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Efficacy comparison of two methods for determining the position of the rebate edge (formed after MDF machining) during automatic monitoring of workpiece delamination

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Abstract: *Efficacy comparison of two methods for determining the position of the rebate edge (formed after machining) during automatic monitoring of workpiece delamination*. Delamination is one of the most common defects in the processing of wood-based materials. It has a massive impact on the quality of the final product. In order to determine the delamination indicators simply and reliably, the automatic image processing method can be used (Śmietańska et al., 2020). Bator and Śmietańska (2019) proposed a special algorithm to estimate the straight line representing a milling edge. However, this algorithm is quite complicated. The aim of this article is to check whether the aforementioned (complicated) algorithmic way can be replaced by a much simpler idea – the precise manual positioning of the scanned sample on a scanner (using a very simple device installed on the scanner). Special experimental research was carried out to compare the effectiveness of the two different methods. The straight line representing the rebate edge identified by the Bator and Śmietańska (2019) algorithm was usually accurate to 1 pixel (0.02 mm). Based on the assumption that the scanned samples were perfectly positioned on the scanner, the analogue line only sometimes fit just as well. At worst, the distance between these lines is 0.2 mm. Usually, the distance did not exceed 0.16 mm but it was significant and quite random. There was no statistically significant correlation between this parameter (D_{max}) and tool condition (VB). It means that the samples were not perfectly positioned. They were placed, more or less, in the same position because of the imperfect stiffness of the frame installed on the scanner and human errors.

Keywords: delamination, MDF, milling, automatic quality monitoring, image processing

INTRODUCTION

Delamination is one of the most common defects in the processing of wood-based materials, including laminated MDF boards. Delamination is a phenomenon consisting of the loss of cohesion of individual layers of the material (e.g., laminate). The common cause can be cutting forces generated during machining. Delamination has a huge impact on the quality of the final product.

Delamination can be unambiguously (quantitatively) defined by the value of the delamination factor, which may take into account the width, diameter or area of the delamination zone (Romoli et al., 2008; Tsao et al., 2012). A delamination factor can be calculated, for example, by using the area of the delaminated zone on the elementary section – length of the cut (Szwajka et al., 2017), determining the average number of chips in 25 mm sections (Lemaster, 2000) or using the maximum width of damage zone (Praveen, 2013; Sreenivasulu, 2013).

The condition of the workpiece edge is one of the most important criteria for assessing product quality (Palanikumar et al., 2009; Śmietańska et al., 2020). Even a small surface defect can lead to the classification of the element as defective, reject it and thus increase the production cost. In order to determine the delamination indicators simply and reliably, the automatic image processing method can be used (Śmietańska et al., 2020). A system based on this method, built of relatively easily accessible elements, would allow quality defects of the finished products to be automatically detected and/or support the production process to achieve a high level of repeatability and quality. Automatic quality monitoring allows for more effective use of materials, machines and human labor, and guarantees high production quality. Consequently, the safety, reliability and profitability of products increases.

According to Bator and Śmietańska (2019), as well as Śmietańska et al. (2020), for the precise measurement of the value of the delamination coefficient of a laminated MDF board of an image analysis method, it is necessary to:

- scan a sample;
- take adequate sub images (presenting one rebate edge);
- classify pixels into pixels inside or outside the delamination zone for each sub image;
- compute an expected (theoretic) borderline between them;
- localize of a line representing an edge of cutting;
- calculate geometric integral as the area of delamination.

The most difficult and important step of the procedure is determining the position of the edge of the workpiece in an extremely precise manner. Bator and Śmietańska (2019) proposed a special algorithm to estimate the straight line representing a milling edge. However, this algorithm is quite complicated. The main problem is a subtle difference between pixels in a milled groove area and those in a delaminated area. The second difficulty is that, even in cases when the delamination is clearly visible, the line could be deformed.

This article aims to check whether the aforementioned (complicated) algorithmic way can be replaced by a much simpler idea – the precise manual positioning of the scanned sample on a scanner (using a very simple device installed on the scanner). Special experimental research was carried out to answer this question.

