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THE INDUSTRIAL SIGNIFICANCE OF NEW TECHNOLOGY IN THE PROCESS OF ASYMMETRICAL VENEERING OF WOOD-BASED COMPOSITES

Empirical research was carried out to determine the significance of new technology in the process of asymmetrical veneering of wood-based panels applied in the furniture industry. The study was conducted in two stages. The first of them comprised a questionnaire survey conducted among 80 medium and large Polish furniture enterprises. The second stage involved individual in-depth interviews. Twelve representatives from the furniture industry took part in qualitative research (CEOs, owners, technologists) along with nine experts representing research and development units connected with the furniture industry. On the basis of the research, the frequency of emergence of factors influencing the process of asymmetrical veneering of wood-based panels was determined. In addition, in-depth analyses were carried out involving the application of a subjective score-based evaluation of the problems of implementing this technology in the production process. This evaluation made it possible to identify problems from the point of view of a company currently conducting the process of veneering wood-based panels, or planning to implement this process. It may have an immediate effect in improving technological operations, while at the same time increasing the quality of the products sold.

Keywords: new technology, wood-based composites, veneering process, furniture industry, in-depth interviews

Introduction

As Hilletoft and Eriksson [2011] suggest, the value advantage, price, technological sophistication, and innovativeness of a product are common characteristics that affect the product's success. Many studies have demonstrated that customer-oriented products have the best chance of succeeding [Dickson 1974; Levitt 1980; Harmancioglu et al. 2009; Kotler and Armstrong 2010; Grzegorzewska and Stasiak-Betlejewska 2014]. With products based on

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renewable natural resources from forests, the furniture sector is well-placed to provide products that enhance long-term environmental, economic and social sustainability [Daian and Ozarska 2009]. Sustainability in the furniture industry is heavily dependent on the selection of materials for sustainable product design [Papadopoulos et al. 2014]. The need for innovation and creativity in forest products is a necessity for a sustainable worldwide forest products industry [Ratnasingam et al. 2013]. Furniture manufacturers are currently paying special attention to environmental and innovative concerns in order to differentiate their products from those of competitors, and also to enter the emerging markets for green products [González-García et al. 2012]. Within the furniture industry, this strategic choice is related to the development of eco-furniture [Papadopoulos et al. 2014].

Most existing research shows a forest products industry that is focused on process innovation [Hovgaard and Hansen 2004; Hansen 2010; Cicala et al. 2013; Grzegorzewska and Więckowska 2016b]. A growing number of new technologies are becoming available within the wood-processing industry that can improve the quality of wood products, reduce costs, and enhance working conditions [Çaushi and Marku 2014]. As Daian and Ozarska [2009] indicate, wood is the most abundant biodegradable and renewable material available, hence there are still numerous reasons to maximise its utilisation. The objective of the present study was to investigate furniture manufacturers' perceptions about the use of new eco-technology in the asymmetrical veneering process. This area has not been previously explored, and the selected research methods have not been applied in this context to date.

Literature background

Forests, and wood as a material in general, play an important role within the context of ecology, because they have the potential to offer green alternatives to unsustainable developments, and represent one of the few natural renewable resources [Daian and Ozarska 2009]. Today, consumer demand for high-quality furniture [Çaushi and Marku 2014] and customer awareness of ecological changes [Daian and Ozarska 2009] are leading to technological improvements. Many furniture consumers are price-sensitive, and distributors therefore focus on low-cost production. However, there is demand for furniture in all price ranges, as several researchers have indicated [Sun and Hammett 1999; Hilletofth and Eriksson 2011]. Wood, when compared with other raw materials used in furniture-making, exhibits several superior attributes, such as reliability and the fact that it is not only environmentally friendly, but also attractive in appearance and highly valued [Pakarinen 1999]. Eco-furniture, as the outcome of implementing green strategies, may represent an important competitive advantage for furniture firms [Papadopoulos et al. 2014]. The consumer perception that wood is attractive and fashionable provides a combination of

attributes that is difficult for substitutes to achieve [Çaushi and Marku 2014]. For Polish customers, wood is preferred to non-wood materials principally because of its ecological properties, environmental appropriateness, renewability and naturalness, as well as its tradition and its good health and safety properties [Paluš et al. 2012]. Nevertheless, in addition to the threat of substitutes, the shortening of product life-cycles imposes many requirements on the designer and others involved in the product development process [Pakarinen 1999; Cao and Hansen 2006; Roosa et al. 2014]. The product life cycle in the furniture industry is not related to the innovativeness of the product. There are products, colours and materials that go in and out of fashion, but these are the same for all price segments [Hilletoft and Eriksson 2011].

