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COMPUTERIZED POLYGRAPHIC SYSTEMS: ANALYSIS OF EFFICIENCY AND PRACTICAL APPLICATION

The academic paper examines the importance of integrating digital technologies in the printing industry in light of global development trends and growing market demands. The relevance of the research is due to the rapid implementation of digital technologies in all spheres of activity, which inevitably affects the printing industry, requiring a detailed analysis of the effectiveness and possibilities of using computerized systems. The development of digital printing opens up new horizons for increasing the productivity and quality of printed products, offering greater opportunities for personalization, quick changes of layouts and savings on medium and small runs. The main part of the academic paper reveals a comparison between traditional and digital printing technologies, highlighting the advantages of the latter in terms of time, cost and quality. Separate consideration is given to the potential of digital printing on textiles, laser printing, and Computer-to-Plate (CTP) technology, all of which greatly improve production processes and lessen environmental effects. The research also focuses on 3D printing, which opens new perspectives for the printing industry, offering high quality, speed and cost-effectiveness of production. The practical significance of the study is to provide specific recommendations and directions for using computerized technologies in the printing industry aimed at increasing the productivity, quality and economic efficiency of the production of printed products. The research shows how the use of computerized systems can simplify production processes, reduce time for production preparation and reduce printing costs, especially when producing medium and small runs. Automation makes it possible to achieve high accuracy and print quality, ensuring better color reproduction, image clarity and uniformity of each print. The conclusions emphasize that the automation and digitization of the printing industry not only increase the efficiency of production processes but also open up new opportunities for the development of the industry in the context of globalization and growing competition. The authors recommend further studies in the field of optimizing the use of digital technologies, which will allow for higher quality of printed products, lower costs and more efficient use of resources, which is critical for the sustainable development of the printing industry.

Keywords: industrial engineering, computerized printing systems, printing equipment, CTP - printing, 3D printing, stereolithography, layer-by-layer fusing.

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КОМП'ЮТЕРИЗОВАНІ ПОЛІГРАФІЧНІ СИСТЕМИ: АНАЛІЗ ЕФЕКТИВНОСТІ ТА ПРАКТИЧНОГО ЗАСТОСУВАННЯ

Стаття розглядає важливість інтеграції цифрових технологій у поліграфічній індустрії з огляду на глобальні тенденції розвитку та зростаючі вимоги ринку. Актуальність дослідження обумовлена стрімким впровадженням цифрових технологій у всі сфери діяльності, що неминуче впливає на поліграфічну промисловість, вимагаючи детального аналізу ефективності та можливостей застосування комп'ютеризованих систем. Розвиток комп'ютеризованої поліграфії відкриває нові горизонти для підвищення продуктивності та якості друкованої продукції, пропонуючи ширші можливості для персоналізації, швидких змін макетів та економії на середніх та малих тиражах. Основна частина статті розкриває порівняння між традиційними та цифровими технологіями друку, підкреслюючи переваги останніх у контексті часу, вартості та якості. Окремо розглядаються можливості комп'ютеризованої поліграфії на текстилі, лазерного друку та технології Computer-to-Plate (CTP), які значно оптимізують виробничі процеси та зменшують вплив на довкілля. Стаття також акцентує увагу на 3D-поліграфії, яка відкриває нові перспективи для поліграфічної індустрії, пропонуючи високу якість, швидкість та економічну ефективність виробництва. Практичне значення дослідження полягає в наданні конкретних рекомендацій і напрямків для використання комп'ютеризованих технологій у поліграфічній індустрії, що спрямовані на підвищення продуктивності, якості та економічної ефективності виробництва друкованої продукції Дослідження показує, як застосування комп'ютеризованих систем може спростити виробничі процеси, скоротити час на підготовку виробництва та зменшити витрати на друк, особливо при виробництві середніх та малих тиражів. Автоматизація дозволяє досягти високої точності та якості друку, забезпечуючи краще відтворення кольорів, чіткість зображення та однорідність кожного відбитка. Висновки підкреслюють, що автоматизація та цифровізація поліграфічної промисловості не лише підвищують ефективність виробничих процесів, але й відкривають нові можливості для розвитку галузі в умовах глобалізації та зростаючої конкуренції. Автори рекомендують подальші дослідження в області оптимізації використання цифрових технологій, що дозволить забезпечити більш високу якість друкованої продукції, зменшення витрат та більш ефективне використання ресурсів, що є критично важливим для сталого розвитку поліграфічної індустрії.

