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# DEFINING THE INFLUENCE OF THE SCREW PRESS LOADING CONDITIONS ON THE CONSUMED CURRENT OF ITS DRIVE WITH THE USE OF ARDUINO MICROCONTROLLER

In scope of this article was developed method for detecting how the loading conditions of a screw press impact its drive's power consumption with the help of sensors and Arduino microcontroller. Since sunflower oil is one of the most common products of the food industry, the problem of efficiency of the seeds processing is an urgent one aimed at improving the performance of presses and decreasing the consumed power of their drives. The research employed scientific methods such as analysis, modeling, experiment, measurement and observation to create valid outcomes. The simplified schematic diagram of the screw press electromechanical system is developed based on its full-scale experimental prototype LiangTai LTP200. The measurements are performed with the help of the current and voltage sensors SCT-013-030 and ZMPT101B connected to the Arduino microcontroller. Study defines the loading levels of the pressing chamber as the ratio between the volume of the sunflower seeds loaded into the chamber and the total active volume of the chamber. The volume of the seeds is defined with the help of the measuring sleeve (volumetric flask) and is additionally calculated as the product of their mass by the corresponding bulk density. The mass is measured by the electronic scales KYA800077. The study tested consumed current at no-load conditions and at the loading levels of 33 %, 67 %, 100 %. The experiments conducted for the case of the sunflower seeds processing confirm the proportional increase in the consumed current of the screw press drive during the increase of the loading level of the pressing chamber. This allows improving the corresponding control algorithms aimed at optimizing the power consumption of the press drive. The significance of utilizing the Arduino microcontroller in this context is profound. This research has set the ground for the possible application of these methods in other oil-containing seeds processing. In addition, the experimental data can be used for monitoring and preventing the overloading conditions that can cause the breakdown of the press drive elements.

**Keywords:** sunflower oil; seeds processing; consumed power; pressing chamber; control algorithm; overloading conditions.

## Introduction / Вступ

Sunflower oil is one of the most widespread food products. Unlike industrial machinery intended for pressing seeds, small household presses are not comprehensively studied in terms of performance and energy efficiency while processing different types of seeds and kernels. Therefor exists problem with defining dependency of the consumed current of the screw press drive on the pressing chamber loading level, to enable optimal performance and energy efficiency the of the oil extraction process. To ensure accurate data and real-time monitoring, it is advisable to use an Arduino microcontroller together with current and voltage sensors.

The existing scientific literature provides a rich analysis of various aspects of screw press operation, with studies exploring mechanical elements, structural parameters, heat creation, oil yield, and lifespan of the device. Advanced methodologies such as regression analysis, strength analysis, and the use of the finite-element method have been employed to optimize screw press design and performance. In particular, the influence of screw design modifications on efficiency and longevity has received significant attention. Some studies have ventured into automation of the oil extraction process, examining potential strategies for temperature regulation, sensor integration for monitoring oil volume and motor current, and electronic systems for adjusting screw rotation frequency.

However, within this body of research, a noticeable gap persists. The specific area of examining the influence of the screw press loading conditions on the consumed current of its drive using a system like the Arduino microcontroller for real-time monitoring and data collection remains largely unexplored.

Given the increased interest in automation and application of smart technologies, this area presents significant potential research opportunities. Exploring the utilization of Arduino microcontroller and similar microcontroller-based systems for process optimization in screw press operation is highly relevant task. Such exploration could provide valuable insights for enhancing energy efficiency, operational control, and overall performance of the oil extraction pro-

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cess, warranting further study.

*Object of research* – application of Arduino microcontroller and sensors SCT-013-030 and ZMPT101B for measuring voltage and current consumed by the press drive at different loading levels.

*Subject of research* – methods and means of quantitative definition of the influence that varying loading conditions in the screw press has on the consumed current of its drive.

*The purpose of the work* – define the influence of the screw press loading conditions during sunflower seeds processing on the consumed current of its drive with the use of smart technologies which will allow to monitor the loading level of the pressing chamber depending on the power consumption.