Veneer is among the most highly regarded wood products. Veneer represents the highest added value for the material, and is often used as a surface coating because of its decorative appearance [Buchelt and Wagenführ 2008; Blomqvist et al. 2013]. Veneer is a thin sheet of wood, generally within the thickness range from 0.3 to 6.3 mm (0.01 to 0.25 in.), used in a laminate [Gooch 2011]. In mechanical terms, veneer is a very thin plane coating material and behaves like a plate. Because of this, and given the known limits of stress due to excessive tensile stress or strain, there are additional problems with stability. Generally, the strong anisotropic behaviour of wood complicates its use in the coating process [Wagenführ et al. 2006], especially when using the asymmetrical veneering technique. For the coating of particleboard or fibreboard surfaces, symmetrical and asymmetrical lamination techniques are used [Bulian and Graystone 2009]. The second of these methods depends on covering wood-based panel surfaces with valuable veneer (for example mahogany, ebony, wenge) on the exposed side, and with veneer made from inexpensive species such as poplar, pine, alder, etc. on the unexposed side. This method is environmentally friendly and may help reduce consumption of endangered species in furniture-making. Nevertheless, coating the surfaces of wood-based boards in this way, as mentioned above, leads to some problems of a technological nature. Therefore, it is the subject of simultaneous ongoing research projects [Oleńska et al. 2011; Oleńska et al. 2014a; Oleńska et al. 2014b]. The behaviour of veneer strictly as a coating material is not discussed in the present article. The aim of this study is to determine how Polish furniture manufacturers perceive asymmetrically veneered wood-based boards as a furniture material, and to determine the main types of technological risk associated with their production.

Çaushi and Marku [2014] indicate that employees are much more likely to accept and adapt to a new process when it forms part of planning and implementation procedures. Studies are currently being conducted on innovative eco-glue and the method of asymmetrically veneering wood-based boards with two different species of wood. For these reasons, in the present research, Polish furniture manufacturers were asked, for example, about the most important determinants of the implementation of the method at their companies, or to

indicate the most urgent issues requiring improvement in the process. Even the best technology system is useless if end users fail to adapt their work processes to include it [Çaushi and Marku 2014]; therefore the need for a better understanding of furniture manufacturers' preferences is an essential part of the success of technological projects [Grzegorzewska and Więckowska 2016a]. On the other hand, Potter [1989] suggests that product innovation should lower customers' costs and help them make financial savings. Reguia [2014] claims that this is regarded as a basic element in achieving customer satisfaction and realising customers' wishes. For these reasons, both the manufacturers' and the customers' points of view were taken into consideration in this study.

Materials and methods

The primary goal of the research was to determine the significance of new technology in the process of asymmetrical veneering of wood-based panels applied in the furniture industry. The first stage comprised a questionnaire survey carried out among 80 medium and large Polish furniture enterprises. The analyses were conducted between September and October 2015. At that time, there were 462 companies in the Polish wood market with 50 or more employees. It follows that the study covered 17% of that population. At this stage, the applied research tool was a survey questionnaire comprising 31 questions divided into four parts:

- I – information on the enterprise;
- II – the development and innovativeness of the enterprise;
- III – the technology used for processing of wood-based panels;
- IV – information on the respondent.

The second stage comprised qualitative research aimed at gathering expert opinions on the subject of chosen aspects of asymmetrical veneering of wood-based panels applied in the furniture industry. The research was conducted in December 2015 and January 2016. The technique used here was individual in-depth interviewing. The interviewees were 12 representatives of the furniture industry (CEOs, owners and technologists) and nine experts representing research and development units carrying out work related to furniture. The quantitative research resulted in 42 stenographic records.

