin–screw extruder: feasibility study", Ind Crop Prod, 2009; 29:455–65.

[10] P. Sari, „Preliminary design and construction of a prototype canola seed oil extraction machine", Ph.D. Thesis, Middle East Technical University, Ankara, Turkey, 2006.

[11] R.P. Hutchins, „Processing of oilseeds and nuts by hydraulic and mechanical screw press method", Journal of the American Oil Chemists' Society, 26:559–563, 1949.

[12] V.V. Jinescu, 2007, „Maşini cu elemente elicoidale", vol. I, Editura AGIR, Bucureşti.

[13] Yaolin Tan. Oils and fats technology, Vol. 6 (1981), p. 287

[14] Yanan Pi, Xingming Wang, Lili Dai, etc. China oils and fats, Vol. 21 (1996), p. 49

[15] Xuege Zhang, Yi Wu, Jinglan Ruan. Packaging and food machinery, Vol. 30 (2012), p. 47

ISSN: 2067-3809