МЕХАНІЗАЦІЯ, АВТОМАТИЗАЦІЯ ТА РОБОТИЗАЦІЯ

MECHANIZATION, AUTOMATION AND ROBOTICS

UDC 621.73.043 : 621.979.15

Vasyl Obdul — Candidate of Technical Science, Associate Professor, Department of Metal Forming, National University Zaporizhzhia Polytechnic, Zaporizhzhia, Ukraine, *e-mail: obdul@zp.edu.ua*, ORCID: 0000-0001-6490-8884

Anton Matiukhin — Candidate of Technical Science, Associate Professor, Head of the Department of Metal Forming, National University Zaporizhzhia Polytechnic, Zaporizhzhia, Ukraine, *e-mail: matiukhin85@gmail.com,* ORCID: 0000-0002-2261-0577

Anna Kawalek — Dr. of Technical Science, Professor, Czestochowa University of Technology, Czestochowa, Poland, *e-mail: anna.kawalek@pcz.pl,* ORCID: 0000-0003-0274-0582

Anton Riabenko — Candidate of Technical Science, Associate Professor, Department of System Analysis and Computational Mathematics, National University Zaporizhzhia Polytechnic, Zaporizhzhia, Ukraine, *e-mail: rjabenkoae@gmail.com*, ORCID: 0000-0001-7738-7918

Oleksandr Yepishkin — Assistant, Department of Metal Forming, National University Zaporizhzhia Polytechnic, Zaporizhzhia, Ukraine, *e-mail: yepishkin@zp.edu.ua*, ORCID: 0000-0003-1447-9473

Viktoria Fedoseeva — Student, Department of Metal Forming, National University Zaporizhzhia Polytechnic, Zaporizhzhia, Ukraine, *e-mail: joxi.victoria@gmail.com*

ENERGY-EFFICIENT DESIGN OF SCREW PRESSES

Purpose. *To improve the energy efficiency of screw presses by developing structures for the rational use of the flywheel kinetic energy, reducing losses on the return stroke and increasing the impact efficiency. This will reduce energy costs and improve productivity in forging, stamping and other technological operations.*

Research methods. *Increasing the energy efficiency of screw presses is achieved by developing and implementing design solutions aimed at reducing the energy accumulated during the reverse stroke, as well as ensuring its efficient use during the forward stroke. The main emphasis is placed on optimising the press mechanisms to minimise energy losses, which will significantly increase the overall efficiency of the equipment.*

Results. *As part of the study, a new design of the slider was proposed, which includes a kinematic disconnection of the nut. This reduces the energy usually accumulated by the flywheel during the reverse stroke and ensures more efficient use of energy during the forward stroke, which in turn reduces energy consumption and increases the efficiency of the press.*

Scientific novelty. *For the first time, designs have been developed that provide kinematic disconnection of the slider nut during the reverse stroke. These designs allow to reduce the accumulated energy and ensure its more rational use during the forward stroke. In addition, the design of the flywheel has been improved to optimise its moment of inertia depending on different press operating modes, which makes it possible to significantly improve the performance of press equipment under variable operating conditions.*

Practical value. *The results of the work make it possible to increase the energy efficiency of screw presses, which can be implemented in forging and stamping industries, especially in precision stamping technologies. The application of the developed structures increases the energy efficiency of screw presses, which reduces energy costs and ensures long-term and stable operation of the equipment.*

Key words: *press, screw, slider, nut, key, flywheel, drive, hydraulic circuit, frame.*

Introduction

In modern production, presses are widely used to perform a variety of technological operations. The efficiency of their operation largely depends on their design features, in particular, on the use of flywheel kinetic energy. The accumulation of this energy on the return stroke remains one of the key issues affecting the energy efficiency and productivity of the equipment. To address this problem, innovative design solutions are being offered to optimise the operation of presses and reduce energy losses.