To achieve this *purpose*, the following main *research objectives are identified*:

1. To analyze the general design and structure of the screw press system LiangTai LTP200.
2. To develop an experimental prototype of the screw press for oil processing and equip it with sensors and Arduino microcontroller for real-time data monitoring.
3. To experimentally investigate the dependency of the screw press drive's consumed current on varying loading levels within the pressing chamber.
4. To analyze the collected experimental data and determine the influence of chamber loading conditions on power consumption.

**Analysis of recent research and publications.** The existing global scientific literature has provided valuable insights into various facets of screw press operation and the factors influencing its efficiency. The examination [9] focused on analyzing the forces and energy exerted within the press chambers of the FL 200 press during the compression of sunflower seeds. To achieve this, a universal compression machine and a tangent curve model were utilized.

The study [13] examines how technological and structural factors of the screw press, such as screw shaft pitch, speed, and cake removal area, affect energy usage in oil extraction. Regression analysis from multifactorial experiments helps estimate these influences, aiding in designing oil press machines. Response surfaces show the relationship between power consumption and cake removal area, screw shaft pitch, and speed. For specific parameters (e.g., shaft pitch of 21.8 mm, cake removal area of 107.99 mm$^2$, shaft speed of 5.12 min$^{-1}$), power usage is 170 W, maximizing oil yield at 36 %.

Using stepwise regression analysis and a normal probability plot, the study [10] finds statistically significant relationships between the theoretical deformation energy, force, pressure, and energy of the FL 200 screw press and several predictors, with coefficient of determination values ranging between 61 % and 86 %. Study [7] suggest a novel screw press design with optimal pressing parameters based on the algorithm of engineering calculations and analytical forecast. Empirical evidence has demonstrated that a reduced screw rotation speed leads to decreased heat creation and enhanced oil recovery.

On the other hand, article [18] analyses the mechanical elements of the screw press, focusing on its design, service cycles, and remaining lifespan. The authors determine that the screw press that operates at a rate of 121 pressing cycles per hour has a total lifespan of 2.625×105 cycles. In studies [5, 8] structural analysis is applied to design safe and efficient screw presses with increased productivity for small-scale applications. Experimental design methods and strength analysis are employed in the study [3]. The significance of screw geometry parameters has been determined, and calculations have been conducted to assess the load and temperature effects. A methodology for evaluating process efficiency and improving the durability of press-extruder components is presented.

The article [2] investigates modifications to the screw design of the JY 200 oil extraction machine, aiming to enhance its efficiency and longevity. By adjusting the pitch of the screw shaft, the study found improvements in oil capacity and the number of cycles to failure, while also reducing the von Mises stress, deformation, and fatigue stress of the press. The paper [11] investigates the design of an advanced screw-type press for oil extraction and explores the screw's stress-strain states under extreme load conditions using the finite-element method. The work clarifies zones of screw overloading and discusses how to ensure screw reliability and longevity.

The study [16] examines a rapid method for assessing the necessary load strength for forging using an extrusion press. A new drive for a modified machine has been experimentally and theoretically tested. Experiments were conducted on two presses to confirm the theoretical approaches. The modified press demonstrated increased energy and load strength. A number of studies are dedicated to defining optimal rotation speed and temperature parameters for extracting oil [1, 14].

This paper [12] delves into optimizing the extraction process of vegetable oils through meticulous analysis and mathematical modeling. By scrutinizing multiple elements influencing the process, such as rotational frequency and flight pitch of the screw, it aims to enhance productivity and efficiency. Authors provide visualized graphical representations to aid in comprehending the relationships between parameters.

The literature reviewed suggests various avenues for automation in the oil extraction process. These include implementing temperature regulation, integrating sensors to track oil volume and motor current, and utilizing electronic systems to adjust screw frequency. The findings serve as a valuable resource for researchers and engineers in refining screw press designs and performance. In one study [17], authors developed a modernized screw-type press tailored for this purpose, demonstrating a commitment to innovation in the field. Additionally, another investigation [6] showcased the practicality of developing a press equipped with a twin screw, further expanding the possibilities for enhancing efficiency and productivity in oil extraction processes.