An important aspect of the empirical research was the acquisition of opinions from furniture producers about current problems occurring in the technological process of veneering wood-based panels, namely problems that are directly connected with or may be a product of this process. In this regard, the frequency of occurrence of certain factors influencing the success or failure of the process was also analysed. Additional in-depth analysis involved the application of a subjective score-based evaluation of the problems of implementing asymmetrical veneering of wood-based panels in the production process. For this purpose, a procedure was used to calculate the weighted value

of an object. This is a research procedure that consists in quality analyses of objects in terms of their designated use or functionality. The stages of this procedure are as follows [Stabryła 2011]:

1. Development of the template for an assessment of the object;
2. Selection of aspects of preferences;
3. Determination of weightings of assessment criteria;
4. Scoring and final classification of the object.

In the last of the above stages, the object is scored based on the degree to which it meets the specified requirements, e.g. standards, functionality and level of quality. The object is then classified according to its weighted value. This is expressed by the following formula [Stabryła 2011]:

$$V_{ij} = w_j \cdot q_{ij}$$

where V_{ij} is the weighted value of object i according to the j th assessment criterion, w_j is the weight of the j th assessment criterion, q_{ij} is the score of object i according to the j th assessment criterion, $i = 1, \dots, m$ denotes objects, and $j = 1, \dots, n$ denotes the assessment criteria.

The aggregate weighted value A_i is calculated from the formula:

$$A_i = \sum_{j=1}^n V_{ij}$$

The aim of the research was to evaluate the problem from the point of view of particular companies currently conducting the process of veneering wood-based panels or planning its implementation. The respondents graded each of the 10 indicated factors that may contribute to the failure of the process with a score from 1 to 10. The higher the score, the more that factor will increase the negative impact (i.e. become a problem). Figures reported here are averages of all scores assigned by the respondents. Next, on the basis of the quantitative research, the identified technological problems were given weightings to reflect the significance of the factors potentially determining the failure of the undertaking. The weightings were determined on the basis of information gathered from furniture manufacturers and experts. The less frequent the emergence of the problems with the highest weightings, the greater the chances of success (indefectibility) of the conducted process.

Results and discussion

It was found that the process of veneering is applied by 25% of the researched enterprises. Of these, 75% use the technology of asymmetrical veneering of chipboards. The same percentage of companies apply the method of asymmetrical veneering in the case of MDF boards. In this process, the materials

most often used for processing chipboards and MDF boards are artificial veneer (paper, foil) as well as laminate.

Respondents were asked which factors have a decisive influence on the introduction into the production process of the technology of asymmetrical veneering of wood-based panels (respondents were asked to indicate the three most important factors). The most important determinant was considered to be customers' tastes (58.8% of respondents selected this option). Other important factors included the intended use or function of the piece of furniture (in certain types of furniture the technology of asymmetrical veneering may be more successful than in others), and current fashion. These were indicated respectively by 36.3% and 30.0% of respondents. The determinant of least significance when taking a decision on the implementation of asymmetrical veneering of wood-based panels was the price bracket of the furniture. Only 16.3% of those interviewed indicated this factor as important. In addition, 18.8% of respondents indicated the availability of certain technologies within the enterprise as a factor determining the implementation of asymmetrical veneering of wood-based panels (Fig. 1).

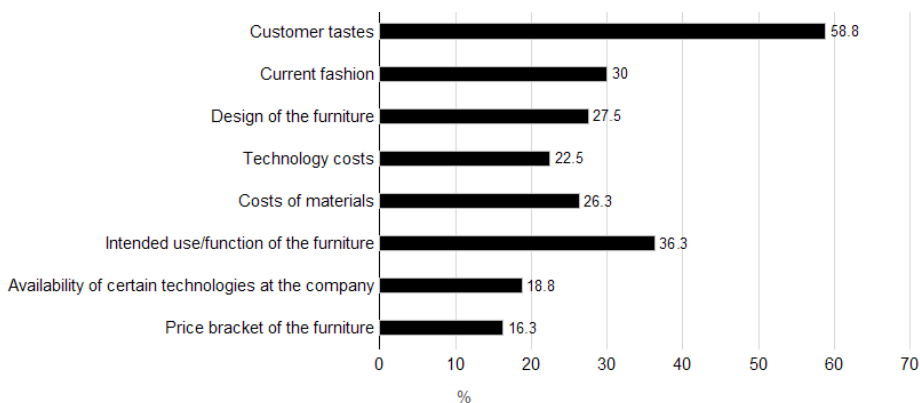


Fig. 1. Determinants of the implementation of asymmetrical veneering of wood-based panels [%]

Source: own study.