Analysis of research and publications

Researchers pay considerable attention to improving press designs to increase their energy efficiency. One of the

DOI 10.15588/1607-6885-2024-4-7

main areas of research is the introduction of mechanisms for the accumulation and rational use of flywheel kinetic energy. Various designs have been proposed to reduce the amount of energy accumulated during the return stroke, including the installation of a nut in the slider with the possibility of kinematic disconnection or the use of a flywheel consisting of two parts [1–3]. Such innovative solutions have the potential to significantly improve the performance of press equipment, but require further research.

Purpose of the work

The aim of the study is to develop constructive solutions to optimise the operation of presses by rationally using the flywheel's kinetic energy. This involves the introduction of mechanisms that reduce energy losses on the return stroke and increase the efficiency of striking by accumulating energy on the forward stroke.

Research results

In recent years, screw presses have taken their rightful place in the list of forging and stamping equipment, especially among the equipment used in precision stamping technology, such as gas turbine engine blades, gears and other parts [4-6]. This led to the development of screw press designs and their individual components. This was especially true for the designs of drives for both the forward and reverse strokes of the press, especially the forward stroke drives for accumulating impact energy [7–9]. The most developed were direct-acting electric drives or those using a gear transmission with a ratio of i = 4 : 5, a main motor with a synchronous speed $n_{синх}$ = 500 : 600 and a unit power of 250 kW.

The motors operate in reverse mode on the down stroke and up stroke, operating in transient mode. And, as you know, theoretically, the transient mode efficiency is 0.5, and in the presence of slippage in the motor itself, it is even lower [10].

The developer of such presses is Weingarten. Along with these types of drives, hydraulic motors for driving the flywheel (Hasenklever) were developed simultaneously [11]. These types of drives are used for the manufacture of presses with a force of up to a nominal force Pn = 12,500 tf and a cold stroke force of up to 25,000 tf. The angular speed of the flywheel does not exceed 200 rpm, and the stroke frequency is ≈ 4.5 x/min (PZS presses). For presses with hydraulic motors, the number of slider strokes is 12 x/min for HSPRZ presses with a maximum force of 6300 tf and 6 x/min for HSPRZ presses with a maximum force of 25,000 tf [12].

The design of these presses uses the main drive in reverse mode to reverse the stroke, so it operates twice per cycle in transient mode with a theoretical efficiency of 0.5. At the same time, the maximum current exceeds $I \geq$ 1000A [13].

All screw press designs currently in operation have a significant drawback: an increase in the reverse stroke speed increases the energy accumulated by the flywheel, which must either be damped by the brake or the main drive operating time on the reverse stroke reduced [14].

The following design solutions are proposed to increase efficiency [15]. Use of pneumohydraulic drives (Fig. 1, 2). They are mounted in the upper crossbar of the press. The design of these accumulators allows for efficient operation of the reverse stroke drives. The principle of operation is clear from the hydraulic diagram of this reverse stroke energy storage device.

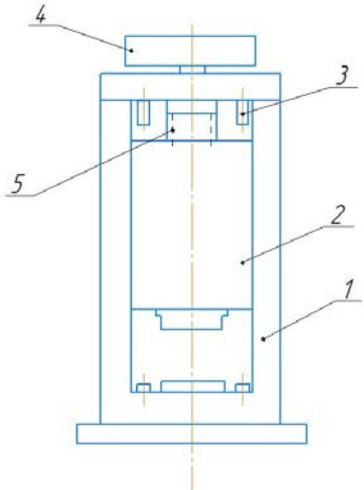

Figure 1. Screw press with energy storage: 1 – bed; 2 – slider; 3 – energy storage shield; 4 – handwheel; 5 – screw spindle

