RESEARCH INTO THE USE OF ENERGY EFFICIENT PRESSES FOR CUTTING TEXTILE MATERIALS

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Abstract: *The research of features of the use energy efficient presses for cutting textile materials was conducted in the article. The experimental drive, main features of which are use of a frequency converter, microprocessor technics, sensors of control parameters of equipment work, tracking system and experimental measuring unit, was developed. The degree of power consumption of cutting presses and their maximum values of energy consumption was established. The coefficient of energy efficiency equipment for one-layer, multilayer and combined fabrics was calculated. The researches, allowed to determined coefficient of efficiency use of equipment for decks of different fabrics, were conducted. A comparison of existing and developed equipment, determined their economic efficiency and economic effect from the use of developed equipment was carried out.*

Keywords: *textile materials, cutting, experimental drive, cutting press, energy efficiency, tracking system.*

1 INTRODUCTION

The current state of the industry is characterized by rapid development of its various branches. Each of them has its own specific features. One of such branches is light industry. Today energy factor occupies one of the most important places in the development of not only light industry, but also the international economy as a whole. Engineers that create equipment go through the effective improvement of existing models and development of new, more economical and technological [1-3]. This provide to a new level of development for all branches of industry.

Electro-hydraulic press equipment in the light industry is used to cut artificial and genuine leather parts by dipping the cutter into the cutting plate [4]. Today the companies of light industry use a large number of modern cutting presses. However, number of new modern presses is insufficient to meet the needs of industry. Especially for small enterprises that are unable to rivalry with the world's giants and also growing crisis in the world economy. Therefore, modifying such equipment and improving its technical and economic indicators is relevant task.

Many technologies are used in the world to cut different materials. Technology of hydrojet forming [5-7] and hydrojet cutting [8] of different materials are widely known and used many years. But there are a number of significant drawbacks of such technology, which prevents its widespread use especially in cutting textiles materials.

Laser cutting is one of the most modern and progressive in terms of innovation and prospects of use [9-10]. This technology is used for cutting different materials but is characterized by high energy consumption. This has a negative impact on the cost of final product and its quality. The edges of cut-off parts are exposed to the laser beam (local thermal action of the beam) and lose their characteristics and aesthetic appearance. It is also worth to say, that this technology is still too expensive for mass use.

Automatic cutting complexes are very popular at various enterprises [11]. They are one of the most modern robotic complexes with a wide range of functional opportunities. This makes it possible to simplify the cutting process as much as possible in the complete technological cycle [12]. The complex of technical solutions of such equipment meets the modern requirements and allows to produce details of complex shapes with high quality of their processing. However, one of the main disadvantages of such cutting complexes is high cost. This is a significant disadvantage for small businesses where the annual volume of manufactured products does not ensure high profits.

The ratios of different indicators that are taken into account when cutting parts from different materials are described in [13]. Parametrization of various equipment and application features are considered. However, one of disadvantages of this work is that it does not taking into account the cutting of textile materials. This does not allow to determine the advantages and disadvantages of such equipment when interacting with textile materials of single and multi-layer decks.

One of the modern requirements in manufacture of textile materials is harmonization of material with the shape and feature of manufacturing on equipment [14]. In this regard, design aspects of manufacture of clothing [15] plays a significant role, as it directly affects on choice of constructive execution, materials and design features of products. Functional purpose of clothing is essential [16], especially if products put forward higher requirements to wear resistance, chemical resistance, radiation resistance and other important characteristics.

The most optimal of above equipment by criterion price-quality, simplicity of technical service and exploitation is the use of electro-hydraulic cutting presses. Their use is relevant for small enterprises where it is possible to make fuller use of their potential. This has a positive effect on the value of the final product, reducing it.

One of the major disadvantages of such equipment is its high power consumption during cutting. This worsens economic efficiency and increases the cost of finished products.

Therefore, there is a need to increase economic efficiency of cutting textile materials on such equipment. To do this, it is necessary to conduct research into the use of modern energy efficient presses and identify ways to improve their energy efficiency.