The implementation of a new technology requires, first of all, the identification of problems and technological barriers. Among the emerging production difficulties indicated by the respondents in connection with the process of veneering wood-based panels were the unsatisfactory adhesion of veneer to the wood-based panel, as well as problems with the choice of parameters of the veneering process (Table 1). Moreover, 10% of those interviewed indicated the issue of stresses deforming the elements. The following phenomena were also mentioned: low efficiency of glue (75%), glue lumps under the veneer layer (55%) and difficulties with applying the glue (45%). Among the problems occurring with low frequency in the process of

veneering wood-based panels, the following were indicated: difficulties with selecting the veneer set (85% responded 'rarely') and excessively long bonding time (85% 'rarely').

Table 1. Evaluation of frequency of emergence of particular factors in the process of asymmetrical veneering of wood-based panels [%]

Item	Factor	Frequency of emergence of factor [%]		
		rarely	often	very often
1	Presence of stresses deforming the elements	40	50	10
2	Lack of dimensional stability of elements	60	40	0
3	Unsatisfactory adhesion of veneer to wood-based panel	35	40	25
4	Glue lumps under the veneer layer	30	55	15
5	Difficulties with cleaning the glue-spreading installation	60	40	0
6	Difficulties with selecting veneering process parameters	40	35	25
7	Difficulties with applying the glue	55	45	0
8	Low efficiency	25	75	0
9	Difficulties with selecting the veneer set	85	15	0
10	Excessively long bonding time	85	15	0

Source: own study.

The results of the quantitative and qualitative research were used to make a score-based evaluation of the problems connected with implementing the asymmetrical veneering of wood-based panels in real production conditions (Table 2). In the questionnaire, respondents gave each of the 10 indicated factors a score from 1 to 10. The higher the score, the greater the degree to which the factor exerts a negative influence on (is a problem for) the process. The figures reported here are averages of the scores given by all respondents. Next, on the basis of the quantitative research, the factors were given weightings to reflect the significance of the factor in determining failure of the undertaking. The less frequent is the occurrence of the problems with the greatest weightings, the greater are the chances of success (indefectibility) of the process. The weightings were determined on the basis of information acquired from furniture producers and experts from research and development units in the course of the study (expert interviews and questionnaire).

Next, the weightings were multiplied by the corresponding evaluations, and the resulting values were summed to arrive at the aggregate subjective value of the problems connected with the process of veneering wood-based panels.

Table 2. Weighted evaluation of the emergence of certain problematic factors in the process of asymmetrical veneering of wood-based panels

Item	Factor	Weighting	Evaluation	Weighting × evaluation
1	Presence of stresses deforming the elements	0.12	5.6	0.7
2	Lack of dimensional stability of elements	0.06	4.6	0.3
3	Unsatisfactory adhesion of veneer to the wood-based panel	0.18	6.7	1.2
4	Glue lumps under the veneer layer	0.16	6.5	1.0
5	Difficulties with cleaning the glue-spreading installation	0.06	4.6	0.3
6	Difficulties with selecting the veneering process parameters	0.16	6.5	1.0
7	Difficulties with applying the glue	0.07	4.8	0.3
8	Low efficiency	0.11	5.8	0.6
9	Difficulties with selecting the veneer set	0.04	3.8	0.2
10	Excessively long bonding time	0.04	3.8	0.2
The aggregate weighting value is 1 (100%)		1	–	5.8

Source: own study.

In total, the problematic factors in the process of veneering wood-based panels received 5.8 out of the maximum of 10 points (the greater the value of the weighted evaluation, the greater the negative influence on the process). This is slightly more than average. The factor contributing most to this total is the unsatisfactory adhesion of veneer to the wood-based panel. This factor had the highest weighting (0.18), and respondents also scored it highly in terms of its influence on problems emerging in the analysed process (6.7 points). As a result, the weighted evaluation of this factor was the greatest among all of the factors, amounting to 1.2 points. Other factors that are a source of technological problems for manufacturers are glue lumps under the veneer layer (weighting 0.16, evaluation 6.5) and difficulties with selecting the veneering process parameters (weighting 0.16, evaluation 6.5). Both of these problems obtained the same weighted evaluation of 1.0. Difficulties with selecting the veneer set and excessively long bonding time were indicated as the least negative factors for the process of veneering (both had a weighting of 0.04 and an evaluation of 3.8).

