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Investigations on the execution accuracy of floor boards

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Abstract: *Investigations on the execution accuracy of floor boards.* Experiments were carried out with the aim to determine execution accuracy of width and thickness dimensions of floor boards in industrial conditions. The obtained research results were evaluated with the assistance of the STATISTICA computer software in which process quality capability indices were calculated and Shewhart $\bar{x}-s$ control charts were prepared.

Keywords: floor boards, quality capability, control charts

INTRODUCTION

Floor boards constitute one of the elements of the architectural internal equipment and are considered to be one of the types of flooring which have been an important element of building engineering for many centuries.

One of the more important elements of processing accuracy is dimensional exactness. It is impossible to manufacture a series of elements of ideal exactitude. The shape, dimension and surface geometrical structure of a processed element should correspond to the element specified on the working drawing (Zakrzewski et al. 2004).

Dimensional accuracy is one of the major factors affecting the quality evaluation of a given object. In order for the dimension of a manufactured element to be considered as acceptable, its value must be contained within a tolerance interval. Assuming that the tolerance interval is a variability proceeding in accordance with normal distribution enforced by standards, the centre of tolerance, which need not always be consistent with the nominal dimension, should be considered as the mean dimension. This consistence occurs only in the case of symmetrical tolerance (Zakrzewski & Staniszewska 2002). The main parameters of the normal distribution include: arithmetic mean and average deviation. As a result of action of various systematic and random factors affecting these processes, they undergo changes which affect the level of quality. The basis of the quality control execution is maintenance during the production process of the variability of these parameters within boundaries which will guarantee the assumed level of quality with a satisfactory margin of probability (Marek et al. 1997).

At the present time, automatic quality control in wood industry frequently cannot be ensured due to lack of modern woodworking machines characterised by high accuracy (Lisičan et al. 2001). In such situation, it is only possible to control the process which makes it possible only to conclude if and at what level acceptable dimensional variability and stability are fulfilled. For a production engineer, what is important is the knowledge of how to maintain dimensional accuracy by woodworking machines employed in the process in accordance with the requirements established for products. The method of control of the maintenance of the dimensional accuracy is appropriate also to examine other quality traits. Therefore, in the literature on the subject (Czyżewski 1993, PN-ISO3534-2), a general term "process quality capability" has been accepted. However, apart from the process quality capability, its stability is equally important which means that it guarantees concentration of its values symmetrically in relation to the centre of the field of tolerance and, in such a way, that the variability interval of the controlled dimension value does not exceed boundaries of the acceptable variability determined for it. The main objective of the application of Shewhart control charts is the achievement of such process condition (Matuszewski & Šatanowá 1997, Iwasiewicz 1999).

This study focuses on the problem of the statistical execution accuracy of floor boards manufactured in the Witar Tartak Tyble Ltd. When assembling floors, it is particularly important to ensure appropriate width and thickness dimensions of elements. According to PN-EN 13990, the tolerance of these dimensions amounts to: T=3 mm for width and T=2 mm for thickness.

The objective of this study was to examine the width and thickness execution accuracy of floor boards conducted in industrial conditions. It comprised determination of quality capability and process alignment as well as evaluation of the dimensional stability of manufactured elements using for this purpose $\bar{x}-s$ control charts.

METHODOLOGICAL ASSUMPTIONS

The experimental material comprised floor boards of 28 mm * 110 mm cross section manufactured from solid pine wood (*Pinus sylvestris L.*) planed on four sides with sides profiled into tongue and key.

The top side of floor boards was planed twice and there were two relief grooves in the bottom side to prevent warping. Board top and bottom surfaces were formed and tongues and keys were made with the assistance of a four-side planer, type Unimat CLASSIC of Weinig Company. Figure 1 shows the spindle arrangement of the employed planing machine.