2 DEVELOPMENT OF EXPERIMENTAL EQUIPMENT FOR INVESTIGATING THE ENERGY CONSUMPTION OF CUTTING PRESSES

2.1 Experimental equipment

The experiments were carried out on Italian cutting press Atom SE20C, which is widely used in many enterprises of different industries. Its main advantages are high reliability, stability of work, low cost of operation and qualitative cutting of parts from various materials including textile. Fabrics are difficult to cut through a specific structure. The interlacing of threads of most fabrics is strong, so the cutting force should be 15-40% greater than when cutting, for example, leather or cardboard. Especially difficult is cutting down the fabrics with a total number of more than 3. This is due to the complication passage of the cutter between threads and their fibers, which in multilayered decks form a complex reinforced surface with high strength. If interlacing of each fabric in deck is difficult, then the overall strength is significantly increased and cutting efficiency is reduced.

Experimental research is based on the goal of improving the economic effectiveness of cutting presses by improving energy efficiency. This provides significant cost saving on implementation technological process of cutting. In general, this contributes to reducing energy consumption and unit cost of finished product, which is a positive factor.

For conducting researches developed experimental drive that used in cutting presses and which is activated only during cutting. The main drive elements are: frequency converter, microprocessor technique, sensors to control parameters of equipment work, tracking system and experimental measuring unit.

For conduct research was used frequency converter Altivar 340 Schneider Electric firm. The specified converter is a component of the drive that performs a number of specific and very important functions that directly affect on its work:

1) reducing electricity consumption;
2) smooth start of the engine;
3) increase reliability work of the engine;
4) smoothing of maximum load on drive during cutting;
5) compensation of failures in engine work at maximum load;
6) improving overall energy efficiency the work of press;
7) improving the quality of manufactured products.

The developed experimental drive has a special construction. Its main advantage is to operate only when performing a technological cutting operation. The starting currents at the engine start are extinguished by frequency drive in a fixed time interval. Another advantage of developed drive is automated work and change of various parameters of functioning drive-press in real time system. Such system is adaptive and allows during the work adjust any features of press and watch them on a PC monitor. This combination makes it easy to adjust the parameters of drive-press system and make adjustments to eliminate disadvantages.

Experimental equipment consists of the following components: cutting press, experimental drive, measuring equipment (tracking system, measuring unit, PC, automated system of control of set parameters of equipment work, system of information collection and processing, system of indicators of effective operation of the drive, system of control energy consumption of equipment). This set of different systems provides complete control over all processes of equipment work. The drive construction is located in a special place in lover part of press. Developed experimental drive provides energy efficiency and reduces the final cost of finished products through the rational use of electricity through a complex of set decisions.

Before cutting into computerized system entered data, which take into account all necessary cutting parameters: physical properties of material, cutting power, number of material layers, type of material, energy consumption parameters, characteristics of measuring systems, connection of all necessary sensors and test equipment. To obtain the necessary experimental data of equipment used measuring unit WB-1 [15-16]. This unit is an element of measuring equipment and works on the principle of analog-to-digital signal conversion of equipment work and obtaining accurate data of measurement values (Figure 1).

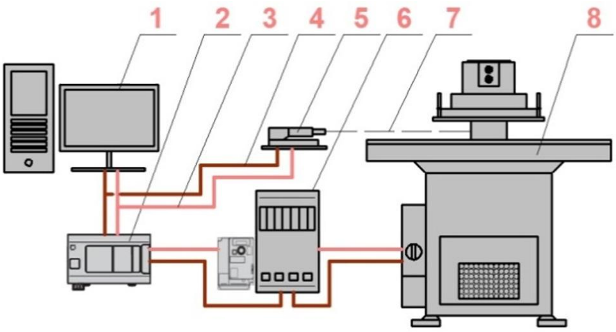

Figure 1 Scheme of experimental equipment work: 1 – personal computer; 2 – measuring unit VB-1; 3 – direct connection line; 4 – feedback connection line; 5 – tracking system; 6 – experimental drive; 7 – line control of the movement of drummer and cutting quality; 8 – cutting press Atom SE20C

Experimental equipment uses various sensors that control entire cutting process – from immersion of the cutter into material to control of oil level in the hydraulic press system. Another feature is the use of a special laser tracking system. It provides control of impactor movement and cutter in the space with high precision, which allows to control the quality of cutting. Particularly useful specified system in available minor errors in cutting various materials. At the same time displaying the characteristics on the PC screen, it is possible to control the quality of cutting down and to harmonize the different characteristics of the equipment in order to reduce power consumption and improve the quality of cutting. Under real conditions, knowledge of these indicators is a great advantage in production, as it allows to immediately correct certain inaccuracies in the work of cutting equipment. When using new material this system greatly simplifies the process of debugging of equipment work.