MATERIAL AND METHODS

The workpieces were rebated using a machining centre CNC and knife-cutter head with a diameter of 40 mm with exchangeable carbide knives. The workpieces were elements measuring 240 mm x 190 mm made of 16mm-thick laminated MDF board. During the experiment, a rebate 12 mm deep and 30 mm wide was milled (Fig. 1). The cutting parameters were as follows: spindle speed – 10 000 rpm; feed rate – 2 m/min. During the experiment, the tool was gradually worn to reflect normal exploitation in real industrial conditions (i.e., during the machining of various wood-based materials). This exploitation was interrupted at some intervals to measure the flank wear (VB). A standard workshop microscope (Mitutoyo TM-500) was used for this purpose. The samples made of laminated MDF were rebated with ten different tool wear states (VB = 0 mm; 0.07 mm; 0.10 mm; 0.14 mm; 0.21 mm; 0.23 mm; 0.24 mm; 0.31 mm; 0.33 mm; 0.34 mm). Generally, the series of 50 experimental workpieces were rebated (five pieces for the same tool wear state).

Next, all of the workpieces were scanned at 1 200 dpi by means of a standard office scanner. The special device (simple frame) was developed and installed on the scanner to enable quick and relatively precise manual positioning of the scanned sample. Theoretically, the rebate edge of each sample should be at the same location on the scanner. This fact enables immediate localization of the rebate edge – always in the same place – on the bitmap (without analyzing the pixels). It turned out that (assuming the frame for setting the workpiece works absolutely reliably) the distance between the milling edge and the up edge of the bitmap should be 116 pixels. Both edges should be parallel, of course. Finally, all scans were analyzed. In this way, the efficacy of the most straightforward method for automatically determining the position of the rebate edge was tested and compared with the efficacy of the algorithm proposed by Bator and Śmietańska (2019).

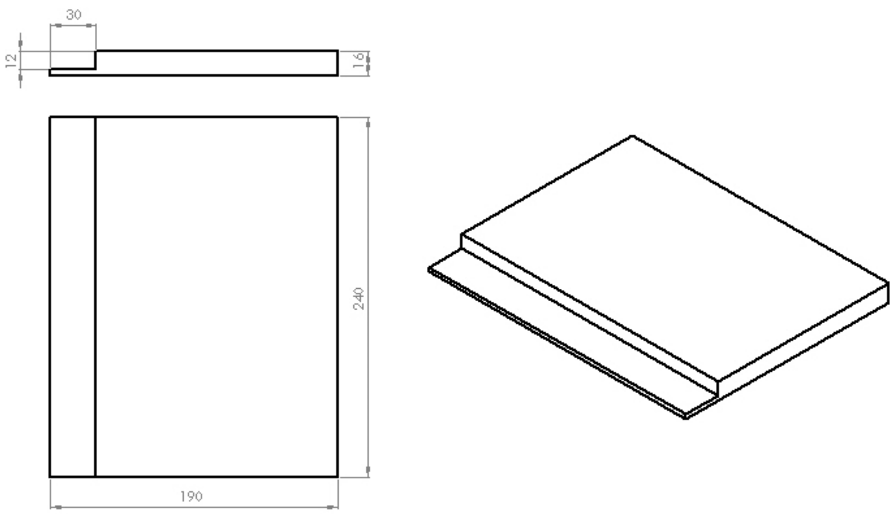

Figure 1. The final shape of the rebated workpiece.

RESULTS

In order to compare the effectiveness of the two different methods, three lines were automatically drawn on each scan (Fig. 2a, b):

1. Line A - a straight line which represents the rebate edge identified by the Bator and Śmietańska (2019) algorithm;
2. Line B - straight line located 116 pixels away from the up edge of the photo;
3. Line C - polyline, which represents the border of the delamination zone.

