# МЕХАНІЗАЦІЯ, АВТОМАТИЗАЦІЯ ТА РОБОТИЗАЦІЯ

# MECHANIZATION, AUTOMATION AND ROBOTICS

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# IMPROVED DESIGN OF THE SCREW PRESS COUPLING

***Purpose.*** *The aim of the work is to increase the energy efficiency and operational reliability of heavy screw presses by creating a new drive design that ensures stabilization of the load on the power grid and eliminates thermal overloads of the electric motor.*

***Research methods.*** *The study employs a critical analysis of modern technical solutions from leading manufacturers (Weingarten, Hasenclever), specifically the RZS series with direct drive. The research utilizes the general theory of electric drives to analyze energy efficiency in transient modes. Kinematic analysis and analytical calculations of the moment of inertia were performed to substantiate the method of separating the driving mass (kinetic energy accumulator) into multiple components to reduce inertial loads.*

***Results.*** *The operational limitations of direct-drive presses, such as high peak currents and thermal overloads, were identified. A new screw press design was proposed featuring a kinetic energy accumulator consisting of a central driving flywheel and lateral driving masses mounted on the motor shafts. This accumulator is connected via a clutch to the working driven flywheel of the press. Separating the driving accumulator into segments allows for a 25-fold reduction in the mass of the driving elements while maintaining the same kinetic energy. To optimize the reverse stroke, the working flywheel itself is also divided into two parts: an inner flywheel (rigidly mounted on the spindle) and an outer flywheel (which is disengaged during the upward stroke of the slide). Recommendations for an autonomous reverse stroke system were provided.*

***Scientific novelty.*** *A method for separating rotating masses into a continuously operating kinetic energy accumulator (driving flywheel system) and a cyclically connected working element is proposed. Unlike traditional rigid-connection drives, the new kinematic scheme utilizes an intermediate driving mass and a friction clutch, allowing the motor to operate continuously without frequent high-current starts.*

***Practical value.*** *The design is applicable for presses with a nominal force from 2 MN and energy up to 5 MJ, suitable for precision forging of turbine blades and gears without stamping inclinations. The use of standard induction motors and the reduction of the drive's metal consumption decrease manufacturing and modernization costs while improving power grid stability.*

***Key words:*** *engagement clutch, screw press, precision stamping, moment of inertia, slider, screw spindle, flywheel.*

## Introduction

The modern stage of development of forging and stamping equipment is characterized by increased requirements for the precision of forgings and the energy efficiency of the equipment. In this segment, screw presses with direct electric drive have taken a leading position, becoming an effective alternative to hammers and crank


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presses in the manufacturing of critical parts (turbine blades, gears, etc.).

### Analysis of research and publications

Recognized leaders in the field, such as Weingarten and Hasenclever, utilize press designs (type RZS) where a single working flywheel is rigidly connected to the screw spindle and simultaneously serves as the rotor of an asynchronous motor [1]. While this scheme ensures precision, it forces the drive to operate in a mode of frequent starts and braking.

As illustrated in Fig. 1, this mode is characterized by peak starting currents exceeding 1000 A and significant thermal losses. According to the general theory of electric drives [2], theoretical efficiency in such modes is limited to approximately 50%. Attempts to solve this using frequency converters [3, 4] increase costs and reduce reliability due to shock loads, while hydraulic alternatives [5] suffer from lower operating speeds. Thus, developing a reliable mechanical drive that eliminates motor operation in transient modes remains a relevant problem.

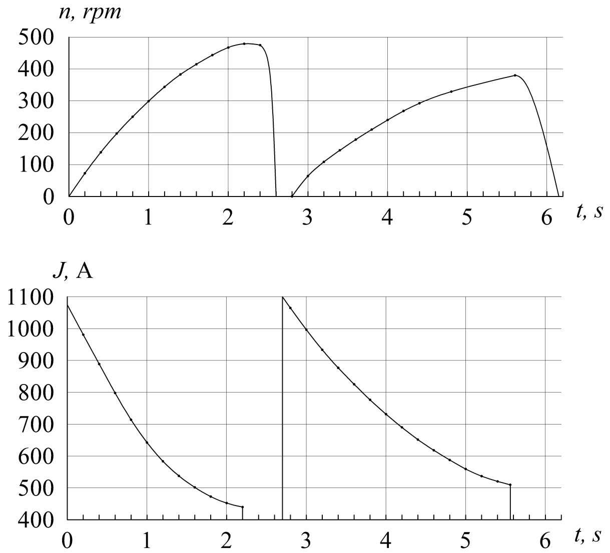


**Figure 1.** Typical diagram of startup modes of the arc-stator drive of RZS series presses (N = 250 kW, $n_{synch}$ = 600 rpm)

### Research material and methodology

A method of separating rotating masses into a continuously operating kinetic energy accumulator and a cyclically connected working element is proposed.