2.2 Methodology of conducting researches

For conducting experimental research were used different fabrics. The cutting efficiency for single-layer, multilayer and combined decks of textile materials, leather, cardboard and rubber, was checked. However, in case of significant deviation of indicators the average values of experimental data were selected.

During the experimental studies, the press worked as follows.

When the press was turned on, the engine did not work – it was in a state of calm. All functional systems work without load on power grid. The panel on control unit set required operation mode of experimental drive.

The VB-1 measuring unit is a key link and receives signals from the drive, monitoring system and all sensors and displays them on a personal computer. Then necessary software is configured to collect and processing experimental data. Before research press was set up on fixed technological parameters, special monitoring system, sensors and measuring unit VB-1.

The tracking system operates on the principle of controlling a movement of striker (video fixation) and the quality of cutting (control was carried out on the principle of contact change with a laser beam in real time). The laser beam was fixed on special photosensitive sections with feedback. Simultaneously with laser work on the PC screen simulated the process of cutting and moving striker, and also dipping the cutter into material. At the same time, there is opportunity to coordinate video and graphics of different characteristics of equipment.

Before cutting was selected desired mode of operation which depends on the following parameters:

1) material;
2) detail shape;
3) number of material layers.

Pressing the control buttons of the press it turns on appropriate electrical equipment, electric motor and hydraulic pump are switched on. The oil from hydraulic pump enters the working cylinder of press through pipelines. After turning the drummer into working position under the action of oil pressure, the drummer drops down, cutting a material. At same time according with cutting, an experimental drive is triggered. That provides stable work of equipment without overloading. After cutting the actuator is unlocked.

Due to use developed drive it is possible to save a considerable amount of energy, reduce the load on electric motor and equipment, improve the quality of the cut parts. The studies were conducted for fabrics in the following combinations: single-layered, multi-layered, combined (Table 1).

Table 1 Technical characteristics of the equipment

Technical equipment parameter	Textile materials		
	one-layer	multilayer	combined
Average value of cutting effort N_{vr},[kH]	61	147	135
Cutting time *t* [s]	0.002	0.0027	0.0025
Quality of cut line of the parts *k*	0.99	0.97	0.98
Maximum power of engine W_{max} [kW]	0.42	0.70	0.64
Efficiency coefficient of equipment use α_{eq}	0.81	0.78	0.79
Total energy consumption for 1 hour W_{Σ} [kW]	0.35	0.41	0.38
Efficiency coefficient of energy consumption e^N	0.89	0.83	0.85

During research, developed drive provided a significant improvement of equipment energy characteristics. At turn on, peak loads were smoothed out, which reduced engine overload.

During cutting, was provide reliability work of the press and its protection from possible breakdowns through the use of various drive safety functions (in accordance with IEC 61508 and ISO/EN 13849-1-2 standards), namely:

1) protective moment shutdown;
2) protective speed limitation;
3) protective stop;
4) safe maximum speed;
5) security door lock.

In addition to standard features used developed, designed to provide dual protection from drive overloading. This protects it from overload, stabilizes the work, and also provides reliability work during cutting multilayered decking of fabrics, especially in the final stages of cutting when highest loads on equipment are observed.

Thus, provides reliable motor work and its protection from possible stops, breakdowns and failure. And this, in the future, provided improved quality of cutting parts.

3 RESULTS AND DISCUSSION

Conducted experiments allowed to establish economic effect from the use of developed drive in the cutting presses, that used for textile materials cutting.

The first stage of the work was to check efficiency of developed drive. To do this, it was loaded to the maximum and at the same time perceived increased pressure from all systems (Figure 2).

It is investigated, that the use of developed drive provides its protection from overload in wide range of values (Figure 2). Drive overload adversely affects on all indicators of cutting process. In the case of emergency stop of engine, the key role is smooth and uniform reduction of drive torque reduction. If such stop is extended over time, it is an overload and possible failure of equipment. The points A1, A2 and A3 (Figure 2) characterize the process of drive stopping during overload – beginning of the stop, beginning of smoothing the overload and the end of overload protection function, respectively. Installed, that compared to conventional drive on 15-21% improves equipment reliability and its failure.