Ключові слова: галузеве машинобудування, комп'ютеризовані поліграфічні системи, поліграфічне обладнання, CTP – поліграфія, 3D-друкук, стереолітографія, пошарове наплавлення.

Problem statement

The relevance of the research stems from several factors that significantly influence the printing industry and its development in modern conditions. Firstly, digital technologies are rapidly penetrating all spheres of human activity, which inevitably affects the printing industry. This necessitates a detailed analysis of the effectiveness and potential applications of computerized systems in this field. Secondly, the transition to computerized technologies opens up new opportunities for increasing the productivity and quality of printed products. Studying these aspects is important for developing effective strategies to optimize workflow processes in printing enterprises. The third aspect of the research relevance lies in the fact that computerized printing systems allow for significantly expanding the range of services that can be offered to clients, including personalized printed products, rapid modifications to layouts, and reduced costs for printing medium and small print runs. Fourthly, it's crucial to examine the effectiveness and real-world applications of computerized printing systems because of the growing ecological consciousness and the need to lessen the environmental impact of industrial processes. Digital technologies can contribute to optimizing resource utilization and reducing waste in the field of industrial engineering. In the context of globalization and growing competition in the printing services market, understanding how computerized systems can enhance the competitiveness of enterprises is crucial for their successful operation. All these aspects underscore the relevance of the research and the importance of its findings for the development of the printing industry.

Analysis of the latest sources

At present, special scientific literature pays considerable attention to studying the current situation in the publishing and printing industry. The problems of using computerized printing systems are described in the scientific works [3, 8]. However, due to the importance of the industry and the dynamics of changes, it is crucial to constantly monitor and evaluate the performance of individual printing companies and the industry as a whole [12]. As of today, the analysis makes it possible to assert that the majority of companies have significant development reserves, both for expanding their product portfolio and enhancing their competencies. Therefore, progress in these areas will enable companies to increase their competitiveness in the printing market.

According to the standpoint [16], globalization and expanded production have led to the current state of the printing industry, characterized by shorter turnaround times, improved product quality, and increased complexity of custom printing orders. This is achieved through increased levels of production automation and the integration of various production areas into a unified computerized manufacturing process [11].

According to the viewpoint [7], currently, major manufacturers of printing equipment and systems increasingly opt for standardized digital printing processes due to established international cooperation within a unified information production environment. This trend is corroborated by the standpoint [1], which indicates that advances in science and technology allow for ongoing improvement of printing technologies and create conditions for the globalization and internationalization of printing.

A review of the literature on the research topic has shown that the situation in the global printing equipment market is unstable nowadays. Significant changes in the economic sphere related to digital platforms are increasingly influencing not only the production and use of printed products but also the entire printing infrastructure associated with this sector (equipment, paper, printing, equipment servicing organization).