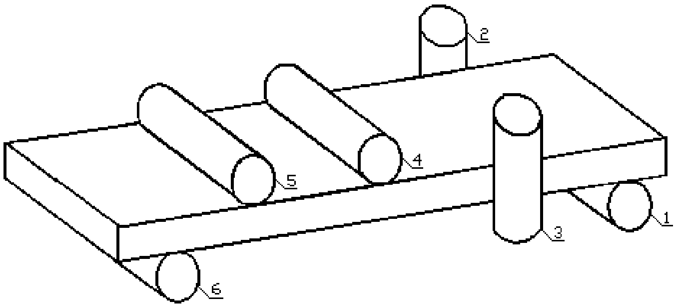

Fig. 1. Spindle arrangement of the applied type Unimat CLASSIC planing machine; 1, 6 – heads forming the top side of boards, 2, 3 – tongue and key profile milling cutters; 4 - disc cutter for relief grooves, 5 – head forming the bottom side

The diagram showing the formation of sides and relief grooves of the floor board is presented in Fig. 2.

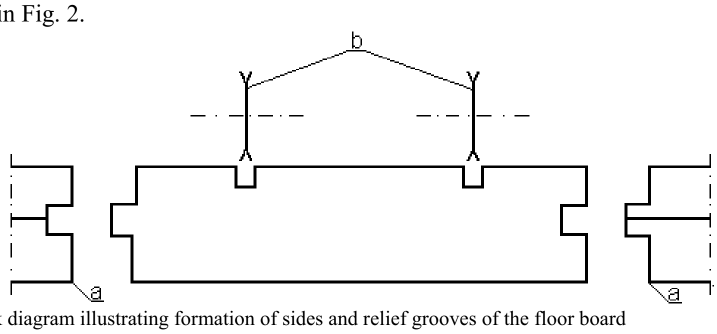

Fig. 2. Block diagram illustrating formation of sides and relief grooves of the floor board
a – double cutters, b – disc cutters

The moisture content of the board surface layer was measured with the assistance of a WIP-20D hygrometer whose principle is based on measurements of the dielectric constant. The instrument makes it possible to take measurements with ±0.1% accuracy in accordance with EN 13183-2. The width and thickness of boards was measured using a calliper with a digital display and ±0.01 mm accuracy.

Width and thickness measurements were conducted after floor boards were totally completed during five consecutive days and on each day, they lasted for 8 hours, i.e. a complete work-shift. Every day, the total of 25 samples was subjected to investigations. Each sample consisted of five elements and the samples were examined at identical time intervals, approximately every 20 minutes with 3 measurements of width and 3 measurements of thickness performed on each element. Therefore, on each measurement day, the total of 125 elements was examined obtaining 750 measurements, including 375 thickness and 375 width measurements. The width of elements was measured on their top plane because the width of the bottom plane (under the key) was by 1 mm smaller. Two measurements were taken at the distance of 200 mm from heads of the examined elements and the third measurement – in the middle of its length. Measurements of the board thickness were taken at the same distance from the heads as in the case of width.

A stabilisation method (Czyżewski 1992) was chosen to prepare $\bar{x}-s$ control charts which were designated on diagrams with X-S letters. Diagrams illustrating the quality capability and position of the process as well as control charts were all computer made using for this purpose the STATISTICA 8PL software. The quality capability and process alignment were assessed by values of c_p, c_{pk} and M_E indices (Zakrzewski and Staniszewska 2002). Description of control charts as well as the method of calculation of their parameters can be found in an article illustrating element execution accuracy of 'duoparquet' (Zakrzewski et al. 2009).

RESEARCH RESULTS AND THEIR ANALYSIS

Table 1 collates index values of the process quality capability c_p and alignment c_{pk}. The Table also includes parameter M_E which constitutes the accuracy of the dimensional setting of the woodworking machine.

Table 1. Index values of the process quality capability c_p and alignment c_{pk} and dimensional setting of the woodworking machine M_E (in mm).

		Day 1	Day 2	Day 3	Day 4	Day 5
Width	c_p	1.82	1.51	2.63	4.61	2.69
	c_{pk}	1.67	1.42	2.52	4.07	2.49
	M_E	0.12	-0.10	-0.06	-0.18	0.12
Thickness	c_p	7.95	5.10	2.28	4.83	6.81
	c_{pk}	7.59	4.73	2.03	4.34	6.22
	M_E	0.05	0.07	-0.11	0.10	0.09

It is evident from data presented in Table 1 that the execution quality capability of board width and thickness dimensions on each measurement day was satisfactory as the dimension scatter was, in the best case, smaller than the tolerance for the width by 4.61 times (day 4) and for the thickness by 7.95 times (day 1) and, in the worst case, by 1.51 times for the width (day 2) and by 2.28 times for the thickness (day 3).