## Research results and their discussion / Результати дослідження та їх обговорення

***Analysis of main elements of screw press LiangTai LTP200.*** The general design of the small household screw press LiangTai LTP200 is presented in Fig. 1. It consists of the press body 1, charging opening 2, pressing chamber 3, discharging opening 4, filter sieve 5, and oil tank 6. The sunflower seeds are loaded (fed) into the opening 2 of the pressing chamber 3, where the screw-type working member processes them and extracts the oil. The latter flows out from the pressing chamber through the grooves (slots) cut on its bottom surface. The extracted oil passes through the filter sieve 5 and is supplied to the tank 6. The sunflower cake is discharged through the opening 4 into a bag, box, or another package.


**Fig. 1.** General design of the screw press LiangTai LTP200 / Загальний вигляд шнекового пресу LiangTai LTP200

The simplified schematic diagram of the screw press electromechanical system is shown in Figure 2. The sunflower seeds are fed into the pressing chamber, where the screw crushes and presses the seeds and extracts the oil. The processed material is discharged in the form of the sunflower cake. The gearbox is used for reducing the rotational frequency and increasing the pressing torque transmitted from the shaft of the asynchronous electric motor to the screw shaft. In order to control the angular speed of the motor shaft, the frequency converter is implemented. The latter is powered by the urban single-phase network of alternating current of 50 Hz (230 V).

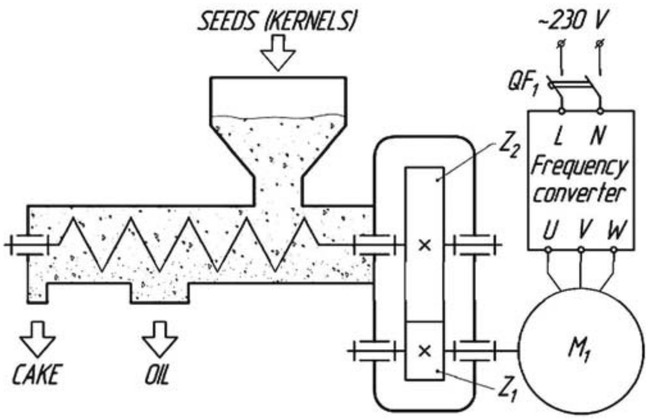


**Fig. 2.** Simplified schematic diagram of the screw press electromechanical system / Принципова схема електромеханічної системи шнекового преса

***Preparing experimental prototype of the screw press for oil processing and equipping it with sensors and Arduino microcontroller for real-time data monitoring***. While performing experimental investigations, the current and voltage supplied to the press drive are monitored for different loading levels of the pressing chamber. The measurements are performed with the help of the current and voltage sensors SCT-013-030 and ZMPT101B connected to the Arduino microcontroller [4]. The Arduino microcontroller, combined with current and voltage sensors like the SCT-013-030 and ZMPT101B, can provide real-time monitoring and data collection of the screw press's performance under different loading conditions. The current sensor measures the consumed current and the voltage sensor records the supplied electrical input to the drive. These sensors are connected to the Arduino microcontroller which digitizes the analog readings and processes them. This setup allows to accurately measure how load conditions in the pressing chamber impacts the consumed current of the drive. The data can then be analyzed to discern patterns and dependencies, which can contribute to the development of control algorithms for optimizing the power consumption of the screw press drive under different loading conditions.

The voltage sensor ZMPT101B (Figure 3) is a precision AC voltage sensor that is a voltage transformer with a 1:1 transformation ratio. In our case, the sensor measures the voltage supplied to the frequency converter from the urban single-phase network of alternating current of 50 Hz (230 V). The corresponding data is processed by the Arduino microcontroller and sent to the laptop in the form of the voltage-time dependencies plotted at the scanning (sampling) frequency of 10 s$^{-1}$.

