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Investigations on geometry of locally modified area in MDF boards by a non-destructive method

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Abstract: *Investigations on geometry of locally modified area in MDF boards by a non-destructive method.* The article presents the method of making observations and taking measurements of internal modified layers of MDFs using for this purpose x-rays. Thanks to the obtained images, it was possible to determine the area of the examined board subjected to local reinforcement using transparent PUR 555.6 preparation. Using the Autodesk Inventor program, which allows 3D graphic modelling, it was possible to obtain a solid reflecting the true modified area possible to measure. The performed experiments showed that the amount of the applied preparation has no impact on the propagation depth into the MDF. However, together with the increase of the applied preparation, the volume of the modified zone as well as the contact surface of the reinforced and unmodified layers changed in a linear manner.

Keywords: MDF, local modification, non-destructive, x-ray, polyurethane

INTRODUCTION

Dry-formatted medium density boards (MDFs), widely applied in furniture industry, are manufactured from wood fibres glued with synthetic a binding agent and subjected to the felting process during pressing. The obtained boards are characterised by uniform mechanical properties on their wide plane but the density and strength of individual three layers of the cross section vary. The internal layer, which has lower density and degree of gluing than the external layers, is also characterised by lower mechanical properties (Nicewicz 2003). The holding capabilities of construction fasteners mounted in the material depend, primarily, on mechanical properties of these layers. One of optimal methods of improving the strength of the entire board is its local strengthening by the application of a reinforcing agent.

Investigations involving strength improvement of chipboards and flaxboards were carried out in Poland since 1960s. The material used to achieve this goal included 20 and 30% solutions of glutin glue or urea-formaldehyde resin (Ławniczak and Paprzycki 1961). This treatment improved fixing capabilities of screws and equalised values for different directions of mounting; however, unfortunately, those agents were not resistant to changing humidity. Investigations carried out in 2008 and 2009 on the application of a polyurethane preparation PUR 555.6 to strengthen chipboards and MDFs characterised by improved resistance to air humidity and temperature exhibited over twofold increase of holding capability of fasteners mounted in both planes of these materials (Pohl et al., 2008; Wołpiuk and Pohl 2009).

Despite determination of the degree of local material reinforcement, the area that underwent modification, its shape and the distribution of the applied preparation inside the board remained unknown. The assessment of the geometry of the modified area can be achieved in two ways: using destructive or non-destructive methods.

The destructive method involves slicing the external layer of the board and measuring the depth of the application as well as determining the planimetry of the surface area of the modified place. The method, apart from destroying the element (sample), is also time- and labour-consuming as well as onerous in situations when it is not possible to apply markers staining colourless reinforcement preparations.

Non-invasive methods are more modern than the above mentioned technique and include: roentgen and isotope radiography as well as computer tomography. They allow penetration of the board inside structure of wood and wood-based materials without affecting their shape and structure. These methods are utilised in investigations of shape, density, moisture gradient, macro-, micro- and submicroscopic wood structure, presence of foreign bodies as well as the extent of wood degradation by fungi or insects. Non-invasive measurement methods employing roentgen radiation (X radiation) were used, among others, for: measurements of the density distribution of oriented strand boards (OSB) (Chen and Wellwood 2002), density distribution analysis on the plane of the chipboard, MGF, OSB and plywood (Siguo Chen et al., 2010) and the impact of density distribution of wood-derived materials on mounting of furniture hardware (Wang et al., 2007).

Analogue radiography remained a satisfactory diagnostic method for many years. However, in the era of computers, pressures were growing to obtain more accurate imaging results and data archivisation which was not possible using ordinary photographic plates. The traditional method depends on several factors such as: plates, development, imaging, archiving and, therefore, inaccurate results were common. That is why attempts were made to find a solution which would shorten, improve and optimise these processes. The initial step was made in 1980 when the first digital systems were introduced into radiography (computer radiography) in which IPI plate was the image carrier, a laser scanner was used to read the plate and, with the assistance of a special computer program, this data was transferred into an image. The next stage in the digital radiography was brought about by DDR systems (direct digital radiography) which eliminated two elements – the plate and scanner. In this system, the memory carrier is a TFT plate which is exposed and transfers images into computer in digital form. Another advantage of digital radiography includes professional processing of photographs in DICOM format. Using special computer software, it is possible to impose various filters onto the obtained image and, in this way, infiltrate into or expose some areas of the image.