In all cases, the alignment index c_{pk} differed slightly from the c_p value and its smallest value amounting to 1.42 (day 2) was determined for board thickness. However, even this worst value exceeded significantly unity below which, as is well known, production defects would occur.

The setting accuracy of the woodworking machine M_E ranged from -0.06 mm for the width (day 3) to 0.18 mm for the width (day 4). This negligible M_E value exerted a significant impact on small differences between c_p and c_{pk} indices and, at a slight dimensional scatter, guaranteed defect-free production.

Process stability was illustrated by control charts presented in Figs. 3 to 6. Due to space limitations of the article, only four control charts are included illustrating the best and the worst cases of process stability.

Figures 3 and 4 present control charts of the thickness dimension for the best and worst process stability.

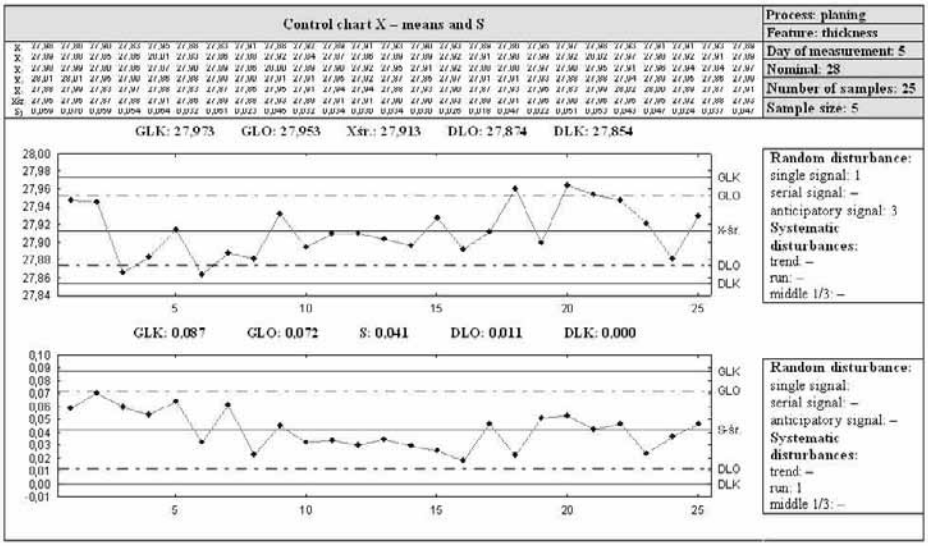

Fig. 3. Control chart for thickness dimension on day 5 of measurements

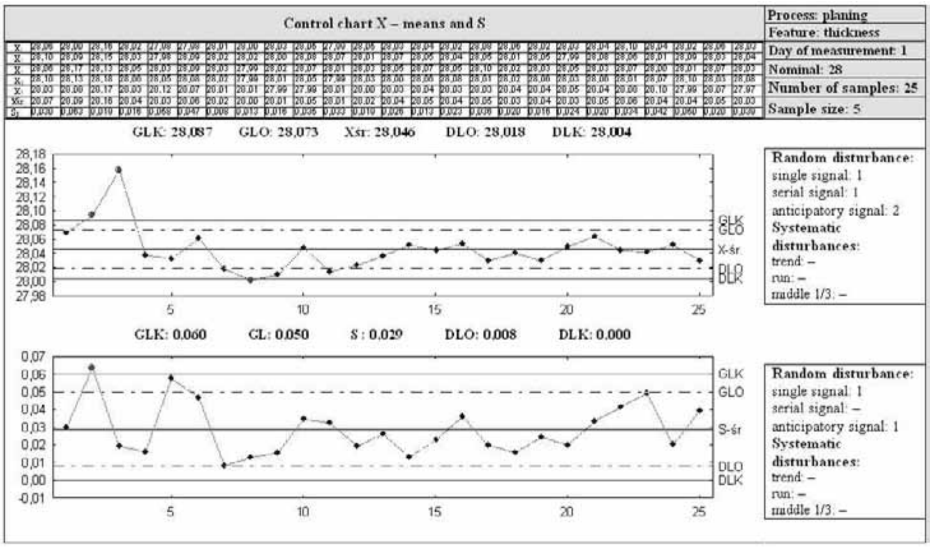

Fig. 4. Control chart for thickness dimension on day 1 of measurements

The process was most stable on the fifth day of measurements (Fig. 3) and its stability was the worst on the first day of measurements (Fig. 4). The central line X-śr and S-śr as well as control lines GLK and DLK are marked as continuous lines, while warning lines GLO and DLO – as dashed lines. The arithmetic mean from individual samples $x_{śr}$ and s_j are marked as squares or when a signal occurred – as circles. In Figure 3, for the path of the arithmetical mean X from individual samples $x_{śr}$, the difference between the position of the top control line GLK and bottom control line DLK amounted to 0.119 mm (27.973 – 27.854), while for the path of mean deviation S: GLK – DLK = 0.087 mm. On path X warning