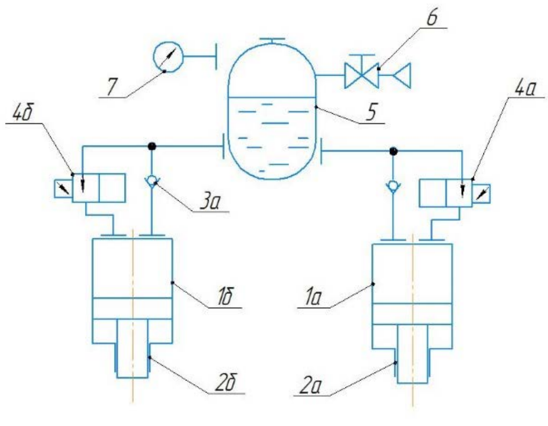

Figure 2. Hydraulic diagram of the reverse stroke energy storage: 1 – energy storage device; 2 – energy storage device shield; 3 – check valve; 4 – spool valve; 5 – pneumohydraulic accumulator; 6 – charging valve; 7 – pressure gauge

To reduce the level of accumulated energy, we propose the design of a slider with a nut, which makes it possible to exclude the flywheel from the reverse stroke as the main accumulator of kinetic energy (Fig. 3). The slider 1 has a rotatable nut 2, which is in kinematic contact with the screw 3. The slider 1 has rotary keys 4 and a system of levers 5, which are triggered when the slider 1 rises and take the slider 1 and nut 2 out of kinematic contact. During the upward movement, the handwheel and screw 3 stand still, only the nut 2 rotates, the moment of inertia of which is much lower than the moment of inertia of the handwheel. The design has a slider of a complicated construction.

DOI 10.15588/1607-6885-2024-4-7

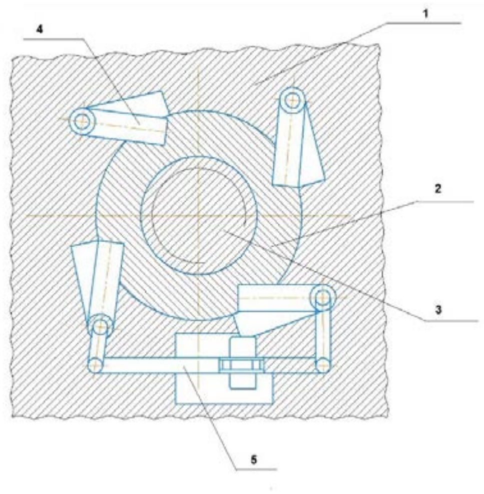

Figure 3. Slider construction: 1 – slider; 2 – nut; 3 – screw spindle; 4 – swivel key; 5 – lever system

According to the design, the flywheel consists of the following parts: outer flywheel 1, inner flywheel 2, key 3, return stroke 4, brake 5, slider 6, and screw 7. The principle of this design is clear from Fig. 4.

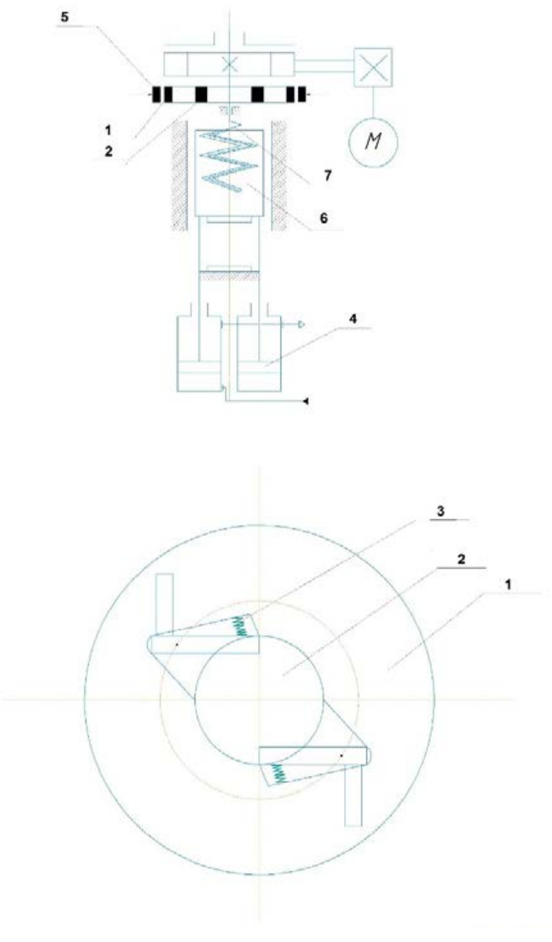

Figure 4. Slider construction: 1 – outer handwheel; 2 – inner handwheel; 3 – keyway; 4 – drive; 5 – brake; 6 – slider; 7 – screw