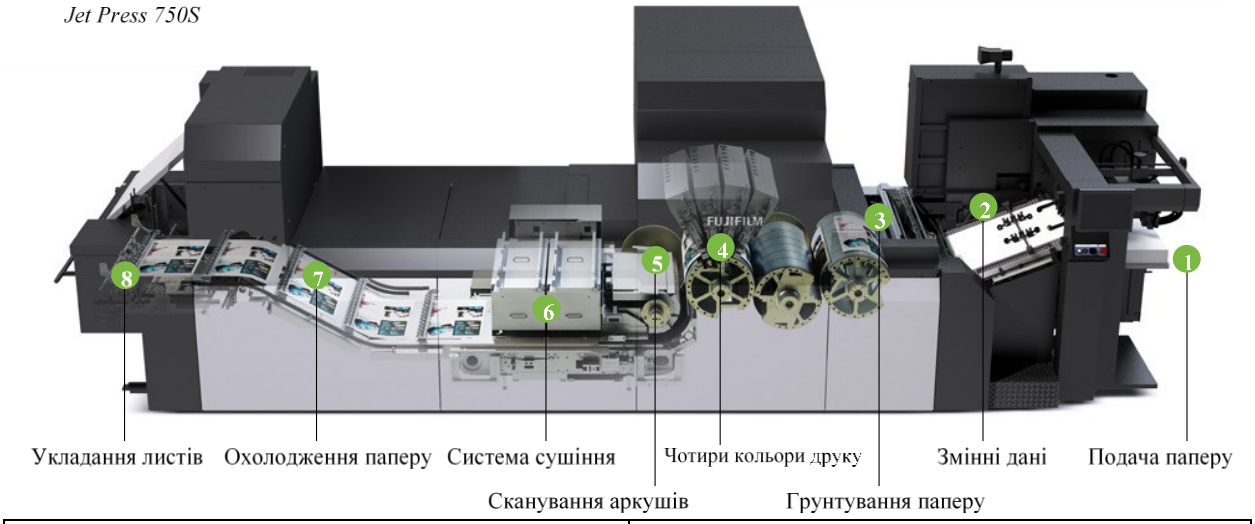
The purpose of the research is to analyze the effectiveness and possibilities of the practical application of computerized printing systems in modern conditions. This includes the study of technical features, and economic benefits, as well as the analysis of the possibilities of integrating such systems into various areas of the printing industry to optimize printing processes and improve the quality of finished products.

Presentation of the main material

Compared to classical printing methods, computerized printing overcomes time and space constraints by using information technologies, such as the Internet. Traditional printing methods are characterized by a single printing mode, a large amount of time for order preparation and fulfillment, and relatively low print speed and quality. This creates difficulties in meeting the requirements of print efficiency and time constraints imposed by traditional processes. Furthermore, in traditional printing, each stage of the process is closely interrelated, complicating printing beyond production capacities and imposing limitations on spatial flexibility. In contrast, the use of computerized printing allows for the rapid processing of original informational materials and their transmission over the network, significantly improving the quality and speed of printing, overcoming temporal and spatial barriers. Digital printing on items such as packaging represents a cutting-edge and revolutionary approach that changes the printing paradigm due to its flexibility and ability to perform on-demand tasks at high speed, opening up new opportunities for rapid market entry [4].

1. Digital printing. The most common technologies of computerized printing are toner and inkjet printing. Digital printing involves a process where a digital image is transmitted to a printing press, where the printing task is carried out within seconds using toner or ink. The image is transmitted digitally, enabling variable data to be printed, such as a unique name on each card or ticket (personalization). Additionally, the first sheet of the machine can have the correct color and almost immediately dry, allowing it to be quickly processed and delivered. Printing on Demand (POD) has also become possible thanks to digital printing. With POD, even if only one copy is printed, it is still economically efficient.

The Samba printing head is used in the "Jet Press 750S". Printing is a reproduction technique based on electrostatic "copying" (Figure 1).



Українська	English
Укладання листів	Stacking of sheets
Охолодження паперу	Paper cooling
Система сушіння	Drying system
Чотири кольори друку	Four colors of printing
Змінні дані	Variable data
Подача паперу	Paper feeding
Сканування аркушів	Scanning sheets
Ґрунтування паперу	Paper priming

Fig. 1. The computerized printing system "Jet Press" by Fujifilm and its technical part [5]

Paper feeding (1) is controlled by a reliable traditional transport system, which delivers the exact amount of paper needed for printing, ensuring high productivity with minimal waste. Then (2), the sheets are scanned for precise registration and variable data for possible duplex printing, after which (3) the paper is primed. This is necessary for water-based ink to adhere to the paper without sinking into it, meaning that regular offset paper can be used instead of digital paper with a special coating, which is superior both commercially and environmentally. The primer also optimizes print quality and ensures that ink can be easily removed from the paper during the recycling process. Color (4) printing with water-based ink is performed by four printing bars with "Samba Si-MEMS" print heads, which simultaneously apply the four primary colors: cyan, magenta, yellow, and black (CMYK) directly onto the paper. The Jet Press printing system also applies methods to reduce the amount of ink to minimize their quantity. After the printing process, (5) the inspection of the printed sheets is conducted. The sheets are automatically scanned for quality one by one using sensors to minimize errors. The drying system (6), with a top drying unit and a heated conveyor belt at the bottom, uniformly dries the printed sheets. Finally, the sheets are cooled (7) and folded (8) for immediate processing. The accuracy of registration from sheet to sheet also minimizes errors that occur during finishing, further reducing waste [5].