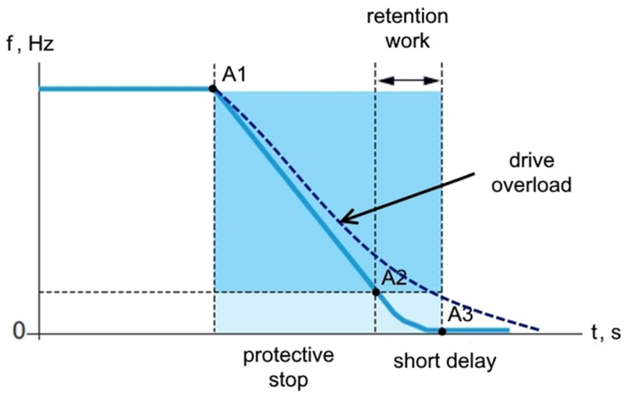

Figure 2 Features of the work of developed drive with overload protection

It is established, that use of developed drive promotes protection from exceeding the preset speed of the engine (Figure 3).

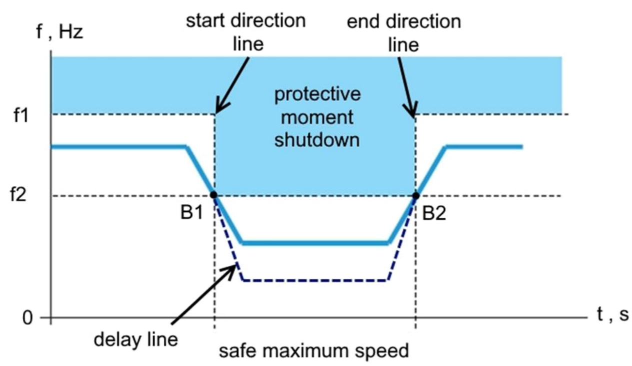

Figure 3 Overload protection from exceeding a set speed of drive motor

When entering amplitude of speed characteristics of the drive, motor speed is great importance. If at fixed points of drive work B1 and B2 do not set the required parameters of operation (Figure 3), then a break is possible between required and operating speeds. This critically affects on the engine dynamics and contributes to its rapid deterioration. The optimal motor speed makes it possible to use qualitatively its power in the fixed sections of technological process of cutting textile materials.

It is investigated, that the use of developed drive provides protection from exceeding speed by reducing rotation speed motor drive (Figure 4).

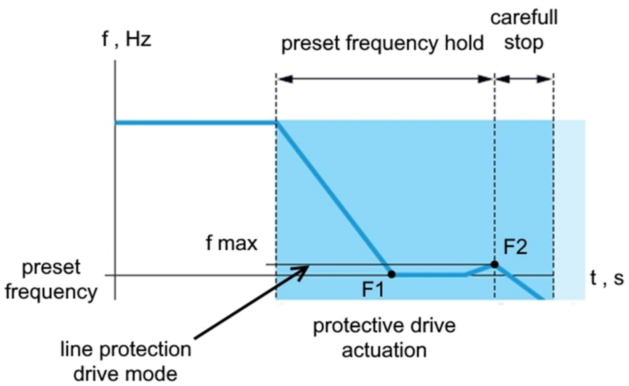

Figure 4 Protection from exceeding speed by reducing rotation speed motor drive

Frequency control of the drive along with motor contributes to quality control of press as a whole. The transition from point F1 to point F2 shows the dynamics of changing the load on motor with protection from critical overload (Figure 4). In this case, F1 is the point of beginning of dynamics change and F2 is the end point of dynamics change of before unlocking.

Another component of the experimental studies was to establish the energy consumption of press equipment, depending on the number of textile materials decks. The results of experiments are presented in the corresponding graphical dependences (Figures 5 and 6).

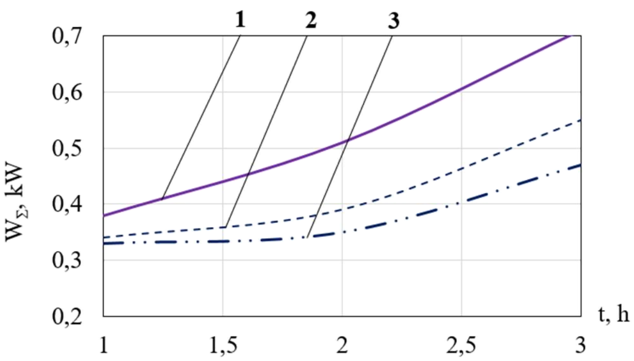

Figure 5 Graphical dependence of changing the maximum amount of energy consumption W_{max} on time *t*, which takes into account the number of decking material *n*: 1 – multilayer; 2 – combined; 3 – one-layer

The experimental researches made it possible to establish the nature of a change of consumed energy from the grid using a developed drive. It is established that the number of decks of textile material significantly influences on the nature of energy consumption by equipment. With increasing a number of material layers the level of energy consumption increases to a great extent.