Conclusions

The problem of increasing the speed of screw presses can be solved by design means: the use of energy storage devices for reverse stroke, or a slight complication of the slider or driven flywheel. A preliminary analysis shows sufficient efficiency of the structures under consideration

References

1. Bocharov, Y. A. (1976). *Screw presses.* Moscow: Mashinostroenie, 247.

2. Polovina, N. N., Obdul, V. D., Polovina, Y. N. (1976). Certificate No. 517509 USSR., Bulletin No. 22.

3. Obdul, V. D., Matiukhin, A Yu., Shirokobokov, V. V., Obdul, D. V., Matiukhina, T. G., Vysotskaya N. I. (2023). Ukraine. Patent No. 127676 23, Bulletin No. 47.

4. Kešner, A., Chotěborský, R., Linda, M. (2017). The effect of microstructure on abrasive wear of steel. *IOP Conference Series: Materials Science and Engineering*, 237, 012040. doi: 10.1088/1757-899X/237/1/012040

5. Pajak, M. (2010). Machine elements. To innovative production presses via roller screw planetary drives. *Konstruktion*, 1–2, 24–25.

6. Pennington, J. N. (2003). High-energy process cuts long products. *Modern Metals*, 59(5), 21–25.

7. Zheng, K., He, Z., Qu, H., Chen, F., Han, Y., Zheng, J.-H., Li, N. (2023). A novel quench-form and in-die creep age process for hot forming of 2219 thin aluminum sheets with high precision and efficiency. *Journal of Materials Processing Technology*, 315, article ID 117931. doi: 10.1016/j.jmatprotec.2023.117931

8. Askarov, E., Zhankeldi, A., Absadykov, B., Smailova, G. (2018). Design features of a cam-screw press with a large effort. *News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences*, 5(431), 192–200. doi: 10.32014/2018.2518-170X.49

9. Landgrebe, D., Rautenstrauch, A., Kunke, A., Polster, S., Kriechenbauer, S., Mauermann, R. (2016). The effect of cushion-ram pulsation on hot stamping. *AIP Conference Proceedings*, 1769, article ID 070014. doi: 10.1063/1.4963414

10. Kriechenbauer, S., Mauermann, R., Muller, P. (2014). Deep drawing with superimposed low-frequency vibrations on servo-screw presses. *Procedia Engineering*, 81, 905–913. doi: 10.1016/j.proeng.2014.10.108

11. Endou, J., Murata, C. (2015). New forming technologies using screw type servo press. *Excellent Inventions in Metal Forming*, 60, 127–133.

12. Mabrouki, T., Boudeau, N., Maier, C. (2018). On energy consumption and optimization in hot metal forming processes. *International Journal of Mechanical Sciences, 1*36, 134–145. doi: 10.1016/j.ijmecsci.2018.01.003

13. Schroder, C., Smirnov, E., Bogdanov, N. (2019). Analysis of energy efficiency of presses with servo drives. *Manufacturing Review*, 6, article ID 35. doi: 10.1051/mfreview/2019032

14. Kim, J. H., Lee, S. W., Kim, K. H. (2014). Development of energy-saving servo press technology. *Journal*

DOI 10.15588/1607-6885-2024-4-7

of Advanced Mechanical Design, Systems, and Manufacturing, 8(3), article ID 112–119. doi: 10.1299/jamdsm.2014jamdsm0006