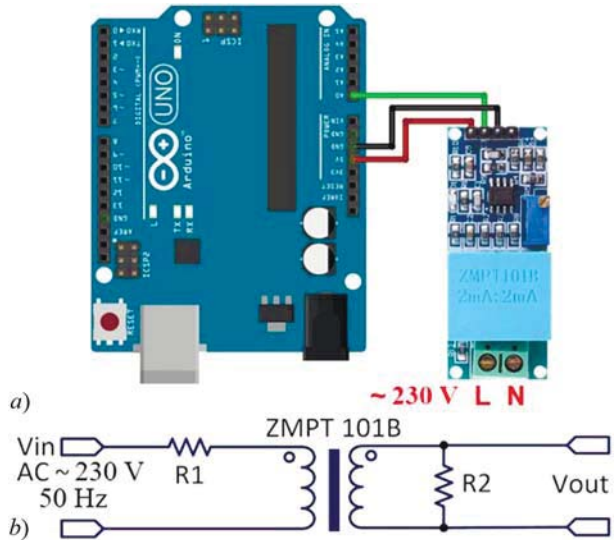


**Fig. 3.** The connection schemes of the voltage sensor ZMPT101B with Arduino / Схема під'єднання давача напруги ZMPT101B до Arduino

The current sensor SCT-013-030 (Figure 4) is designed as a measuring transformer, in which the role of the primary winding is played by a wire conducting the measured current. Such transformers are made on closed cores in the form of a ring made of ferromagnetic materials. Herewith, the cores of some models have a cut through which a wire is inserted into the core ring hole. When alternating current flows along the wire, an electromotive force (EMF) occurs in the coil, and if an ammeter is connected to it, the circuit is closed and the device shows the current proportional to the measured one. The proportionality coefficient depends on the number of coil turns. In order to connect the current sensor SCT-013-030 to the Arduino microcontroller, the additional SMD-resistor of 62 Ω is applied. The controller measures the voltage on this resistor at the following interrelation: 1 V voltage corresponds to 30 A current.

The experimental prototype of the screw press based on the LiangTai LTP200 model is presented in Figure 5. The locations of the voltage and current sensors are shown by the positions 1 and 2, respectively. The frequency converter 3 powers the electric motor 4, which sets into motion the gearbox 5 actuating the pressing screw. The analysis of the consumed current and voltage of the press drive is carried out at different loading levels of the pressing chamber. The latter are determined as the ratio between the volume of the sunflower seeds loaded into the chamber and the total active volume of the chamber (60 ml).