lines were found exceeded for four samples: 3, 6, 18 and 20. No signals were found, however, from single samples that would indicate destabilisation of the process. On path S, phenomena of "trend" type can be observed for samples 9-16 and of "run" type for samples 10-16. On the other hand, in Figure 4 the range of stability on path X: GLK – DLK = 28.087 – 28.004 = 0.083 mm, while the difference of values of control lines on path S amounted to GLK – DLK = 0.060 mm. Disturbances occurred in Figure 4 indicating destabilisation of the process. Samples 3 and 8 gave a signal on path X, whereas sample 2 – both on paths and X and S. Samples 9 and 11 on path X exceeded the bottom warning line, while on path S, top warning line was observed to be exceeded for sample 5.

Figures 5 and 6 show control charts prepared for the width dimension for the best and worst stabilised processes.

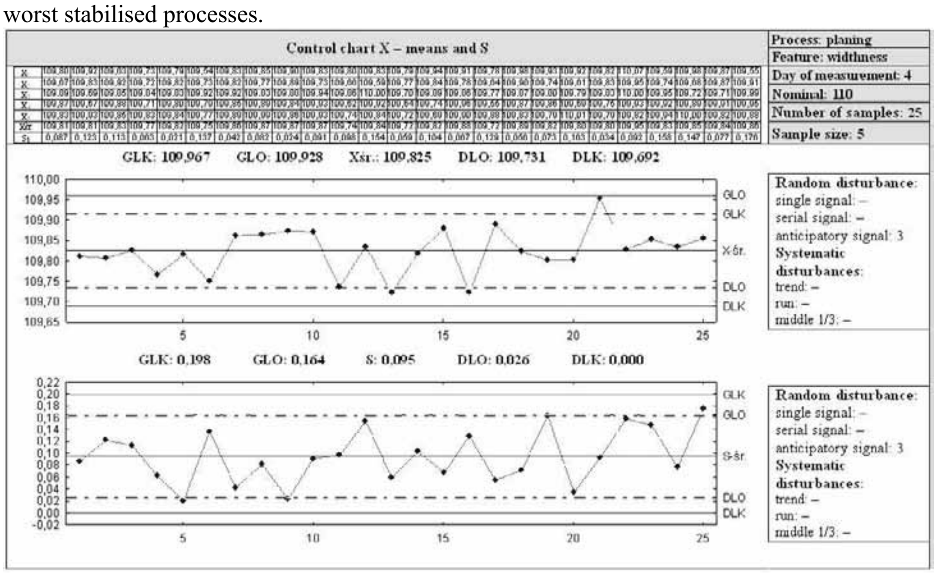

Fig. 5. Control chart for width dimension on day 4 of measurements

The process was found to be most stable on day 4 of measurements (Fig. 5) and its stability was worst on day 2 (Fig. 6). In Figure 5, for the path of the arithmetic mean X from individual samples $x_{śr}$, the difference between the position of the top GLK and bottom DLK control lines amounted to 109.967 – 109.692 = 0.275 mm, while for the path of standard deviation S, GLK – DLK = 0.198 mm. On the other hand, in Figure 6, the range of stability on path X: GLK – DLK = 110.190 – 109.622 = 0.568 mm, whereas the value difference of control lines on path S amounted to: GLK – DLK= 0.414 mm. On day 4 of measurements, no signal of transgression of the control line occurred from individual samples and in three cases, on path X, warning lines were trespassed, namely for samples 13, 16 and 21. On the other hand, on path S, such transgressions took place for samples 5, 9 and 25.