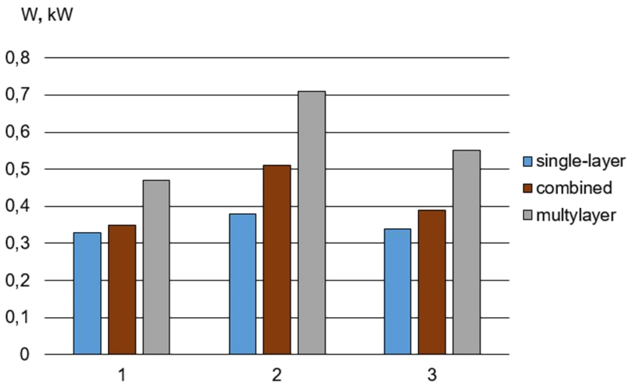

Figure 6 Graphical dependence of changing energy consumption *W* on number of decks of textile material and coefficient, which takes into account the type of material *k*: 1 – fabrics with a simple weave; 2 – fabrics with difficult weave; 3 – combination of fabrics with different materials

This is due to the occurrence of additional forces of resistance in the drum-cutter-material system. They complicate the cutting process and deteriorate a quality of cutting parts. Conducted researches are consistent with the work, described above [1-5].

Compared to cutting single-layer flooring fabrics, energy consumption is 15.5% higher for combined and 43.6% higher for multi-layer flooring fabrics. In turn, when cutting multi-layered materials, electricity consumption from the grid increases by 28.1%. At the same time, maximum energy consumption values for fixed materials are set, which are: 0.71 kW for multi-layered fabrics; 0-55 kW for combined fabrics and 0.47 kW for single-layer fabrics.

It is calculated coefficient of efficiency use of equipment α_{eq} for flooring of different fabrics: 0.81 for single-layer; 0.78 for multilayer and 0.79 for combined. Such values are consistent with previous energy consumption experiments for different materials.

Considering the total energy consumption of cutting equipment, calculated coefficient of energy efficiency e^N: 0.89 – single-layer, 0.78 – multi-layer and 0.79 – combined. Thus, according to this coefficient, the highest energy consumption characteristics are when cutting single-layer textile materials, and the worst – multi-layer. That is, when cutting single-layer fabrics, there is the least energy consumption, which has a positive effect on the cost effectiveness of cutting equipment.

The percentage difference between multi-layered and combined is insignificant – 5%. In general, the whole complex of conducted investigations has allowed to establish economic efficiency of cutting presses with the use of developed drive. In comparison with existing equipment, the economic effect is 35.4%. With continuous work of equipment such savings are significant. It is also important to take into account disadvantages of conducted researches.

A limited number of materials used in research should be noted. This is due to determination of power consumption of equipment in the range of basic fabrics. However, taking into account the behavior in cutting down a large number of tissues will identify ways of further research and establish the features of interaction of different tissues during cutting. However, consideration behavior of a large number of fabrics during cutting will identify the ways of further researches and to establish features of interaction of different fabrics at cutting. At the same time developed drive is experimental and cannot be used for prolonged exploitation. Therefore, there is a need to develop an industrial sample of experimental drive. These disadvantages need to be addressed in the next studies.

4 CONCLUSIONS

It was conducted a study of energy efficient presses for cutting textile materials, as a result of which determined features of their energy consumption and advantages over existing equipment.

A new experimental drive has been developed for use in cutting presses. Its main features are the use of a frequency converter, microprocessor technics, sensors to control parameters of equipment work, monitoring system and experimental measuring unit.

The degree of power consumption of cutting presses has been established. The maximum power consumption is: 0.71 kW for multi-layered fabrics; 0.55 kW for combined fabrics and 0.47 kW for single-layer fabrics. In comparison with cutting one-layer flooring of fabrics, in combined fabrics was energy consumption higher on 15.5% and in multi-layer on 43.6%.

Calculated coefficient of energy efficiency of cutting equipment for fabrics, which is: 0.89 – one-layer, 0.78 – multilayer and 0.79 – combined. Conducted researches have allowed to establish the coefficient of efficiency application of equipment for decks of different fabrics: 0.81 for one-layer; 0.78 for multi-layer and 0.79 for combined.

Comparison developed equipment with existing allowed to establish their economic efficiency. It is determined that economic effect of using developed equipment is 35.4%.

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