Furthermore, with the assistance of software for modelling 3D graphics, it is possible to generate a three-dimensional solid body of the examined object which can then be described mathematically.

It was, therefore, decided to carry out an experiment in which a locally modified MDF was x-rayed to assess the shape of the reinforced area.

REREARCH OBJECTIVE

The objective of the experiment was to determine the zone of penetration of the reinforcing agent PUR 555.6 in a dry-formatted medium density board (MDF) with the assistance of an x-ray apparatus and to use the obtained x-ray images and software for 3D graphic modelling to develop 3D solids presenting modified zones.

RESEARCH METHODOLOGY

The experiment was conducted on samples made of 18 mm thick MD fibreboard manufactured in Żary Kronpol. Significant parameters affecting the research results were board moisture content and temperature of the surroundings. The moisture content of the examined MDF was 7.7% and the temperature of the room where the experiment was carried out - 20±2^{o}C. Sample dimensions were 50x50x18 mm. Holes 15 mm deep used for the application of the preparation were made using a bench drill and their diameter corresponded to the predrilling diameter (2.4 mm) of the plain part of a 4x40 mm conical screw.

The experimental material was modified using a Kleiberit Company preparation known under commercial name of PUR 555.6 nano which is a polyurethane agent intended for the of reinforcement of wood and wood-derived materials. Table 1 presents properties of the preparation given by the manufacturer.

Table 1. Properties of Kleiberit PUR 555.6 nano (www.klejstol.pl)

Basis		Single-component polyurethane pre-polymer, hardening under influence of moisture
Density		about 1.18 g/cm^3
Colour		Light yellow, transparent
Viscosity (20^{o}C)	Brookfield	about 12 mPa·s
	Ford cup, 2 mm	about 75s
Consistence		of low viscosity
Smell		specific, mild
Solid bodies		100%

The amount of the preparation used for reinforcement was established on the basis of the coil thread volume calculated as the difference between the cylinder volume of the external diameter of the thread and the cylinder of the plain part of the thread of a conical screw, which is further on referred to as an application unit (0.12 cm^3), for the 4x40 mm screw mounted at 15 mm. Seven variants of modification were used injecting from 1 to 7 application units into the narrow and wide plane of the board. The procedure was carried out manually using an ordinary medical syringe of 1 cm^3 capacity with 0.01 cm^3 accuracy. After injection, samples were left for 72 hours to allow polymerisation of the applied preparation.

X-rays of the modified MDFs were performed using a digital Shimadzu model ZUD-L40DS x-ray apparatus. Operational parameters of the apparatus were established experimentally with the aim to obtain images as clear as possible. It was found that MDF images were the sharpest at the lamp voltage of 40 kV, lamp current intensity of 4.85 mA and time exposure of 50 ms. The distance of the lamp from the detector was 80 cm. Samples for x-ray were placed directly on the TFT detector plate to eliminate scatter of the beam going through the examined object. Samples reinforced by PUR 555.6 nano preparation were x-rayed in two planes. Following the x-raying, images of MDFs in DICOM format were obtained which were stored in computer memory.

The obtained files in DICOM format were reformatted into JPEG format maintaining the highest picture quality (without compression) so that they could be utilised in AutoCad program. Next, the images were subjected to precise re-scaling and zones with the reinforcement agent, which were characterised by a significantly brighter colour in comparison with the remaining MDF layers, were identified. The delineated areas were then exported to the Autodesk Inventor program in which a 3D solid was modelled showing the volume of the reinforced zone. The applied program made it possible to determine in the obtained solid its height (depth of the agent propagation), the contact surface area of the non-strengthened layer with the modified layer and the solid volume.