15. Oh, J. Y., Park, S. H. (2020). Energy optimization strategies for high-speed mechanical presses. *Journal of Manufacturing Processes*, 50, 670–680. doi: 10.1016/j.jmapro.2020.01.008

Received 16.12.2024

ЕНЕРГОЕФЕКТИВНІ КОНСТРУКЦІЇ ГВИНТОВИХ ПРЕСІВ

Василь Обдул — канд. техн. наук, доцент, доцент кафедри обробки металів тиском Національного університету «Запорізька політехніка», м. Запоріжжя, Україна, *e-mail: obdul@zp.edu.ua*, ORCID: 0000-0001-6490-8884

Антон Матюхін — канд. техн. наук, доцент, завідувач кафедри обробки металів тиском Національного університету «Запорізька політехніка», м. Запоріжжя, Україна, *e-mail: matiukhin85@gmail.com*, ORCID: 0000-0002-2261-0577

Анна Ковалек — доктор технічних наук, професор PCz, Ченстоховський політехнічний університет, Ченстохова, Польща, *e-mail: anna.kawalek@pcz.pl*, ORCID: 0000-0003-0274-0582

Антон Рябенко — канд. фіз.-мат. наук, доцент, доцент кафедри системного аналізу та обчислювальної математики Національного університету «Запорізька політехніка», м. Запоріжжя, Україна, *e-mail: rjabenkoae@gmail.com*, ORCID: 0000-0001-7738-7918

Олександр Єпішкін — асистент кафедри обробка металів тиском Національного університету «Запорізька політехніка», м. Запоріжжя, Україна, *e-mail: yepishkin@zp.edu.ua*, ORCID: 0000-0003-1447-9473

Вікторія Федосєєва — студентка, кафедра обробки металів тиском Національного університету «Запорізька політехніка», м. Запоріжжя, Україна, *e-mail: joxi.victoria@gmail.com*

Мета роботи. *Підвищення енергоефективності гвинтових пресів через розробку конструкцій для раціонального використання кінетичної енергії маховика, зменшення втрат на зворотному ході та підвищення ефективності удару. Це дозволить знизити енергетичні витрати та поліпшити продуктивність при виконанні ковки, штампування та інших технологічних операцій.*

Методи дослідження. *Підвищення енергоефективності гвинтових пресів досягається шляхом розробки та впровадження конструктивних рішень, які спрямовані на зменшення енергії, накопичуваної під час зворотного ходу, а також на забезпечення її ефективного використання під час прямого ходу. Основний акцент зроблено на оптимізацію механізмів преса для мінімізації енергетичних втрат, що дозволить значно підвищити загальну ефективність обладнання.*

Отримані результати. *У рамках дослідження було запропоновано нову конструкцію повзуна, що містить кінематичне відключення гайки. Це дозволяє зменшити енергію, яку зазвичай накопичує маховик під час зворотного ходу, і забезпечує більш ефективне використання енергії на прямому ходу, що в свою чергу знижує витрати електроенергії і підвищує ефективність роботи преса.*

Наукова новизна. *Уперше розроблено конструкції, що забезпечують кінематичне відключення гайки повзуна в процесі зворотного ходу. Ці конструкції дозволяють зменшити накопичену енергію і забезпечити більш раціональне її використання на прямому ходу. Крім того, було вдосконалено конструкцію маховика, що дозволяє оптимізувати його момент інерції залежно від різних режимів роботи преса, що дає можливість значно покращити роботу пресового обладнання в умовах змінних робочих умов.*

Практична цінність. *Результати роботи дозволяють підвищити енергоефективність гвинтових пресів, що може бути впроваджено в ковальсько-штампувальних виробництвах, особливо у технологіях точного штампування. Застосування розроблених конструкцій підвищує енергоефективність гвинтових пресів, що дозволяє зменшити витрати на енергію та забезпечити довготривалу та стабільну роботу обладнання.*

Ключові слова: *прес, гвинт, повзун, гайка, шпонка, маховик, накопичувач, гідросхема, станина.*

DOI 10.15588/1607-6885-2024-4-7

Список літератури

1. Бочаров Ю. А. Винтовые прессы / Ю. А. Бочаров. – М. : Машиностроение, 1976. – 247 с.