2. The use of computerized printing on textile materials. Digital printing is a process where printing is performed automatically using digital means. For clarity, it is worth noting that there has been a rapid development of digital printing technologies in recent years used for applying designs on fabric, textiles, and nylon, through various services. Currently, many companies specializing in textile production use digital printing technologies, allowing them to avoid the need for manual preparation of templates or patterns, which typically require significant time to prepare. A key aspect of using digital printing on fabric is the necessity of pre-treating the fabric and ensuring proper fixation before printing. Depending on the fibrous nature of the fabric, dyes with corresponding affinity (such as reactive, acid, or disperse) are used; various types of additives are applied according to the fabric's content to ensure the relevant dye types are used. With this pre-treatment, the fabric is prepared before printing, and the best print quality is achieved on the fabric to prevent bleeding or spreading of the dye. In this system, there is no need for constant monitoring of the printing process [2].

Laser printing technologies can produce the highest resolution and print quality. The quiet operation, quality, and speed of laser printers are important characteristics. These printers can produce high-quality prints. Although the devices are relatively expensive, they are desirable because they are fast, reliable, and cost-effective. Laser printers are considered economical printers since they are cheaper and more durable in terms of toner.

3. CTP - printing. CTP (Computer-to-Plate) printing technology involves computer-controlled lasers exposing images, or in other words, transferring digital data directly onto aluminum or polyester plates. These plates are then processed and ready for installation on the printing press [10]. The CTP technology completely eliminates the need for film as an intermediate image carrier – essentially, the image is transferred directly from the computer to the surface of the printing plate. However, adapting to the computer and software aspects of the new workflow organization can prove to be a challenging task. That's why many companies prefer to transition to digital output on

film first, and then, once confident in the efficiency of investing large sums, implement CTP technology. The productivity increase brought about by the removal of manual processes is one of the numerous benefits of CTP. Table 1 provides examples of CTP typographic machines that integrate well into the workflow of the printing production.

Fig. 2: Digital printing machine for printing on textiles

Table 1

Comparative features of CTP - printing machines [2, 15]

CTP machine brands	The level of demand	Integration into the workflow
luescher: XDrum! UV	+	+
HP SmartStream DFE	+	+
Afga Avalon N8		-
Printware PlateStream Color+ SC	-/+	+
Heidelberg Prosetter 52-102	+	+
Creo Trendsetter 800 Quantum	-/+	-

The system allows for highly efficient management of the print queue by creating the "Job Ticket" (order flow chart) with the ability to fully automate data processing and use parallel processing. The system allows for JDF connection to various MIS systems. HP SmartStream DFE raster processor servers (Figure 3) are operated with Windows Server for receiving, rasterizing, viewing and controlling materials before printing, calibration and diagnostics. The workflow management system, based on JDF (Digital ICS v1.3), uses the GG Harlequin 8.0 RIP core as a high-performance RIP [15].

Fig. 3. "HP SmartStream DFE" printing machine [5]

High-quality, cost-effective, and fast digital printing is in high demand today in practically all print shops that aim to offer their customers a full range of services, including quick printing of variable data and small print runs. The use of modern digital printing solutions allows for generating good profits, enhancing the competitiveness of the print shop, and providing customers with a high level of service.