The essence of the proposed solution lies in the development of a press kinematic scheme with an alternative drive, in which the electric motor is kinematically decoupled from the screw during the working stroke. Instead of a rigid connection (as in the RZS scheme), an intermediate link is introduced – a kinetic energy accumulator (driving flywheel system), which is accelerated by the electric motor to the nominal speed and maintains rotation in a steady-state mode with high efficiency.

Energy transfer to the screw is carried out through a controlled friction clutch. Such a design allows the electric motor to operate without frequent starts and reversals, using the flywheel inertia to cover peak deformation loads.

Dissipating this heat from the stator windings poses a significant problem, despite the use of an electric fan, which complicates the operating conditions and maintenance of the press.

To mitigate these drawbacks, it is proposed to utilize kinetic energy previously accumulated by the driving flywheel system. In this case, the mechanism is implemented via an engagement clutch, where the working driven flywheel serves as the driven part, and the driving part acts as the central driving flywheel of the accumulator.

### Research results

Fig. 2 presents an operation diagram illustrating the process of engagement and acceleration of the working flywheel to the nominal rotational speed. Up to point 2, a decrease in the angular velocity of the central flywheel and the acceleration of the working flywheel occur.

At point 2, full engagement of the central driving and working flywheels takes place; subsequent motion continues as the movement of a single mass up to point 3. At point 3, the clutch disengages, and the motion of the working flywheel continues by inertia.

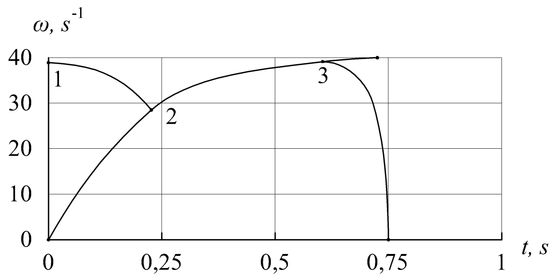


**Figure 2.** Changes in angular velocity of the central driving flywheel and the working driven flywheel during clutch engagement (qualitative representation)

Fig. 3 presents the kinematic scheme of the press. A slide 2, kinematically connected to the screw spindle 3, is installed in the press frame 1. The working flywheel 4 is mounted at the end of the spindle, above which the central flywheel (the main component of the accumulator) 5 is installed. Lateral driving masses 6 and 7 are positioned diametrically and mounted, for example, on the shafts of drive motors 8 and 9. The return movement of the slide is performed by the return drive 10.

As is known [6–7], the moment of inertia of the driving flywheel system is determined by the ratio (formula placeholder), and its practical value lies within the range of 2.5 ÷ 10. This allows for easy calculation of the moment of inertia of the accumulator.

In order to reduce the mass of the driving flywheel system, it can be divided into several components. Specifically, one part serves directly as the central flywheel (the driving member of the engagement clutch), while the other parts are made as separate discs with a gear rim, through


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which they are kinematically connected to the central flywheel, which also features gear teeth [8-9]. These lateral masses can be directly mounted on the shafts of drive motors with a synchronous rotational speed of, for example, 1500 rpm or 3000 rpm.

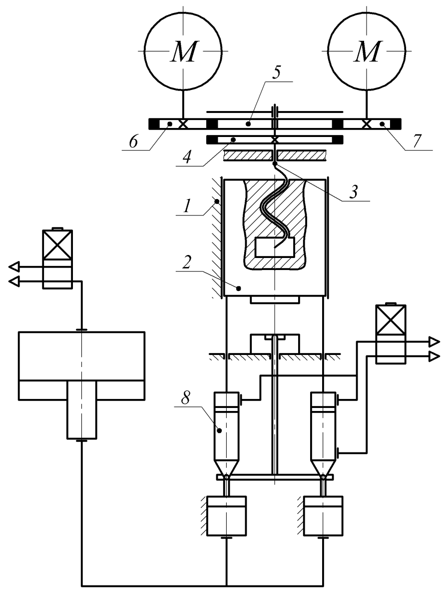


**Figure 3.** Kinematic scheme of the screw press:
1 – frame; 2 – slide; 3 – screw spindle;
4 – working driven flywheel; 5 – central driving flywheel;
6, 7 – lateral driving masses; 8 – slide return drive

This allows reducing the moment of inertia of these lateral masses by a factor of $i^2$; for instance, with a clutch engagement speed of 300 rpm ($i = 5$) and a motor speed $n_{mot}$ = 1500 rpm, $i^2 = 25$. That is, the elements of the accumulator can have a weight 25 times lower while maintaining the same kinetic energy. Standard serial induction motors are used as drive motors, the maintenance of which presents no difficulties [10–11].

The return stroke drive can be pneumatic, hydraulic, or pneumohydraulic [11–12]. In order to reduce the level of kinetic energy accumulated in the working flywheel during the return stroke, which must be dissipated, it is proposed to divide the working flywheel into two parts [13–15].

The inner flywheel part is rigidly mounted on the screw spindle (Fig. 4), while the outer flywheel is able to rotate freely. The kinematic connection of both parts during the downward stroke is ensured by rotary keys. During the return stroke, the outer flywheel is braked; simultaneously, the keys rotate, the parts of the working flywheel lose kinematic contact, and during the slide ascent, only the screw spindle and the inner flywheel rotate.