RESEARCH RESULTS

Images obtained in the course of the experiment are presented in Figures 1-3. Images in Figs. 1a-1d show the positions of samples on the detection plate, with Figs. 1a and 1b showing MDF modification across its wide and Figs. 1c and 1d – across its marrow planes.

The x-ray images in Figs. 2a-2d clearly show areas with the reinforcing agent. Pictures from Figs. 3a-3d present 3D images obtained from the Autodesk Inventor program. The solid from Fig. 3a represents the modified area from the wide plane of the MDF treated with a single PUR 555.6 applications unit, while the solid from Fig. 3b – with 7 application units. Modified solids from Figs. 3c and 3d represent MDF samples treated with the same amounts of PUR units but viewed in the narrow plane.

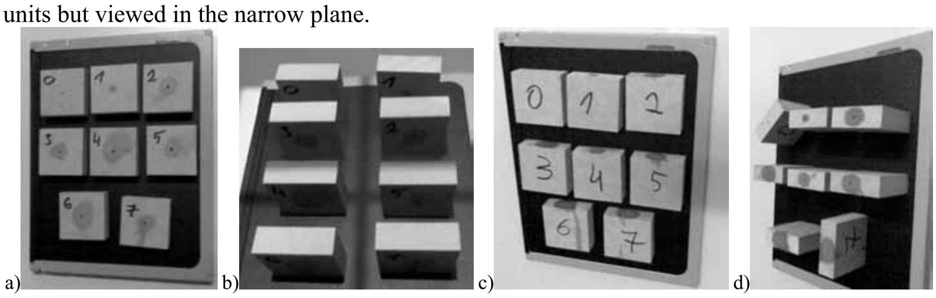

Fig. 1. View of samples arranged on the TFT detector plate; a), b) modification on the wide plane; c), d) modification on the narrow plane.

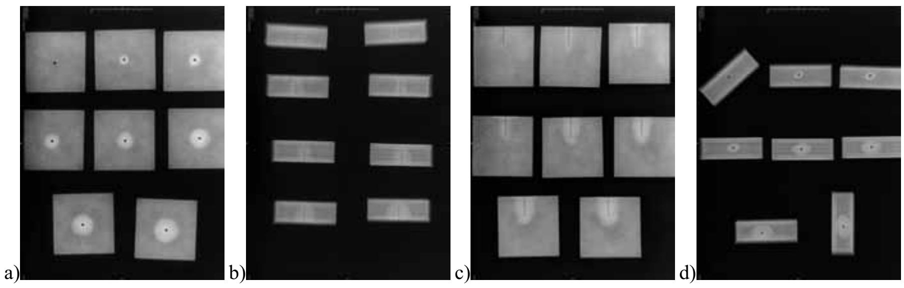

Fig. 2. View of x-ray images of MDF samples with local structure modification; a), b) modification on the wide plane; c), d) modification on the narrow plane.

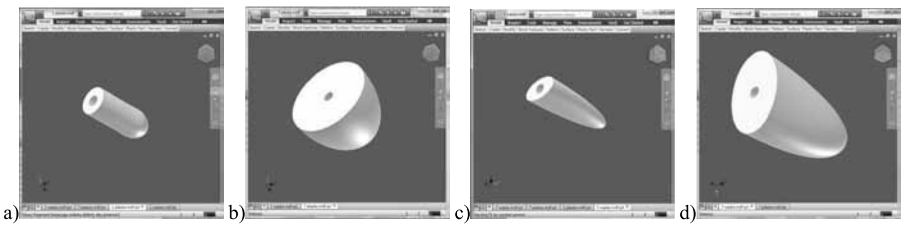

Fig. 3. Images of solids obtained from the Autodesk Inventor program; a), b) modification zones in the wide plane; c), d) modification zones in the narrow plane; a), c) one application unit; b), d) seven application units.