2. А. с. № 517509 СРСР. Винтовой пресс / Н. Н. Половина, В. Д. Обдул, Ю. Н. Половина. – опубл. 15.06.1976, Бюл. № 22.

3. Пат. 127676 Україна, МПК B30B 1/18 (2006.01). Винтовий прес / В. Д. Обдул, А. Ю. Матюхін, В. В. Широкобоков, Д. В. Обдул, Т. Г. Матюхіна, Н. І. Висоцька ; заявл. 28.06.2022 ; опубл. 22.10.2023; Бюл. № 47.

4. Kešner A., The effect of microstructure on abrasive wear of steel / A. Kešner, R. Chotěborský, M. Linda // IOP Conference Series: Materials Science and Engineering. — 2017. – Vol. 237. – P. 012040. http://doi.org/10.1088/1757-899X/237/1/012040.

5. Pajak M. Machine elements. To innovative production presses via roller screw planetary drives / M. Pajak // Konstruktion. – 2010. – No. 1–2. – P. 24–25.

6. Pennington J. N. High-energy process cuts long products / J. N. Pennington // Modern Metals. – 2003. – Vol. 59(5). – P. 21–25.

7. A novel quench-form and in-die creep age process for hot forming of 2219 thin aluminum sheets with high precision and efficiency / K. Zheng, Z. He, H. Qu et al. // Journal of Materials Processing Technology. – 2023. – Vol. 315. – article ID 117931. http://doi.org/10.1016/j.jmatprotec.2023.117931.

8. Design features of a cam-screw press with a large effort / E. Askarov, A. Zhankeldi, B. Absadykov, G. Smailova // News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences. – 2018. – Vol. 5(431). – P. 192–200. http://doi.org/10.32014/2018.2518-170X.49.

9. The effect of cushion-ram pulsation on hot stamping / D. Landgrebe, A. Rautenstrauch, A. Kunke, S. Polster, S. Kriechenbauer, R. Mauermann // AIP Conference Proceedings. – 2016. – Vol. 1769. – article ID 070014. http://doi.org/10.1063/1.4963414.

10. Kriechenbauer S. Deep drawing with superimposed low-frequency vibrations on servo-screw presses / S. Kriechenbauer, R. Mauermann, P. Muller // Procedia Engineering. – 2014. – Vol. 81. – P. 905–913. http://doi.org/10.1016/j.proeng.2014.10.108.

11. Endou J. New forming technologies using screw type servo press / J. Endou, C. Murata // Excellent Inventions in Metal Forming. – 2015. – Vol. 60. – P. 127–133.

12. Mabrouki T. On energy consumption and optimization in hot metal forming processes / T. Mabrouki, N. Boudeau, C. Maier // International Journal of Mechanical Sciences. – 2018. – Vol. 136. – P. 134–145. http://doi.org/10.1016/j.ijmecsci.2018.01.003.

13. Schroder C. Analysis of energy efficiency of presses with servo drives / C. Schroder, E. Smirnov, N. Bogdanov // Manufacturing Review. – 2019. – Vol. 6. – article ID 35. http://doi.org/10.1051/mfreview/2019032.

14. Kim J. H. Development of energy-saving servo press technology / J. H. Kim, S. W. Lee, K. H. Kim // Journal of Advanced Mechanical Design, Systems, and Manufacturing. – 2014. – Vol. 8(3). – article ID 112–119. http://doi.org/10.1299/jamdsm.2014jamdsm0006.

15. Oh J. Energy optimization strategies for high-speed mechanical presses / J. Y. Oh, S. H. Park // Journal of Manufacturing Processes. – 2020. – Vol. 50. – P. 670–680. http://doi.org/10.1016/j.jmapro.2020.01.008.

DOI 10.15588/1607-6885-2024-4-7