4. 3D printing. FDM (Fused Deposition Modeling) is a popular additive manufacturing technology that

utilizes a layer-by-layer fusing method. It is applied in the creation of three-dimensional models, prototypes, and products that do not have specific requirements for surface quality and manufacturing precision. The FDM technology involves the creation of three-dimensional objects by applying successive layers of material that replicate the contours of a digital model. Thermoplastics, supplied in the form of spools of threads of various colors, serve as the printing material. The production cycle begins with the processing of the three-dimensional digital model. The model in STL format is sliced and oriented most appropriately for printing. If necessary, support structures are created, which are required for printing overhanging elements. The typographic system based on the "UP Mini" (Figure 4) is a new development by "PP3DP", a portable 3D printer that allows printing models from a computer or a laptop. The printer is made of steel and has a durable structure, making it wear-resistant and capable of operating 24 hours a day.

Fig. 4. General view of the 3D printing machine "UP 3D Printer Mini" [6]

Easy to use and cost-effective, the printer utilizes an additive printing method. The "UP Mini" is optimized for printing with ABS plastic and features a heated platform, while its enclosed chamber collects heat from the extruder and platform, stabilizing the temperature required for printing with ABS plastic. The sealed chamber ensures safety and printing stability. Printing with ABS allows for the creation of individual parts, which can then be assembled if necessary. Examples of works produced on this printer are shown in Figures 5 and 6.

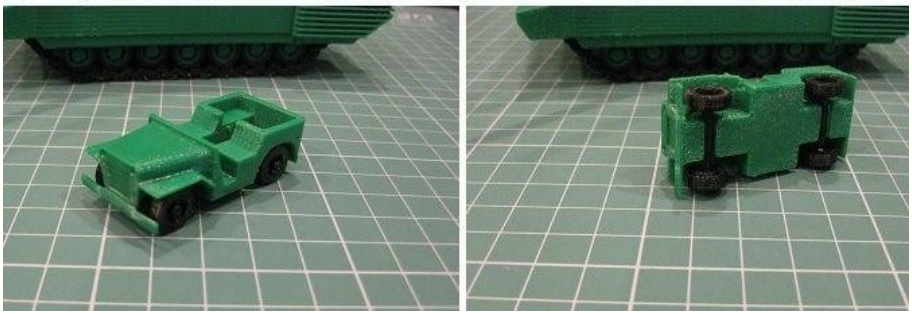


Fig. 5. Items made with a 3D printer [9]

Fig. 6. An item made with a 3D printer [9]

The examples of photographs provided demonstrate the poor surface quality and apparent roughness. In order to achieve higher quality, mechanical post-processing is required. As the processing progresses, the linear dimensions of the product will decrease, which needs to be considered when designing the model.

The 3D printer "Roland ARM-10" (see Figure 7) is one of the representatives of models that provide reliable 3D printing of complex objects.

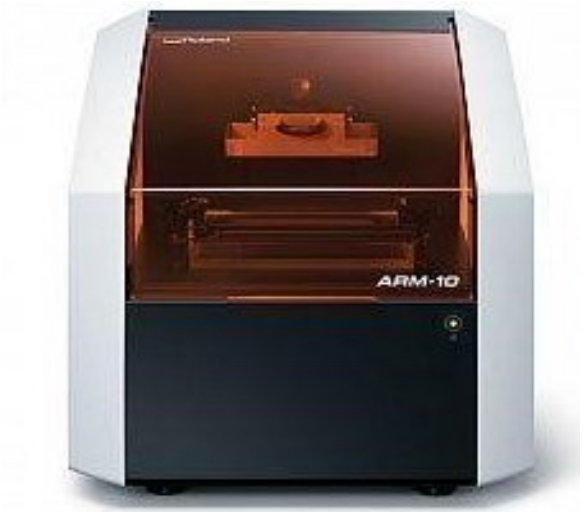


Fig. 7. 3D printer "Roland ARM-10" [13]

In the "Roland ARM-10" 3D printer, stereolithography technology is combined with UV-LED radiation sources: the model is "grown" by successive application of polymer layers coming from a container with a liquid composition. The ability to form several objects in one working area simultaneously saves time. This option can be considered the main advantage over the technology of laser exposure of individual zones. Figure 8 shows an object made on a Roland ARM-10 printer.

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Fig. 8. An example of "Roland ARM-10" work [13]

Complex products that previously required multi-axis mechanical processing, such as parts with undercuts and cavities inside the object, or objects with through holes, can now be easily and quickly printed. In the suspended object cultivation system, minimal polymer is consumed, thus, reducing the cost of the finished model. The high-precision 3D printer for rapid prototyping ARM-10 has a user-friendly interface and is an ideal tool for realizing various ideas.