Figures presented below show results obtained from measurements taken in the Autodesk Inventor program. Figure 4 presents the penetration depth of the PUR 555.6 reinforcement agent into the experimental MDF depending on the injected number of the application units. The penetration depth was determined from the board edge to the most distant layer of the modified material along the leading hole. The volume of the modified area in the function of the number of application units is shown in Fig. 5, while Fig. 6 shows the contact surface area of modified and non-modified layers of MDF.

Examination of the depth of the preparaton od the reinforcing agent PUR 555,6 revealed lack of correlatin with the numer of aplication units. The preparation penetrated a litle beneath the lead hole, although it propagated into side layers of MDFs forming eliptical shapes.

A distinct dependence is apparent in Figures 5 and 6 of the volume of the modified zone and the area of the adjacent layers of the material on the quantity of the injected reinforcing preparation as evident in the uniform distribution of the PUR 555.6 reinforcement agent in the internal board layer. Thanks to such investigations, it is possible to predict what quantity of the preparation is required to modify a definite MDF volume.

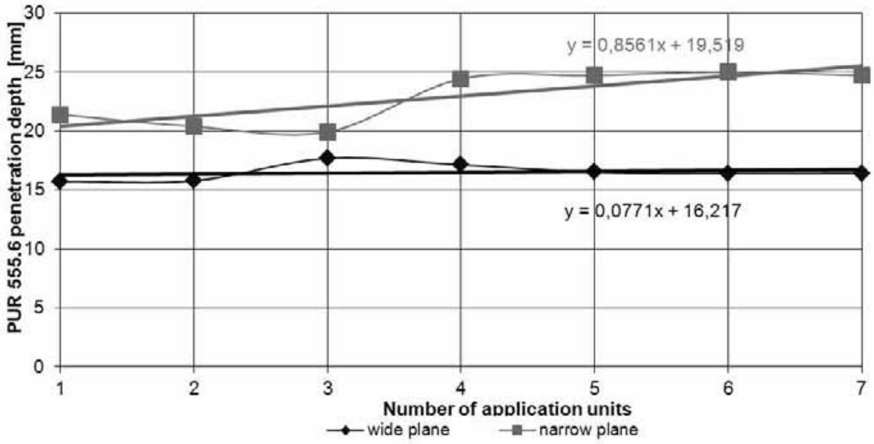

Fig. 4. Depth of the penetration area of the reinforcing agent in MDF.

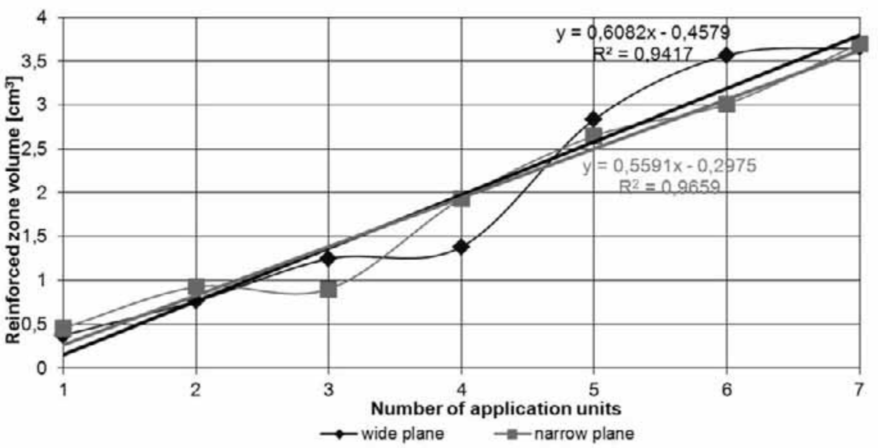

Fig. 5. Volume of the modified area in relation to the number of application units