The number of lateral masses can be two, four, or six, which allows reducing the moment of inertia and, consequently, the weight of the upper part of the press, which, in turn, positively affects the stability of the press.

Thus, this will allow, with reduced metal consumption of the screw press drive, to maintain its basic energy and power parameters, which ultimately makes it possible to reduce the cost of manufacturing new equipment and modernize existing equipment.

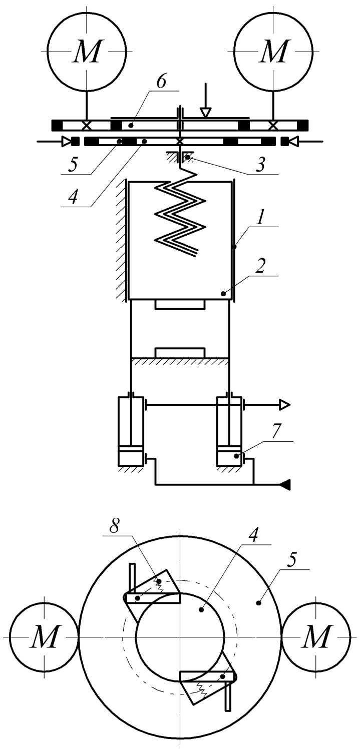


**Figure 4.** Kinematic scheme of the screw press:
1 – frame; 2 – slide; 3 – screw spindle; 4 – inner flywheel;
5 – outer flywheel; 6 – central driving flywheel;
7 – return drive; 8 – springs

## Conclusions

An analysis of the operation of an electric screw press was carried out and a defect was identified, caused by the transient mode of operation of the drive, which is undesirable for the optimal operation of the device.

A screw press is proposed in which the reverse drive is autonomous, and the working stroke is performed by means of a drive with a clutch, in which the working flywheel is the driven part, and the driving part is the accumulator necessary for accelerating the working flywheel.

The proposed kinematic scheme with separation of flywheel masses allows significantly reduce the metal content of the drive and reduce inertial loads on the system during transient processes. The elements of the accumulator, specifically the lateral masses, can be 25 times lighter while maintaining the same kinetic energy. This increases the overall efficiency of the press by minimizing energy losses during acceleration and deceleration of massive parts (such as the outer flywheel) during the reverse stroke, and also ensures high maintainability of the equipment through the use of standard industrial components.


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# УДОСКОНАЛЕНА КОНСТРУКЦІЯ МУФТИ ГВИНТОВОГО ПРЕСУ

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***Мета роботи.*** *Підвищення енергоефективності та експлуатаційної надійності важких гвинтових пресів шляхом створення нової конструкції приводу, яка забезпечує стабілізацію навантаження на електромережу та усуває теплові перевантаження електродвигуна.*

***Методи дослідження.*** *Критичний аналіз сучасних технічних рішень від провідних виробників (Weingarten, Hasenclever), зокрема серії RZS із прямим приводом. Для аналізу енергоефективності в перехідних режимах використано загальну теорію електроприводів. Було проведено кінематичний аналіз та аналітичні розрахунки моменту інерції для обґрунтування методу розділення приводної маси (накопичувача енергії) на декілька компонентів з метою зниження інерційних навантажень.*

***Отримані результати.*** *Визначено експлуатаційні обмеження пресів із прямим приводом, такі як високі пікові струми та теплові перевантаження. Запропоновано нову конструкцію гвинтового преса, яка оснащена накопичувачем кінетичної енергії що складається з центрального ведучого маховика ті бічних приводних мас на валах двигуна. Цей накопичувач з'єднується через муфту з робочим (веденим) маховиком преса. Розділення приводного накопичувача на сегменти дозволяє зменшити масу приводних елементів у 25 разів при збереженні тієї ж кінетичної енергії. Для оптимізації зворотного ходу сам робочий маховик також розділено на дві частини: внутрішній маховик (жорстко закріплений на шпинделі) та зовнішній маховик (що відключається під час підйому повзуна). Надано рекомендації щодо автономної системи зворотного ходу.*

***Наукова новизна.*** *Запропоновано метод розділення приводної маси на накопичувач енергії, що працює безперервно, та робочий елемент, що підключається циклічно. На відміну від традиційних приводів із жорстким зв'язком, нова кінематична схема використовує проміжну масу маховика та фрикційну муфту, що дозволяє двигуну працювати безперервно без частих пусків із високими струмами.*

***Практична цінність.*** *Конструкція придатна для пресів з номінальним зусиллям від 2 МН і енергією до 5 МДж, які підходять для точного кування турбінних лопаток і шестерень без штампувальних ухилів. Використання стандартних асинхронних двигунів і зниження металоємності приводу зменшують витрати на виготовлення та модернізацію, водночас покращуючи стабільність електромережі.*

***Ключові слова:*** *муфта зчеплення, гвинтовий прес, точне штампування, момент інерції, повзун, гвинтовий шпиндель, маховик.*

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