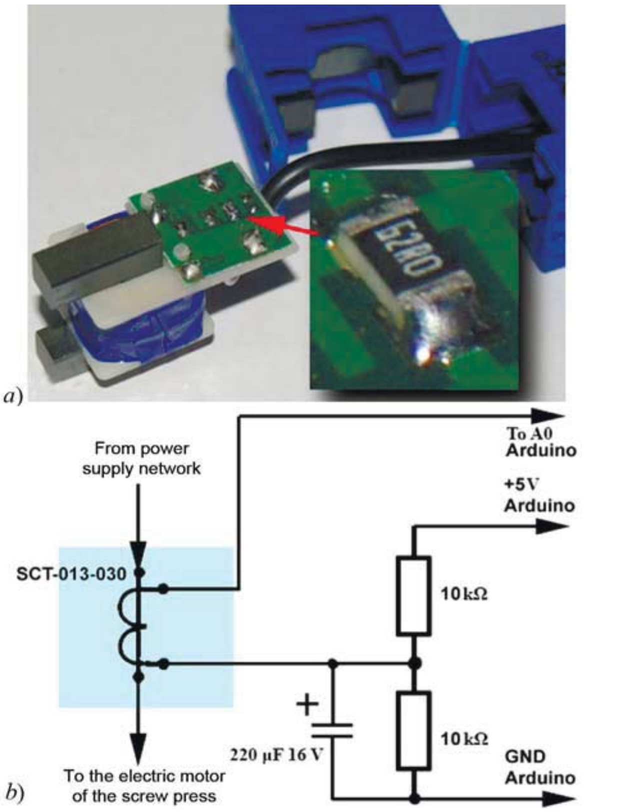


**Fig. 4.** The connection schemes of the current sensor SCT-013-030 / Схеми під'єднання давача струму SCT-013-030

The volume of the seeds is defined with the help of the measuring sleeve (volumetric flask) and is additionally calculated as the product of their mass by the corresponding bulk density (410 kg/m$^3$). The mass is measured by the electronic scales KYA800077. The experimental testing is performed at no-load (idle) conditions and at loading levels of 33 % (20 ml, 8.2 g), 67 % (40 ml, 16.4 g), and 100 % (60 ml, 24.6 g).

***Analyzis of the collected experimental data and the dependency of the screw press drive's consumed current on varying loading levels within the pressing chamber.*** The experimental results are presented in Fig. 6. Considering the case of powering the screw press from the urban single-phase network of alternating current of 50 Hz (230 V), the corresponding measurements of the supplied voltage are shown in each experimental plot by a full (solid) black line. In general, the voltage changes within the range of 227.6 …228.2 V regardless of the press loading conditions. The plot shown in Fig. 6(*a*) presents the time changes of the consumed current of the press drive at no-load (idle) conditions (see the full (solid) red line). The current changes within the range of 1.4…2.0 A. Therefore, the instantaneous value of the consumed power varies from about 320 W to 460 W.

In the case when the pressing chamber is loaded at the level of 33 %, i.e., when 20 ml of the sunflower seeds are fed into the chamber, the supplied current significantly increases and varies in the range of 2.4…2.65 A. This allows for the conclusion that the instantaneous value of the consumed power changes from approximately 540 W to 600 W. Therefore, the increase in the loading level by 33 % (from 0 to 20 ml) causes the increase in the consumed current and power by 23…41 %.

Further increase of the loading level of the pressing chamber to 67 %, when the 40 ml volume of the sunflower seeds is charged into the chamber, causes a proportional increase in the consumed current. In this case, the current minimal value is about 2.5 A, while the maximal value reaches 2.8 A. Therefore, the instantaneous value of the consumed power changes from about 570 W to 640 W. This allows for the conclusion that a further increase in the loading level by 34 % (from 33 % to 67 %) causes the increase in the consumed current and power by 5…7 %.

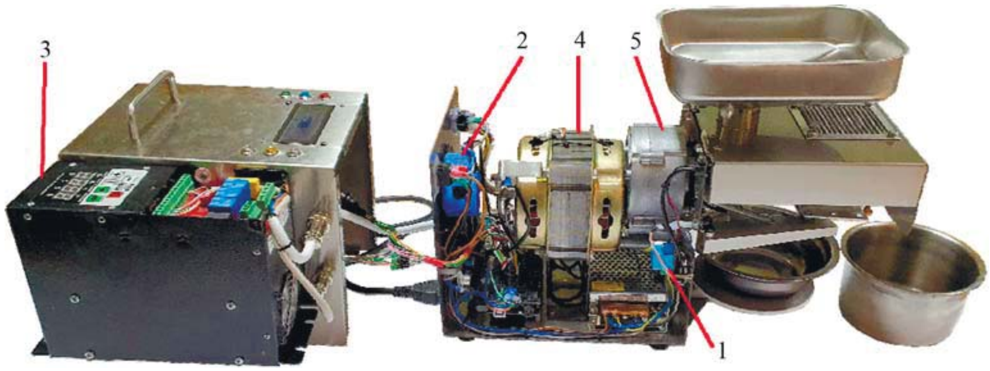


**Fig. 5.** Experimental prototype of the screw press / Експериментальний зразок шнекового преса

Considering the case of the maximal loading level (100 %), when the full volume of the pressing chamber (60 ml) is filled with the sunflower seeds, the nominal current changes within the range of approximately 2.45…3.0 A. This allows for concluding that the instantaneous value of the consumed power varies from about 558 W to 685 W. Therefore, a further increase in the loading level by 33 % (from 67 % to 100 % or from 40 ml to 60 ml) causes the increase in the consumed current and power by approximately 6…7 %.