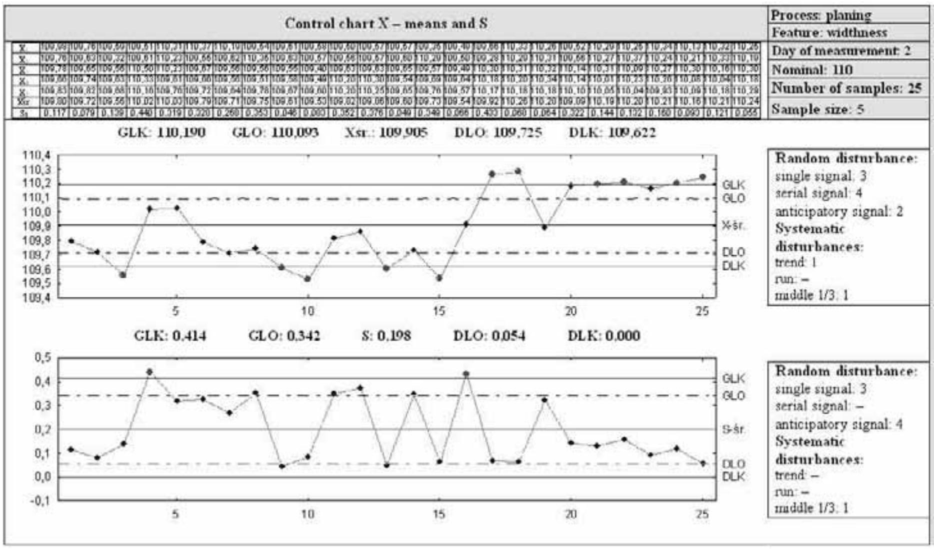

Fig. 6. Control chart for width dimension on day 2 of measurements

On the second day of measurements, up to thirteen signals from individual samples occurred, of which eleven signals were observed on path X and two on path S. In addition, a "run" took place on path X for samples 6-15 below the X-śr axis and on both paths, a phenomenon of "middle one third" occurred (a collective publication 1999) indicating too large value scatter from individual samples. The likely cause was a too large difference in the width dimension before processing in individual samples on this measurement day.

CONCLUSIONS

1. On the basis of observations of the process capability c_p and alignment c_{pk} indices, the process was assessed as quality capable.
2. A partial instability of thickness and width dimension maintenance in the course of the process occurred caused by signals of transgression of lines controlling values by some samples. In addition, phenomena of 'trend', 'run' and 'middle one third' type developed on some control charts.
3. The performed investigations revealed that the degree of the tool point dulling during the five-day interval failed to influence the obtained research results.

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Streszczenie: *Badanie dokładności wykonania desek podłogowych*. Przedmiotem badań była kontrola dokładności wykonania wymiarów grubości i szerokości elementów desek podłogowych przeprowadzona w warunkach przemysłowych. Wyniki badań opracowano z użyciem programu komputerowego STATISTICA 8PL służącego między innymi do obliczania wskaźników zdolności jakościowej c_p i c_{pk} oraz do tworzenia kart kontrolnych Shewharta. Badanie zdolności jakościowej oraz stabilności utrzymania wymiarów w procesie produkcyjnym prowadzono w okresie pięciu tygodni kartami kontrolnymi w odniesieniu do wymagań normy PN-EN 13990:2005. Na podstawie obserwacji wartości wskaźników c_p i c_{pk} proces oceniono jako zdolny jakościowo, zaś na podstawie analizy kart kontrolnych częściowo niestabilny.

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