Apart from indicating areas requiring improvement, the interviewees also indicated the actions that they have taken in their enterprises to improve the processing of wood-based panels with veneer (Fig. 2).

It was found that in the analysed enterprises, actions were introduced primarily with the aim of eliminating the technological problems that most influence the visual effect of the end product. Among them are stresses deforming the elements (47% of responses), and damage occurring in internal movement and transport of goods (about 41% of responses). The taking of such

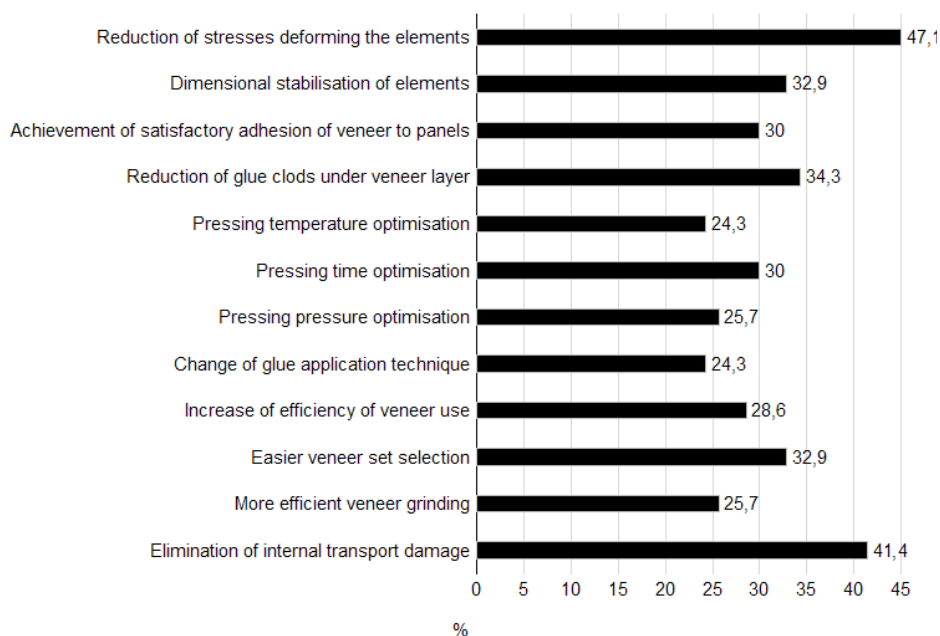


Fig. 2. Technological improvements introduced in the processing of wood-based panels with veneer by the researched enterprises [%]

Source: own study.

actions signifies that furniture producers are aware of the possibility, or even the necessity, of improving the process of veneering wood-based materials. On the other hand, 24% of responses referred to changes in the application of glue, and an average 27% referred to pressing parameters (time, temperature, pressure), indicating that knowledge regarding the possibilities of preventing the emergence of technological problems in this area is limited. It turns out that the suggested innovative solutions are still unavailable on the market.

Additionally, the respondents indicated technological operations which, in their opinion, remain problematic and require the immediate introduction of improvements (Fig. 3). These include the grinding of edges finished with the use of a natural wood edge band (44% of responses), lacquering of veneered elements (about 43%) and preparation of veneer sheets (about 41%).

However, among the most important and most needed innovations connected with the asymmetrical veneering of wood-based panels, as indicated by the respondents, were the application of new, fully environmentally friendly glue (about 53% of responses) and the introduction of new linings (43% of responses) (Fig. 4).

Every third respondent expressed an interest in the application of new veneering technology with regard to adjustment of the parameters of the production machinery. Aspects connected with shortening the glue bonding time and simplifying its application appear slightly less important.