Summarizing all of the above, it can be stated that the no-load and part-load conditions are not recommended to be used from the viewpoint of the screw press performance and energy efficiency. Therefore, the control system should be provided with the opportunity to continuously monitor the loading level of the pressing chamber and to change the screw angular speed in such a way that the pressing chamber is maximally loaded. The continuous monitoring of the loading level can be implemented in different ways. For instance, the current sensor may be used for registering the instantaneous values of the consumed current. When its average value calculated for the specified period of time is less than the normative one, the control system slows down the screw in order to increase the loading level of the pressing chamber. The change in the screw angular speed can be provided by integration of the control system into the frequency converter.

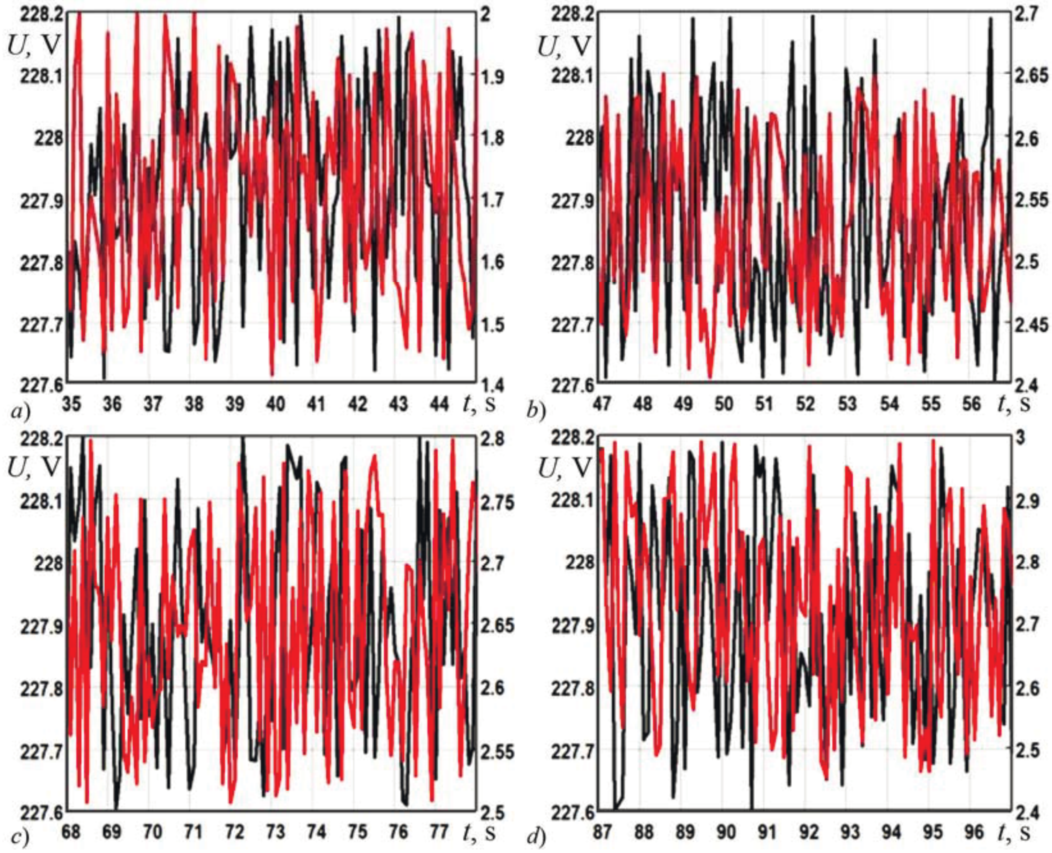


**Fig. 6.** Results of experimental investigations performed at different loading levels of the pressing chamber / Результати експериментальних досліджень, проведених при різних рівнях навантаження камери пресування: *a*) 0 % (no-load conditions) / 0 % (без навантаження); *b*) 33 % (20 ml, 8.2 g) / 33 % (20 мл, 8,2 г); c) 67 % (40 ml, 16.4 g) / 67 % (40 мл, 16,4 г); d) 100 % (60 ml, 24.6 g) / 100 % (60 мл, 24,6 г)