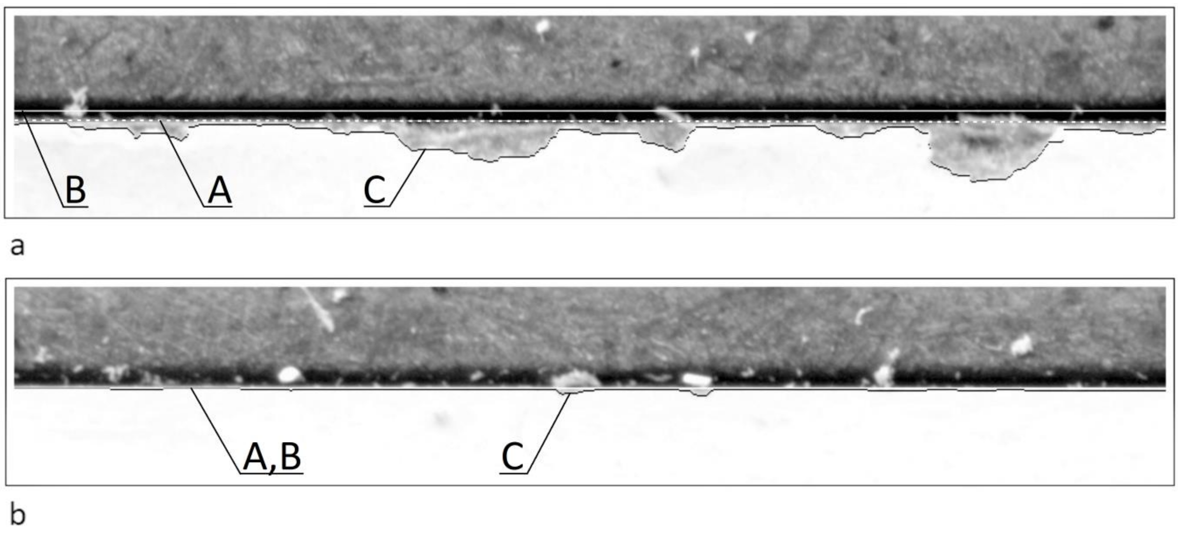

Figure 2. Examples of images analyzed to compare the effectiveness of the two different methods for automatically determining the position of the rebate edge. More detailed description in the text.

It turned out that Line A was usually accurate to 1 pixel. Sometimes Lines A and B coincided with each other (Fig. 2b), but – usually – they were non-parallel and spaced lines (Fig. 2a). The maximum distance (D_{max}) between these lines were determined for all scans. The effect of tool wear (VB) on the distance between Lines A and B (D_{max}) is shown in Figure 3. There was no statistically significant correlation between VB and D_{max}. It turned out that there was a notable and completely random distance between both compared lines – sometimes the distance was 0.2 mm (unfortunately). Most often, D_{max} did not exceed

0.16 mm, but it was too big anyway. Probably the most important reasons for this significant unconformity were the imperfect stiffness of the frame installed on the scanner and human errors.