The "3D Systems ProJet 360" ("ZPrinter 350") is a model of a monochrome inkjet 3D printer (Figure 9), representing one of the first single-color automated 3D printers. It is capable of producing relatively large models and is characterized by high speed and ease of use. Suitable for office use in creating monochrome models, it can be utilized in various fields ranging from education systems to industrial design.

3D printing technology is based on the principle of layer-by-layer 2D printing. During production, a liquid water-based adhesive, used to bind the powder, is distributed using a jetting print head. This process forms the layers of the model. The adhesive is applied according to a specified program and solidifies immediately after application. After forming one layer, the printer checks its thickness and proceeds to create the next layer. Upon completion of the procedure, the model is removed from the powder. The unused powder from the construction process is then used for printing subsequent models. The professional 3D printer "Systems ProJet 360" can be utilized in various fields of application. For example, it can be used to create designer and architectural three-dimensional models used for

demonstrating prototypes of future products. It can also be used in industry to make the appropriate templates.

Summarizing the examined technologies of computerized printing, we will form a comparative table in which we define the main features and peculiarities of these technologies (Table 2).

Fig. 9. 3D printer "ProJet 360" [14]

Table 2

Comparative analysis of computerized printing systems and the level of efficiency of their use (compiled by the authors)

Type of the technology	Description of the technology	Advantages of using	Technological effect	Opportunities for the printing business
Digital printing	Direct printing from digital files to paper or other materials without using traditional printing plates.	Fast setup, low costs for small batches, high quality, and the possibility of personalization.	Increased production speed and flexibility in order fulfillment.	Expanding the range of services, increasing market share through personalized printing.
Digital printing on the surface of textiles	Printing on textiles using specialized digital equipment makes it possible to apply images directly from a computer.	High image quality, the ability to print on various types of fabrics, speed and cost savings.	Improving the quality and variety of textile products, saving resources.	Opening new markets, in particular, in fashion and individual design, and expanding services.
CTP - printing	The technology that makes it possible to transfer images from a computer directly to printing plates, bypassing the use of film.	High speed and accuracy of plate manufacturing, reduced production costs, and improved print quality.	Significant reduction in print preparation time and material savings.	Improving the quality of printed products, reducing costs, and increasing productivity.
3D printing	Using 3D printing to create three-dimensional objects from various materials, including plastic, metal, and resins.	The ability to create complex three-dimensional products, rapid prototyping, and product individualization.	Revolutionary changes in design and production, the ability to manufacture products to order.	Entering new market niches, offering unique products, expanding business in the direction of modern technologies.

The above table provides an overview of the opportunities offered by digital printing technologies for the printing business, pointing to development paths and innovative approaches to printing. To sum up, modern printing production is a complex, high-tech, computerized process in which printing machines are equipped with electronic, mostly digital, control systems.

Conclusions

The printing industry has experienced significant innovative changes in recent years due to the rapid development of network information technologies, computer equipment, laser technologies, and software. This is evident from an overview of the current state of automation and quality control in the production of printed products. This has led to the transformation of both the external and internal structure of production, as well as the printed products market, improving automated and digital management systems on a permanent basis. The introduction of regional and global information networks has ensured more efficient interaction between remote enterprises and production locations.

These changes have significantly influenced trends in the production of printing equipment, reflecting the key areas of future development of the printing industry, which are closely linked to progress in information technology. Currently, automation covers not only production processes, but also their management, using artificial

intelligence, direct interaction with customers, and adaptation of equipment to specific customer requirements in printing. This trend makes it possible to personalize not only digital printing but also all printing processes, including complex automated processing. Such innovations have become an influential trend in the industry, defining development directions for manufacturers of printing equipment, technologies and software developers. Modern digital control is widely used in the printing industry, where online control systems create conditions for managing digital equipment and exchanging information, for example, via the Internet, ensuring transparency of the entire production process and the ability for customers to monitor the fulfillment of their orders at every stage.

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