Considering the obtained experimental data (Figure 7), the following conclusion can be drawn. At the no-load (idle) operational conditions, the average value of the consumed current is equal to 1.68 A. Therefore, the average power needed to be supplied to the press drive is approximately equal to 380 W. When the pressing chamber is loaded at the level of 33 %, the average consumed current rises to 2.54 A or by 34 %. Further increases in the loading level to 66 % and 100 % cause increases in the average current to 2.64 A and 2.73 A or by 4 % and 3 %, respectively. This means that the most energy efficient operation of the screw press can be provided at its full-load conditions.

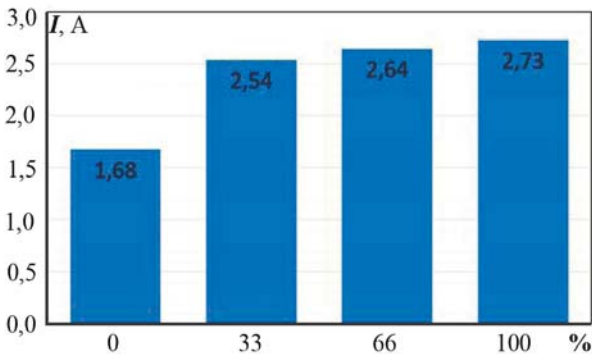


**Fig. 7.** Diagram of the average consumed current of the press drive at different loading levels of the pressing chamber / Діаграма середнього споживаного струму приводу преса при різних рівнях завантаження камери пресування

**Discussion of research results.** Our study aimed to investigate the influence of screw press loading conditions on the consumed current of its drive using an Arduino microcontroller system for real-time monitoring and data collection. The results indicated a clear relationship between the loading levels of the pressing chamber and the consumed current of the press drive. It was discovered that optimal efficiency of the screw press can be achieved at the maximal loading levels and by appropriately modulating the screw angular speed [19].

Interestingly, this conclusion harmonizes with previous research findings in the field. For example, authors in paper [9] demonstrated a similar relationship involving the compression processes of bulk oil seeds. However, compared to work our results present a more in-depth understanding as we have considered a wider range of load conditions.

The work done in paper [7] also revealed the correlation between the increase in load and the enhanced performance of a screw press. Our study echoes this conclusion and adds onto this by demonstrating how different loading conditions in the pressing chamber influenced the consumed current of its drive. Authors of study did not take this specific aspect into consideration, so our study significantly adds to this topic and provides a fresh perspective.

The research [18] bears a similarity to ours, as they analyzed the functioning of a screw press machine. However, their work did a failure analysis while ours studied how the loading conditions affected the consumed current of the press drive. Indeed, insights from both studies could be combined to enhance the durability and efficiency of screw press machines.

Another noteworthy comparison is with the study [8], which looked into the design aspect of the system. Our research supplements this work by highlighting how critical it is to consider the loading conditions and their influence on the current of the press drive while designing a screw press machine.

Moreover, our results concerning optimal loading conditions for energy efficiency align well with a study [5]. Here too, there was a focus on the design, specifically the stress analysis of the screw shaft, but the reiteration of the importance of load management in our findings adds further weight to their postulations.

In summary, our investigation into exploring the correlation between the screw press loading conditions and the consumed current of its drive offers novel insights that not only align with the previous studies but also significantly enrich the body of knowledge in this domain. Future investigations can use our research to further explore the development of robust and energy-efficient screw presses [15].

So, based on the results of the work performed, it is possible to formulate the following scientific novelty and practical significance of the research results.