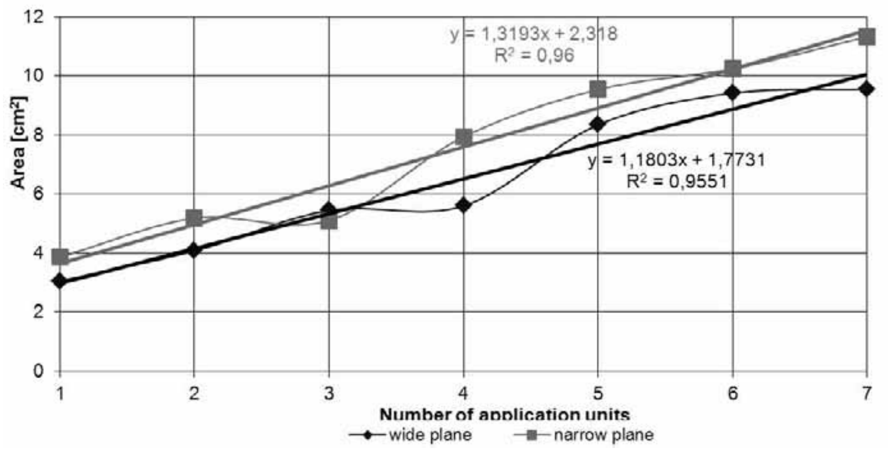

Fig. 6. Contact surface area of modified and non-modified layers of MDF.

CONCLUSIONS

- Examination of the MDF modified with the PUR 555.6 reinforcement agent using x-rays revealed invisible modified structure.
- The volume of the modified zone closely depended on the amount of the applied preparation.
- The amount of the applied preparation exerted a slight impact on the penetration depth in the examined MDF.
- The surface area of the internal modified layer was proportional to the number of application units and this correlation was of linear nature.

LITERATURE

1. Chen S., Liu X., Fang L., Wellwood R., (2010): "Digital X-ray analysis of density distribution characteristics of wood-based panels", Wood Sci Technol 44:85–93
2. Chen S., Wellwood R., (2002): „Nondestructive evaluation of oriented strand board. In: Proceedings of the 13th international symposium on nondestructive testing of wood", University of California, Berkeley, California, USA, August 19–21
3. Ławniczak M., Paprzycki O., (1961): „Możliwości zwiększania zdolności utrzymywania wkrętów przez płyty wiórowe i paździerzowe", Przemysł Drzewny nr 6.
4. Nicewicz D., (2003): „Płyty pilśniowe MDF", SGGW Warsaw.
5. Pohl P., Radzikowski K., Wołpiuk M., (2008): "Investigations on the local reinforcement of chipboards in the place of anchoring screw fasteners" Annals of Warsaw University of Life Sciences – SGGW, Forestry and Wood Technology No 64, 180-184
6. Wang X., Salenikovich A., Mohammad M., (2007): „Localized density effects on fastener holding capacities in woodbased panels", Forest Prod J 57(1/2):103–109
7. Wołpiuk M., Pohl P., (2009): "Investigations on the effect of a polyurethane preparation on the holding capacity of screw connectors mounted in a dry-formed MDF board", Annals of Warsaw University of Life Sciences – SGGW, Forestry and Wood Technology No 69, 450-455
8. http://www.klejstol.pl (2010)

Streszczenie: *Badania geometrii miejscowo zmodyfikowanej strefy w płycie MDF metodą nieniszczącą.* W pracy przedstawiono sposób dokonywania obserwacji i pomiarów wewnętrznych zmodyfikowanych warstw płyty MDF przy pomocy prześwietlenia promieniami Roentgena. Dzięki otrzymanym obrazom określono obszar płyty poddany miejscowemu wzmacnianiu przezroczystym preparatem PUR 555,6. W programie Inventor umożliwiającym modelowanie grafiki 3D otrzymano bryły odzwierciedlające rzeczywisty obszar zmodyfikowany, który można było pomierzyć. Badania wykazały, że ilość aplikowanego preparatu nie ma wpływu na głębokość propagacji substancji w głąb płyty MDF, natomiast w sposób liniowy wraz ze wzrostem ilości aplikowanego preparatu zmienia się objętość strefy modyfikowanej oraz powierzchnia styku warstwy wzmacnianej i niewzmacnianej.

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