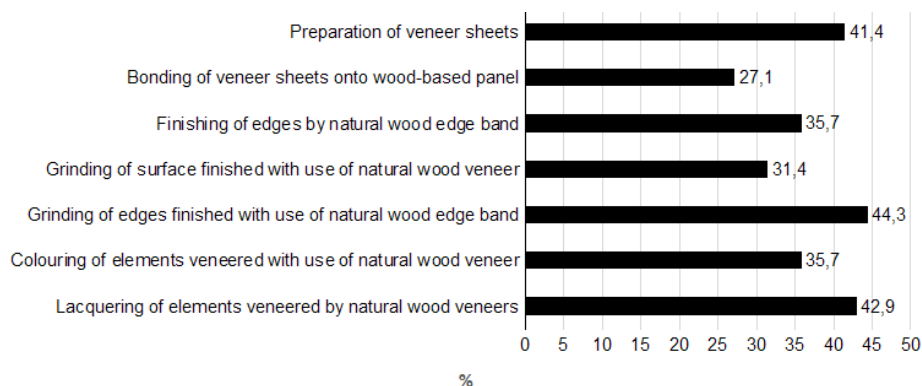


Fig. 3. Technological operations in processing wood-based panels with veneer that require immediate improvements in implementation [%]

Source: own study.

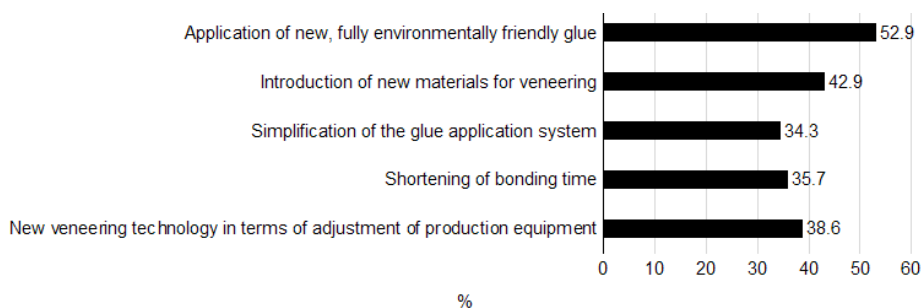


Fig. 4. Innovations in the processing of wood-based panels with veneer, regarded as necessary by respondents [%]

Source: own study.

Conclusions

The primary goal of the empirical research was to determine the significance of new technology in the process of asymmetrical veneering of wood-based panels applied in the furniture industry. The research was conducted in two stages. The first stage comprised a survey questionnaire conducted among 80 medium and large Polish furniture enterprises. The second part of the research involved individual in-depth interviews. Twelve representatives of the furniture industry took part in the qualitative research, as well as nine experts representing research and development units connected with the furniture industry.

Among the factors having a decisive influence on the implementation of technology of asymmetrical veneering of wood-based panels in the production process, the most frequently indicated was customers' tastes – selected by almost 60% of respondents. Other important factors were the intended use or function of the piece of furniture, and current fashion. Among the least important factors

when deciding on the introduction of asymmetrical veneering of wood-based panels were the price bracket of the furniture and the availability of certain technologies at the enterprise.

The qualitative research indicated that unsatisfactory adhesion of the veneer to the wood-based panel has the greatest negative influence on the process of asymmetrical veneering of wood-based panels. This factor received the highest weighted evaluation (1.2). Other factors that are a source of technological problems are glue lumps under the veneer layer (weighted evaluation 1.0) and difficulties with selecting the veneering process parameters (weighted evaluation 1.0). The factors with the least negative influence on the veneering process, according to respondents, were difficulties in selecting the veneer set and excessively long bonding time (both of these factors received a weighted evaluation of 0.2).

The surveyed companies indicated the actions that they have taken to improve the processing of wood-based panels with veneer: first of all, eliminating stresses deforming the elements (47% of responses) and preventing damage in the internal movement and transport of products (about 41% of responses). They also indicated technological operations that, in their opinion, remained problematic and required the introduction of improvements. These comprised: grinding of edges finished with the use of natural wood edge band (44% of responses), lacquering of elements with natural wood veneers (about 43%), and the preparation of veneer sheets (about 41%).

The research indicates that manufacturers of veneered furniture are interested in the introduction of innovative improvements in the processing of wood-based panels with veneer. Those which they would like to implement in their enterprises relate primarily to the application of new, fully environmentally friendly glue (about 53% of responses) and the introduction of new linings for the veneering process (43% of responses).

The research was conducted among medium and large furniture companies. Therefore, on the basis of the results obtained, there is limited possibility to make inferences about technological problems in micro and small furniture enterprises, which may have somewhat different production processes. In addition, only selected technological problems occurring in the implementation of the modern technology were analysed. Therefore, due to the great importance of the issues addressed for the productivity, profitability and competitiveness of Polish furniture enterprises, it is proposed that further research should be conducted in this area.

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