*Scientific novelty of the obtained research results* – developed method for defining the influence of the screw press loading conditions on the consumed current of its drive with the use of Arduino microcontroller for real-time monitoring and data collection.

*Practical significance of the research results* – the obtained experimental results allow for recommending the developed system for practical implementation in real production in order to provide the energy-efficient conditions of the oil extraction process performed with the help of the screw presses for different types of seeds.

## Conclusions / Висновки

In this research, we focused on understanding how different loading conditions in the pressing chamber influenced the consumed current of its drive with a help of an Arduino microcontroller system for real-time monitoring and data collection. Based on the results of the research the following main conclusions can be drawn.

Through comprehensive experimentation and in-depth data analysis, the study established a clear relationship between the loading levels of the pressing chamber and the consumed current of the press drive. It was defined that the operation efficiency of the screw press can be significantly improved by maintaining maximal loading levels and modulating the screw angular speed suitably.

The real-time monitoring enabled by the Arduino microcontroller allowed for continuous performance evaluation, which has significant potential to improve operational control. Further, this approach could facilitate the development of advanced control algorithms to optimize power consumption under different loading conditions.

This study provides insightful data and techniques that can be employed to enhance the operation of small household screw presses, improving energy efficiency, and oil extraction capabilities. There is also substantial potential to extend our methodology to the study of other oil-rich seeds, and to larger, industrial scale presses.

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# ВИЗНАЧЕННЯ ВПЛИВУ УМОВ ЗАВАНТАЖЕННЯ ШНЕКОВОГО ПРЕСА НА СПОЖИВАНИЙ СТРУМ ЙОГО ПРИВОДУ ЗАСОБАМИ МІКРОКОНТРОЛЕРА ARDUINO

Розроблено методику визначення впливу умов завантаження шнекового преса на споживаний струм та потужність його приводу за допомогою давачів та мікроконтролера Arduino. Оскільки соняшникова олія є одним із найпоширеніших продуктів харчової промисловості, то актуальною є проблема автоматизації процесу перероблення насіння соняшнику, спрямована на підвищення продуктивності пресів та зниження споживаної потужності їх приводів. Для отримання якісних результатів у дослідженні використано такі наукові методи, як аналіз, моделювання, експеримент, вимірювання та спостереження. Розроблено спрощену принципову схему електромеханічної системи шнекового преса на підставі його повномасштабного експериментального прототипу моделі LiangTai LTP200. Проведено аналіз споживаного струму та напруги приводу преса за різних рівнів завантаження камери пресування. Вимірювання проводили за допомогою давачів струму і напруги SCT-013-030 і ZMPT101B, під'єднаних до мікроконтролера Arduino. Ступінь завантаження камери пресування визначено як відношення об'єму завантаженого в камеру насіння соняшнику до загального активного об'єму камери. Об'єм насіння визначено за допомогою мірного стаканчика (мірної колби) та додатково розраховано як добуток його маси на відповідну насипну щільність (густину). Масу вимірювали електронною вагою KYA800077. Експериментальні випробування проведено у ненавантаженому стані (на холостому ходу) та за таких рівнів завантаження як 33, 67 і 100 %%. На підставі отриманих результатів проаналізовано споживану потужність приводу шнекового преса за різних рівнів завантаження камери пресування. Експериментально підтверджено пропорційне збільшення споживаного струму приводу шнекового преса у разі збільшення рівня завантаження камери пресування. Результати дають змогу вдосконалити відповідні алгоритми управління, спрямовані на оптимізацію енергоспоживання. Перспективи подальших досліджень можуть містити аналогічні дослідження для інших видів насіння олійних культур. Експериментальні дані можна використати для практичних рекомендацій щодо розроблення відповідної системи управління, яка дасть змогу оптимізувати енергоспоживання приводу преса, для моніторингу та попередження умов перевантаження, які можуть спричинити поломку елементів приводу преса.

**Ключові слова:** соняшникова олія; перероблення насіння; споживана потужність; камера пресування; алгоритм управління; умови перевантаження.