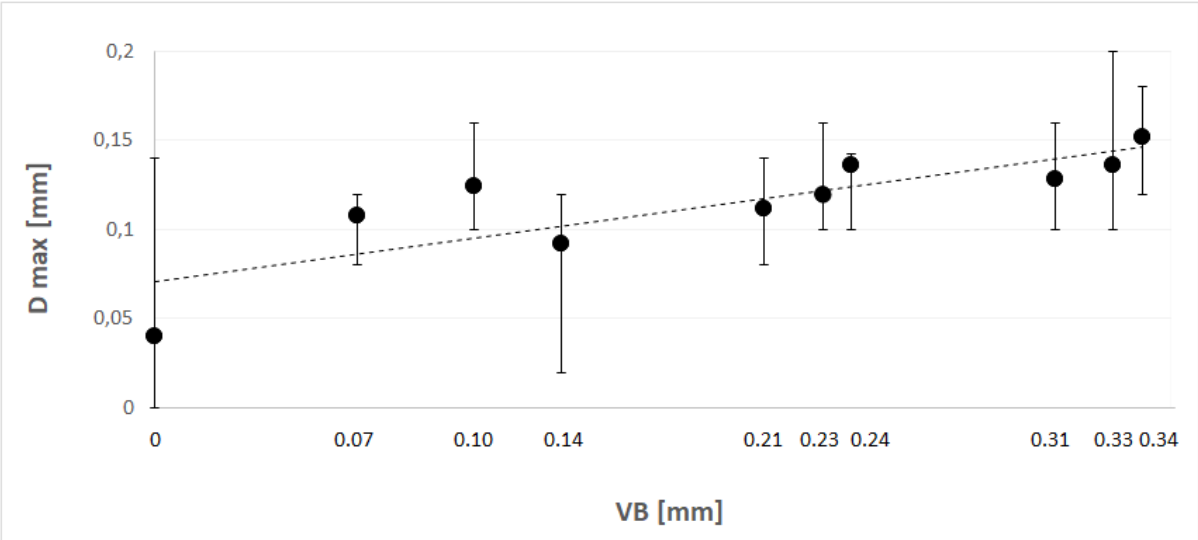

Figure 3. The effect of tool wear (VB) on the maximum distance between Lines A and B (D_{max}). More detailed description in the text.

CONCLUSIONS

The straight line representing the rebate edge identified by the Bator and Śmietańska (2019) algorithm was usually accurate to 1 pixel. Based on the assumption that the scanned samples were perfectly positioned on the scanner, the analogue line only sometimes fit just as well. At worst, the distance between these lines is 0.2 mm. Usually, the distance did not exceed 0.16 mm but it was significant and quite random. There was no statistically significant correlation between this parameter (D_{max}) and tool condition (VB). It means that the samples were not perfectly positioned. They were placed more or less in the same position because of the imperfect stiffness of the frame installed on the scanner and human errors.

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Streszczenie: *Porównanie efektywności dwóch metod wyznaczania położenia krawędzi wręgu (powstałego po frezowaniu MDF) podczas automatycznej oceny delaminacji przedmiotu obrabianego.* Delaminacja jest jedną z najczęściej występujących wad powstałych w wyniku obróbki skrawaniem materiałów drewnopochodnych. Stan krawędzi jest niezwykle ważnym kryterium oceny jakości wyrobu finalnego. W celu prostego i rzetelnego określenia wskaźnika delaminacji doskonałym rozwiązaniem wydaje się zastosowanie metody automatycznego przetwarzania obrazu (Śmietańska i in. 2020). Bator i Śmietańska (2019) zaproponowali specjalny, jednak dość skomplikowany, algorytm pozwalający na estymację prostej reprezentującej krawędź wręgu powstałego w procesie frezowania.
Celem artykułu jest sprawdzenie, czy powyższą metodę (z zastosowaniem algorytmu) można zastąpić znacznie prostszym rozwiązaniem - precyzyjnym ręcznym pozycjonowaniem skanowanej próbki na skanerze (przy pomocy specjalnego nieskomplikowanego przyrządu). Aby porównać skuteczność dwóch metody przeprowadzono badania eksperymentalne. Linia prosta reprezentująca krawędź wręgu oszacowana z zastosowaniem algorytmu Batora i Śmietańskiej (2019) osiągała przeważnie dokładność 1 piksela (0,02 mm). W przypadku linii analogowej opartej na założeniu, że zeskanowane próbki były idealnie umiejscowione na skanerze zaobserwowano znacznie mniejszą dokładność. W najgorszym przypadku różnica pomiędzy liniami wynosiła 0,2 mm (zwykle nie przekraczała 0,16 mm). Nie zaobserwowano także istotnej statystycznie korelacji między parametrem Dmax, a stopniem zużycia narzędzia VB. Ręczna metoda okazała się zdecydowanie mniej precyzyjna. Za przyczynę tego można uznać niewystarczającą sztywność przyrządu do pozycjonowania próbki na skanerze oraz błędy ludzkie.

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